# Acta Balneologica

ISSN 2082 - 1867

Published since 1905

JOURNAL OF THE POLISH BALNEOLOGY AND PHYSICAL MEDICINE ASSOCIATION

2025 SEPTEMBER-OCTOBER VOL. LXVII ISSUE 5 (189)

THERMAL MEDICINE – THERAPY, PREVENTION, REHABILITATION

PHYSICAL THERAPY • BIOKLIMATOLOGY • BALNEOGEOLOGY • BALNEOCHEMISTRY



Patronage of Committee of Rehabilitation, Physical Education and Social Integration of the Polish Academy of Sciences

ISSN 2082-1867

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Aluna Publishing

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**PUBLISHER:**
ALUNA Publishing
29 Z.M. Przesmyckiego St.
05-510 Konstancin Jeziorna, Poland
www.actabalneologica.pl

**PROJECT COORDINATOR:**
MEDDOM PRESS
tel. 604-208-453
barbadom@wp.pl

**GRAPHIC DESIGN:**
PHU Piotr Dobrzyński,
www.poligrafia.nets.pl



The journal is indexed in Web of Science – ESCI, Index Copernicus, EBSCO, Ministry of Science and Higher Education and the Polish Medical Bibliography

# CONTENTS

ORIGINAL ARTICLE

# Effect of Bobath on autonomic regulation and analysis of gait in patients after stroke

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## ABSTRACT

**Aim:** Heart rate variability (HRV) is one of the best indicators of autonomic regulation of heart rate. HRV measurement became the point of the evaluation of variability of autonomic nervous system after stroke as well as the possible connection of disturbed heart rate variability with respect to functional efficiency. The present study aims to clarify whether the systematic use of NDT Bobath neurorehabilitation method affects the change of the autonomic nervous system activity and time-space gait analysis (as a motor assessment) in relation to the classical model of physiotherapy after stroke in Poland.

**Materials and Methods:** Randomized controlled trial included two groups of patients who suffered after the first ischemic stroke – first group included 20 middle-aged people 66.1±7.9 years and second group – 21 people with a mean age of 60±11.2 years. Holter analysis and spatio-temporal parameters of gait were on the first day after admission to the rehabilitation department, then after 6-week therapeutic process completed, final tests were performed on the last day. In group 1, patients performed therapies according to the classic improvement model, in group 2 therapy according to neurophysiological methods represented by the Bobath concept.

**Results:** Patients in a group of Bobath therapy significantly improved parasympathetic parameters of the autonomic nervous system. Bobath therapy and classical model of physiotherapy have improved the common spatio-temporal parameters of gait.

**Conclusions:** Two different physiotherapeutic methods in people after ischemic stroke have differently influenced the modulation of the autonomic nervous system in the domain of time and frequency.

**KEYWORDS:** stroke, heart rate variability, autonomic nervous system, analysis of gait

Acta Balneol. 2025;67(5):319-327. doi: 10.36740/ABAL202505101

## INTRODUCTION

Stroke is one of the most dangerous health, social and economic problems in the world. Recovered individuals frequently need support with routine tasks as a result of both physical and psychological limitations, including muscular weakness, communication impairments, persistent fatigue, and difficulties with cognition [1]. According to a 2020 publication by Puciarelli et al., the estimated direct expenditure for stroke across Europe amounted to EUR 16 billion, while in the United States it reached USD 23.6 billion [2]. These figures are projected to rise to USD 66 billion by the year 2035 [2]. Within the United Kingdom alone, annual and societal expenses were approximated at £26 billion, encompassing contributions from the National Health Service (13%), Personal Social Services (20%), unpaid caregiving (61%), and losses related to productivity (6%) [3]. Notably, stroke occurrence rises markedly with advancing age, approximately doubling each subsequent decade following the age of 55 [2]. This progression positions stroke as either the third or potentially even the second leading cause of mortality globally [4].

The study assessed impact of the classical model of rehabilitation based on the commonly used systematics of movement exercises such as active, passive, active-passive, self-assisted, active with resistance exercise and gait training. The second was the Bobath concept representing neurorehabilitation methods. The basic assumptions of Bobath are inhibition of pathological reflexes and the priming of the physiological reactions necessary to maintain selectivity and control of spatial movements. The difference in access to services related to neurorehabilitation, lack of adequate infrastructure and standard physiotherapeutic

procedures often cause permanent disability in people who survived the vascular incident [1, 3]. Heart rate variability (HRV) is one of the best indicators of autonomic regulation of heart rate. HRV measurement became the point of the evaluation of variability of the autonomic nervous system after a stroke as well as the possible connection of disturbed rhythm variability with respect to functional efficiency [5]. However, based on the available scientific studies, the assessment of the impact of available physiotherapeutic procedures on the modulation of the autonomic nervous system has not been fully elucidated.

## AIM

The present study aims to clarify whether the systematic use of NDT Bobath neurorehabilitation method affects the change of the autonomic nervous system activity and time-space gait analysis (as a motor assessment) in relation to the classical model of physiotherapy patients after stroke in Poland.

## MATERIALS AND METHODS

The current study was a randomized clinical trial designed to compare the effect of NDT Bobath neurorehabilitation method and classical model of physiotherapy on autonomic nervous system activity and time-space gait analysis (as a motor assessment) in patients after stroke. The study protocol and informed consent form were approved by the Bioethics Committee of the Nicolaus Copernicus University in Toruń at the Collegium Medicum Ludwik Rydygier in Bydgoszcz (consent No. KB 53/2016, the consent was granted on 26.01.2016 until the end of 2020). All subjects were informed about the purpose of the tests and procedures, and also voluntarily signed consents to participate in the experiment. The trial was not masked, but staff who collected data on study outcomes were unaware of study group assignments. The study was not registered in the clinicaltrials.gov database, however the research project was positively reviewed by the bioethics committee, meeting the standards of good clinical trial practice.

This study preliminary included 247 patients with an average age of 68.5±12.4 years, who had suffered the first ischemic cerebral stroke and sterted treatment at the Neurological Rehabilitation Department of the Kuyavian-Pomeranian Pulmonology Center in Bydgoszcz. Patients were included in the study only if they fulfilled all the following criteria: age 25-79 years old, clinically stable, first ischemic stroke, time from stroke <3.5 years, independent locomotion on distance 50 meters, 8-16 points on the Barthel scale. The exclusion criteria were diabetes, heart failure, myocardial infarction in the last 3 months, permanent atrial fibrillation, previous fracture of the lower limb in the last 12 months, patient can't walk 50 meters, hemorrhagic stroke, pacemaker, peripheral neuropathy, hyperlipidemia, second and subsequent stroke, taking sleeping pills, refusal to participate in the study.

### 24-HOUR HOLTER MONITORING

Registration of changes in the cardiovascular system was made using the 24-hour Schiller Medilog AR4 Plus ECG holter. Heart Rate Variability was analyzed by computer used commercial system Medilog Darwin 2 Professional. Very high sampling frequency - 8000 Hz and high resolution of 15.5-bit camera allowed it to obtain excellent detection of signals and its further analysis. This method is used in studies evaluating the monitoring of autonomic regulation after stroke. Accurate analysis of heart rate variability in the domain of time, frequency and non-linear dynamics methods allows to assess the heart rhythm in terms of sympathetic-parasympathetic balance [6, 7].

### SPATIO-TEMPORAL GAIT ANALYSIS

Gait evaluation was made on the time-space parameters from the FDM-TDSL-3i treadmill. Zebris FDM has a large number of sensors under the transmission belt, which allows for an accurate gait analysis. Each included patient had to go on the treadmill at a speed of 0.50 m/s without any help within 30 seconds. Two gait measurements were recorded, which were preceded by a 10-second transition without registration. This method is used in studies assessing gait re-education resulting from physiotherapy in patients after stroke. The assessment of spatio-temporal indicators determines changes in the movement pattern and may be a marker of improved gait function [8-10].

### RAND – 36 SCALE

The assessment quality of life according to the international Rand 36-Item Short Form Health Survey was prepared on basis answers to 36 questions concerning the patients' health. High score on the scale is associated with a higher health score. Rated items were in the range from 0 to 100 points. After collecting all the responses were decoded according to the appropriate key in two steps. The final scores show the percentage of the final score possible. The Rand-36 is a very effective tool for assessing functionality related to daily activities and for identifying health in relation to physical limitations and emotional [11].

Holter analysis and spatio-temporal parameters of gait were on the first day after admission to the rehabilitation department, then after 6-week therapeutic process completed, final tests were performed on the last day. In both groups, people participated in a 6-week individual therapeutic programs. Physiotherapy took place from Monday to Friday two hours a day, divided into two one-hour meetings. Total time of individual therapy for each patient regardless of the group was 60 hours. In group 1, patients performed therapies according to the classic improvement model, in group 2 therapy according to neurophysiological methods represented by the Bobath concept. Both groups before and after therapy were examined by one person.

### NDT BOBATH THERAPY

During the 6-week therapeutic period, individuals from both research groups participated in individual physiotherapy every day from Monday to Friday for two hours a day, divided into two one-hour meetings (Fig. 1). Group 1 implemented the classic rehabilitation model according to the Polish school of rehabilitation. Daily therapy included

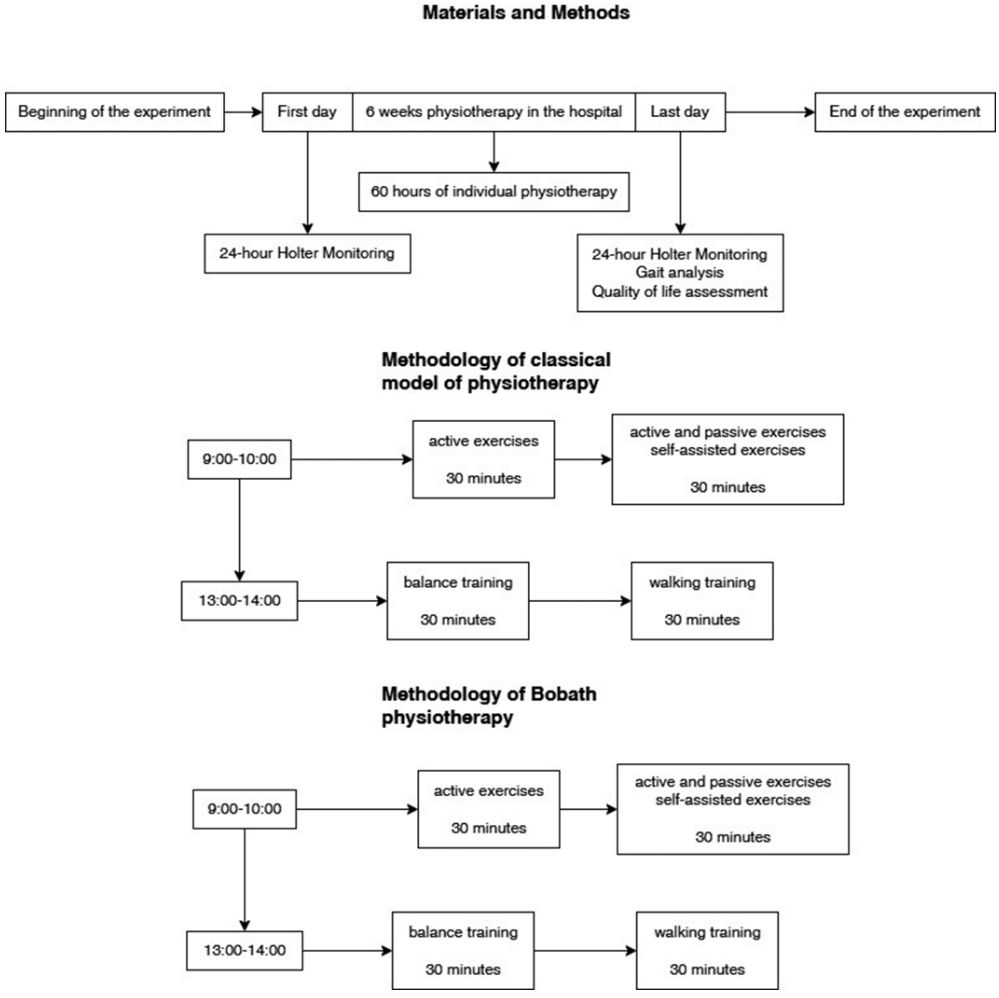


**Fig. 1.** Study design
*Source: compiled by the authors of this study*

active exercises (30 min), active-passive and self-assisted exercises (30 min), balance exercises and preparation for learning to walk (30 min) and walking training (30 min). The walking training included elements of motor exercises aimed at improving the support phase and the swing phase of the lower limb. The first therapy during the day took place between 9:00-10:00 am, the second therapy between 1:00-2:00 pm. Group 2 implemented individually tailored therapy according to the IBITA Bobath assumptions. Individual physiotherapy included mobilization of trunk structures (30 min), i.e. improvement of the flexibility of key muscle structures that disrupt the so-called aligment of the body, trunk facilitation (30 min) mainly techniques improving selective trunk control in the sagittal and frontal planes using previously developed structures translating this into specific activities, gait re-education (30 min) based mainly on training of adjustment and balance reactions in high body positions and walking training (30 min). The walking training included elements of motor exercises aimed mainly at improving the support phase of the lower limb. The first therapy during the day took place between 9:00-10:00 am, the second therapy between 1:00-2:00 pm. The modification of techniques was selected for specific individual functional deficits and modified in accordance with the patient's movement capabilities, so that it was possible to obtain the correct movement pattern. The total time of individual physiotherapy for each patient, regardless of the group, was 60 hours.

### STATISTICAL ANALYSIS

Statistical analyses were performed using Statistics 13.0 (StatSoft). The normality of continuous variables was assessed using Shapiro-Wilk test. Descriptive statistics were expressed as means and standard deviations (±SD). Depending on data distribution and variance homogeneity, intergroup differences were analyzed using Student's t-test or the nonparametric Wilcoxon signed-rank test. Stepwise backward regression analysis was used to assess relationships between functional parameters of the autonomic nervous system and quality of life, as well between changes in quality of life and spatio-temporal gait parameters. Correlations between selected variables were evaluated using Spearman's nonparametric test. The level of statistical significance was set at $p<0.05$ for all tests.

## RESULTS

We initially recruited 247 patients for the study. Out of this group, 120 (48.6%) were women and 127 (51.4%) were

men. Most of them were patients with ischemic stroke n= 184 (74.5%). In the group of patients 118 (47.8%) patients are people with damage in to the right hemisphere, and 129 (52.2%) with damage in to the left hemisphere. To eliminate interfering interactions, 206 people were excluded due to the presence of diabetes mellitus, intracerebral hemorrhage or subarachnoid haemorrhage, permanent atrial fibrillation, II and III degree obesity, heart failure (mainly myocardial infarctions, cardiomyopathies, valvular dysfunctions, as well as left ventricular dysfunctions), presence of cardiostimulator, significant hemiparesis making it impossible for the patient to walk at least 50 meters on their own, in the period before the hospitalization of previous strokes and depression. Selection groups was made using simply randomization. This was an RCT that followed the CONSORT guidelines. Randomization was by simple random sampling using a computer-generated random number sequence. Patients were randomly assigned to one of two groups. Inclusion and exclusion criteria were strictly observed. As a result, first group included 20 middle-aged people 66.1±7.9 years (8 middle-aged women 66.6±9.8 and 12 middle-aged men 65.8±6.8), in the second group – 21 people with a mean age of 60±11.2 years (7 middle-aged women 61.1±11.1 years and 14 men with a mean age of 59.4±11.5). Time from the stroke to the start of the experiment was respectively 1 – 148 days, group 2 – 164 days. The BMI index for both groups was very similar and was respectively the group 1 – 26±3.9 and the group 2 – 25.9±2.5. In the stroke location group 1 had 10 people with damage to the right hemisphere (50%) and 10 people with damage to the left hemisphere (50%), while group 2 consisted of 13 people with damage to the left hemisphere and 8 people with damage to the right hemisphere. In group 1, the average time from stroke to the start of the experiment was 148 days and in group 2 – 164 days. BMI for both groups was very similar and amounted to 1 – 26±3.9 and group 2 – 25.9±2.5. The stroke location in group 1 consisted of 10 people with infraction to the right hemisphere (50%) and 10 people with infraction to the left hemisphere (50%), while group 2 consisted of 13 people with infraction to the left hemisphere and 8 people with infraction to the right hemisphere.

## DISCUSSION

High availability of physiotherapeutic methods and techniques gives the possibility of an intensive impact on the person after stroke to optimize the effectiveness of the therapy [12]. In Poland, the proportion of individuals experiencing disability after a stroke exceeds 70%, whereas in more developed nations, the average rate is approximately 50% [13]. Holistic post-stroke rehabilitation plays a critical role in lowering both mortality risk and the likelihood of profound disability among stroke survivors [14]. Neurological treatment must include physiotherapy maximally focused on ADL, including functional improvement and neutralization of neurological deficit based on neuroplasticity [15]. The effectiveness of physiotherapy after a stroke in recent years has been very intensified. One of the most popular therapeutic concepts used in the world is NDT Bobath. The effectiveness of this concept in the treatment of stroke patients has been evaluated for many years. The results of these studies are still ambiguous. In gait rehabilitation, several studies have examined the impact of the Bobath method on improving gait parameters and balance. For instance, Krukowska et al. demonstrated that the application of NDT-Bobath, in comparison to other physiotherapeutic techniques, leads to measurable improvements in center of pressure (COP) parameters in post-stroke patients [16]. Mikołajewska's work supports these findings, indicating significant results in post-stroke gait reeducation associated with NDT-Bobath interventions [17]. Moreover, comparative studies show that when applied alongside traditional approaches, the Bobath treatment may enhance dynamic balance and gait symmetry, suggesting its specific benefits in post-stroke reeducation [18].

The cardiovascular system illustrates variable cortical activity. The analysis of heart rate variability in time and frequency domain is widely used in assessing the activity of the autonomic nervous system. Post-stroke autonomic dysfunction may provide a sensitive indicator of changes associated with therapeutic intervention and the final outcome of rehabilitation. Jimenez-Ruiz et al. indicate that correct assessment of sympathetic and parasympathetic activity at various periods after a stroke may have a beneficial role in predicting complications during a multi-month physiotherapy [19]. To understand the effect of movement therapy on the modulation of the autonomic nervous system after stroke therapeutic intervention should include analysis of heart rate variability in the time and frequency domain. Cardiac autonomic dysfunction among stroke patients has been identified through reduced heart rate variability (HRV), characterized by a standard deviation of NN intervals (SDNN) below 100 ms and an HRV triangular index of 20 or less, as specified by the Guidelines of the European Society of Cardiology (ESC) and the North American Society of Pacing and Electrophysiology [20].

Beyond the acute phase, there is a growing body of literature suggesting that extended monitoring HRV may provide additional prognostic information. Bai et al. observed that abnormal HRV indices can persist for up to 7 days post-stroke, indicating that continued monitoring over several days might unveil delayed autonomic derangements that are not apparent during the initial 24-hour period [21]. Moreover, extended monitoring periods can improve the detection of paroxysmal arrhythmias and changes related to circadian rhythm disruptions, which have been associated with increased risk of recurrent stroke and cardiovascular events. The studies underline that while 24-hour recordings capture essential data, there may be benefits in specific clinical scenarios to extend the monitoring period beyond a single day [22].

In the assessment of the effectiveness of rehabilitation, the study was based on a comparative assessment of the effectiveness of two therapeutic concepts in the multidirectional aspect. The variability of the heart rhythm of the analyzed results shows a better effect of NDT Bobath

therapy towards changes in the domain of time and frequency of cardiac rhythm variability in relation to the subjects who underwent therapy according to the classical model of physiotherapy in Poland. The variability of the heart rhythm of the analyzed results shows a better influence of NDT Bobath therapy towards changes in the domain of time and frequency of cardiac rhythm variability than the classical model of physiotherapy in Poland. The SDDN increased significantly in people from the Bobath method group, the other parameters of the time analysis also increased: r-MSSD and pNN50, this change may indicate an increased activity of the parasympathetic component in these people (Table 1). A lack of information on the methodology of therapeutic treatment is a considerable limitation in the context of the assessment of the impact on the autonomic nervous system. More recently, Fyfe-Johnson et al. [23] examined both time- and frequency-domain indicators of heart rate variability (HRV) using 2-minute ECG recordings from 12,550 adults in midlife, 816 of whom experienced a first-ever stroke during a median follow-up of 22 years in the Atherosclerosis Risk in Communities (ARIC) study. Within the overall study population, Cox regression models adjusted for demographic factors (including age, sex, and race) revealed that individuals in the lowest quintiles for SDNN (hazard ratio [HR] = 1.4; 95% confidence interval [CI] = 1.1-1.7), mean NN intervals (HR = 1.7; 95% CI = 1.3-2.1), and RMSSD (HR = 1.4; 95% CI = 1.2-1.8) exhibited a heightened stroke risk. However, these relationships became weaker after comprehensive adjustment for additional covariates. Notably, when models were further adjusted for diabetes presence, individuals in the lowest HRV quintiles still showed elevated stroke risk for SDNN (HR=2.0; 95% CI=1.1-4.0), RMSSD (HR=1.7; 95% CI=0.9-3.2), LF ratio (HR=1.5; 95% CI=0.8-3.0), and HF power (HR=1.7; 95% CI=0.9-3.0). Despite several models yielding statistically non-significant outcomes, the study overall demonstrated that diminished HRV parameters in both time and frequency domains were consistently linked with a greater incidence of stroke, especially among diabetic individuals, suggesting potential prognostic relevance in cerebrovascular risk prediction [23]. The opposite situation was observable in people from the Bobath method group, where the value of HRV, SDNN and RMSSD parameters increased significantly. Log LF/HF as an important indicator of the balance between the sympathetic and parasympathetic components after therapy significantly decreased value, which is described by many authors as an increase in the parasympathetic component. In summary, available research employing short-term HRV as a direct predictor of stroke remains scarce, with only two out of five included studies presenting predictive modeling. Nevertheless, when considered collectively, these investigations indicate that time-domain HRV metrics (e.g., SDNN), frequency-domain components (e.g., LF and HF), along with emerging measures such as Zugaib variability,

**Table 1.** Holter analysis of HRV parameters in time and frequency domain in each group before and after therapeutic intervention and between group 1 *vs* group 2 after therapeutic intervention

| Parameter | Group 1 | | | Group 2 | | | G1 vs G2 after intervention |
|---|---|---|---|---|---|---|---|
| | Before mean±SD | After mean±SD | p | Before mean±SD | After mean±SD | p | p |
| SDANN-i | 109.38 | 101.59 | >0.05 | 108.2± | 120.6 | >0.05 | 0.1087 |
| 24-hour rhythm index | 1.15 | 1.12 | >0.05 | 1.2 | 1.2 | 0.016 | 0.0322 |
| HRV Index | 33.33 | 31.09 | >0.05 | 33.8 | 37.4 | 0.0918 | 0.0381 |
| Trend min (bpm) | 45.99 | 46.92 | >0.05 | 49.5 | 45.7 | 0.0041 | 0.4573 |
| Trend mean (bpm) | 68.04 | 68.87 | >0.05 | 72.27 | 69.91 | >0.05 | 0.8245 |
| SDNN (ms) | 122.35 | 115.59 | >0.05 | 123.1 | 134.3 | 0.0389 | 0.1087 |
| r-MSSD (ms) | 27.89 | 24.62 | 0.0365 | 24.4 | 27.9 | 0.0078 | 0.0828 |
| pNN50 | 4.54 | 3.51 | 0.0303 | 5.2 | 6.5 | 0.0172 | 0.0381 |
| VLF | 1408.92 | 1317.39 | >0.05 | 1390.5 | 1495 | >0.05 | 0.3153 |
| LF | 429.08 | 378.42 | >0.05 | 438.7 | 489.5 | >0.05 | 0.0659 |
| HF | 136.32 | 114.99 | >0.05 | 168.9 | 209.4 | 0.0629 | 0.0147 |
| log LF/HF | 0.53 | 0.55 | >0.05 | 0.5 | 0.4 | 0.0382 | 0.2458 |
| TOTAL | 2397.58 | 2251.13 | >0.05 | 2415.31 | 2675.03 | >0.05 | 0.1967 |

*Note: Group 1 (G1) – Classical model of physiotherapy, Group 2 (G2) – Bobath physiotherapy. Values are presented as mean±standard deviation, number (%), or median. SDNN-i, mean of the standard deviations of all NN intervals for all 5-minutes segments of the entire recording; SDANN-i, index of standard deviation of averaged NN intervals ; HRV Index, index of heart rate variability; Trend min, minimal trend of beats per minute; Trend mean, mean trend of beats per minute; SDNN, standard deviation of NN; r-MSSD, square root of the mean squared difference of successive RR; pNN50, percentage of differences between RR intervals that are greater than 50 ms; VLF, very low frequency; LF, low frequency; HF, high frequency; log LF/HF, logarithm of low frequency to high frequency; TOTAL, total power of heart rate variability.*

*Source: compiled by the authors of this study*

**Table 2.** Spatio-temporal analysis of gait in each group before and after therapeutic intervention and between group 1 *vs* group 2 after therapeutic intervention

| Parameter | Group 1 | | | Group 2 | | | G1 *vs* G2 after intervention |
|---|---|---|---|---|---|---|---|
| | Before mean±SD | After mean±SD | p | Before mean±SD | After mean±SD | p | p |
| Step lenght left | 24.30 | 28.15 | <0.01 | 22.95 | 31.62 | <0.01 | 0.1042 |
| Step lenght right | 24.35 | 27.85 | 0.0168 | 25.95 | 32.38 | <0.01 | 0.0532 |
| Stance phase left | 72.36 | 71.88 | >0.05 | 71.04 | 70.51 | >0.05 | 0.4730 |
| Stance phase right | 72.14 | 71.78 | >0.05 | 72.21 | 72.16 | >0.05 | 0.6955 |
| Swing Phase left | 27.63 | 28.11 | >0.05 | 28.95 | 29.48 | >0.05 | 0.4730 |
| Swing Phase right | 27.85 | 28.21 | >0.05 | 27.78 | 27.83 | >0.05 | 0.6955 |
| Double stance phase | 44.43 | 43.72 | >0.05 | 43.27 | 42.74 | >0.05 | 0.8756 |
| Cadence | 104.95 | 94.10 | <0.01 | 104.71 | 79.71 | <0.01 | 0.0105 |
| Length of gait line left | 165.41 | 179.39 | <0.01 | 144.97 | 181.06 | <0.01 | 0.9065 |
| Length of gait line right | 149.15 | 170.38 | <0.01 | 157.36 | 191.68 | <0.01 | 0.0209 |
| Single support line left | 43.34 | 45.52 | >0.05 | 44.21 | 62.48 | <0.01 | <0.01 |
| Single support line right | 43.06 | 48.16 | 0.0123 | 45.64 | 59.83 | <0.01 | 0.1058 |

*Note: Group 1 (G1) – Classical model of physiotherapy, Group 2 (G2) – Bobath physiotherapy. Values are presented as mean±standard deviation, number (%), or median.*

*Source: compiled by the authors of this study*

**Table 3.** Analysis quality of life parameters according to the Rand-36 scale in each groups before and after therapeutic intervention, and inside the group 2 before and after therapeutic intervention

| Parameter | Group 1 | | | Group 2 | | | G1 *vs* G2 after intervention |
|---|---|---|---|---|---|---|---|
| | Before mean±SD | After mean±SD | p | Before mean±SD | After mean±SD | p | p |
| Role limitations due to physical problems | 17.50 | 20.23 | 0.6669 | 32.50 | 64.28 | <0.01 | <0.01 |
| Role limitations due to emotional problems | 40.00 | 39.69 | 0.9895 | 44.99 | 82.54 | <0.01 | <0.01 |
| Energy/fatigue | 45.27 | 45.00 | 1.0000 | 53.75 | 63.57 | <0.01 | <0.01 |
| Emotional well-being | 51.60 | 50.85 | 0.5838 | 56.20 | 68.19 | <0.01 | <0.01 |
| Social functioning | 41.87 | 41.66 | 0.9687 | 50.00 | 64.89 | 0.0109 | <0.01 |
| Pain | 78.87 | 76.07 | 0.8245 | 81.25 | 90.23 | 0.0900 | <0.01 |
| General health | 28.25 | 30.00 | 0.8043 | 34.50 | 60.47 | <0.01 | <0.01 |

*Note: Group 1 (G1) – Classical model of physiotherapy, Group 2 (G2) – Bobath physiotherapy. Values are presented as mean±standard deviation, number (%), or median.*

*Source: compiled by the authors of this study*

exhibit notable differences in stroke patients compared to healthy controls. Consequently, these parameters may serve as potential candidates for constructing future predictive frameworks aimed at identifying stroke risk [5].

The total reduction in spectral power (TOTAL) was also reported in our own research. The reduction in total HRV was associated with decreased LF and HF values, like in other research by Kuzemczak et al. [24]. In available studies, there is no information about the impact of NDT Bobath therapy and the classical model of physiotherapy in Poland as a modulator of the autonomic nervous system in people after ischemic stroke. There are individual reports that take attention to the possibility of therapeutic effect on ANS modulation in patients after stroke. Indeed, alterations in frequency-domain heart rate variability (HRV) indices, particularly LF and HF components, were found to predict stroke occurrence or correlate with clinical outcomes, such as post-stroke complications, functional recovery, and patient survival. Likewise, time-domain HRV variables, including SDNN and RMSSD, as well as non-linear entropy-based parameters like multiscale entropy (MSE) and fractal dimension (FD), not only predicted stroke onset but also

**Table 4.** Model of regression parameters of the autonomic nervous system and assessment quality of life according to the Rand-36 scale

| Parameter | Parameter | R | R2 | P |
|---|---|---|---|---|
| Role limitations due to physical problems | Del Index HRV | 0.20 | 0.04 | 0.3800 |
| | Del SDNN | 0.20 | 0.04 | 0.3686 |
| | Del r-MSSD | 0.25 | 0.06 | 0.2736 |
| | Del pNN50 | 0.08 | <0.01 | 0.7035 |
| | Del log LF/HF | -0.29 | 0.08 | 0.2004 |
| Energy/fatigue | Del Index HRV | 0.12 | 0.01 | 0.5841 |
| | Del SDNN | 0.28 | 0.08 | 0.2094 |
| | Del r-MSSD | 0.25 | 0.06 | 0.2608 |
| | Del pNN50 | 0.43 | 0.19 | 0.0463 |
| | Del log LF/HF | -0.46 | 0.21 | 0.0349 |
| Pain | Del SDNN | 0.51 | 0.26 | 0.0163 |
| | Del r-MSSD | 0.45 | 0.20 | 0.0375 |
| | Del pNN50 | 0.46 | 0.21 | 0.0327 |
| | Del TOTAL | 0.64 | 0.41 | <0.01 |
| | Del log LF/HF | -0.44 | 0.19 | 0.0449 |
| General health | Del Index HRV | 0.08 | <0.01 | 0.7264 |
| | Del SDNN | 0.29 | 0.08 | 0.1869 |
| | Del r-MSSD | 0.19 | 0.03 | 0.4074 |
| | Del pNN50 | 0.24 | 0.06 | 0.2820 |
| | Del TOTAL | 0.39 | 0.15 | 0.0782 |
| | Del log LF/HF | -0.20 | 0.04 | 0.3829 |
| Role limitations due to physical problems | Del Index HRV | -0.05 | <0.01 | 0.8128 |
| | Del SDNN | <0.01 | <0.01 | 0.9770 |
| | Del r-MSSD | 0.17 | 0.03 | 0.4483 |
| | Del pNN50 | 0.29 | 0.08 | 0.1908 |
| | Del TOTAL | 0.29 | 0.08 | 0.1896 |
| | Del log LF/HF | -0.04 | <0.01 | 0.8398 |
| Del Energy/fatigue | Del Index HRV | -0.41 | 0.17 | 0.0607 |
| | Del SDNN | -0.46 | 0.21 | 0.0350 |
| | Del r-MSSD | 0.20 | 0.04 | 0.3819 |
| | Del pNN50 | 0.11 | 0.01 | 0.6099 |
| | Del TOTAL | -0.27 | 0.07 | 0.2289 |
| | Del log LF/HF | 0.25 | 0.25 | 0.2613 |

*Note: Group 1 (G1) – Classical model of physiotherapy, Group 2 (G2) – Bobath physiotherapy. Del, Delta; HRV, heart rate variability; SDNN, standard deviation of NN; r-MSSD, square root of the mean squared difference of successive RR; pNN50, percentage of differences between RR intervals that are greater than 50 ms; log LF/HF, logarithm of low frequency to high frequency; TOTAL, total power of heart rate variability.*

*Source: compiled by the authors of this study*

yielded valuable information regarding stroke intensity, motor deficits, recovery trajectory, and overall mortality [22].

The results of the current study show that positive influence of physiotherapy on reeducation of gait is in both groups. Analysis of walking speed is not the best method to assess motor quality improvement and increase of speed may be associated with frequent compensation strategies after stroke [25]. Therefore, to precisely evaluate spatio-temporal gait parameters, a constant speed of the treadmill was established for all patients subjected to the test 0.50 m/s. Decreasing Cadence value indicates a positive change due to the constant speed of the treadmill (Table 2). The improvement of gait function in reducing the number of performed steps per minute and increasing length of the steps is associated with better normalization of muscle tone and better coordination, which is associated with

dynamic stabilization, which determines the correct quality of head and limbs movements [26]. The value of changes in the spatio-temporal parameters of gait depending on the groups studied, which was clearly higher in the group 2 after Bobath intervention. These results are according to reports from Ungureanu et al. who also showed that NDT Bobath is a more effective therapeutic method in relation to the group rehabilitated by classical methods in relation to the improvement of gait parameters during 12-week training [27]. This is consistent with the systematic review by Van Criekinge al. who demonstrated that trunk training is important in the clinical improvement of patients after stroke better walking and optimizing cadence [28]. Mikołajewska using Bobath among a group of 60 people after ischemic stroke showed correlation between changes in cadence, gait length and walking speed [17]. In our studies, single support line left, and length of gait line right increased in group 2 which provides a better stance phase for both legs. The results of these parameters indicate a more effective reeducation of walking in a group improved by Bobath treatment than patients who participated in physiotherapy in the classic model (Table 3 and 4) [27, 29].

STUDY LIMITATIONS

This clinical trial had several significant limitations. The first one is the number of patients included in the final analysis. It was relatively small compared to all the people originally qualified. This was the result of applying very restrictive inclusion and exclusion criteria, which were aimed at ensuring the homogeneity of the group and clinical validity of the sample. The second limitation is the fact that the treadmill gait analysis provides standardized measurement conditions, but it may not fully reflect gait patterns in natural conditions. The third limitation is the issue of the lack of registration of the study in the international registry of clinical trials (clinicaltrials.gov), because at the time of the project it was not a formal requirement. Despite this, full consent was obtained from the bioethics committee, and all procedures were carried out in accordance with the principles of clinical practice.

## CONCLUSIONS

1. Two different physiotherapeutic methods in people after ischemic stroke have differently influenced on the modulation of the autonomic nervous system in domain of time and frequency. As a result of the Bobath therapy, patients in group 2 significantly improved parasympathetic parameters of the autonomic nervous system. These changes were not observed in patients in group 1 treated with classical model of physiotherapy.
2. Bobath therapy and classical model of physiotherapy have improved the common spatio-temporal parameters of gait, but Bobath therapy is more effective.

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## CONFLICT OF INTEREST

The Authors declare no conflict of interest

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**RECEIVED:** 30.04.2025
**ACCEPTED:** 15.08.2025

 

ORIGINAL ARTICLE

# The relevance of determining tissue perfusion in the rehabilitation of traumatic limb injuries in the servicemen

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## ABSTRACT

**Aim:** Improving the effectiveness of therapeutic exercise for injuries of the musculoskeletal system in military personnel by substantiating the effect of perfusion on the level of pain syndrome when providing rehabilitation care to military personnel.

**Materials and Methods:** The study involved 50 adult men receiving care in a rehabilitation department (Group I). The control group (Group II) included 15 healthy men. Methods: pain assessment using a visual analogue scale, perfusion index study using a MasimoSet iSpO2 pulse oximeter with an application for data transfer to an Apple iPhone 7, statistical processing.

**Results:** The perfusion index (PI) in the study group decreased from 4.67±1.38 to 2.17±1.26, with pain syndrome on the VAS scale above 5 points and 3.32± 0.33 with pain syndrome below 4 points. With a decrease in PI below 1.72±1.15, there can be predicted the need for pain relief, these patients had a high risk of failure of adaptation to the load, inability to continue training. The high level of correlation of the perfusion index with the visual analogue scale indicators makes it objective and reliable in assessing adaptation mechanisms.

**Conclusions:** The capillary filling index is reliable in assessing adaptation mechanisms and the quality of rehabilitation. When the PI decreases below 1.75, it is possible to predict a decrease in muscle function and the need for pain relief.The use of PI determination in patients undergoing rehabilitation with injuries is a non-invasive, simple, real-time method that allows for timely prediction of slowing rehabilitation and impaired adaptation to the load.

**KEYWORDS:** perfusion index, pain syndrome, VAS scale, rehabilitation in the military

Acta Balneol. 2025;67(5):328-332. doi: 10.36740/ABAL202505102

## INTRODUCTION

Rehabilitation of wounded servicemen is a priority in our time and leads to a burden on the healthcare system. Many studies are being conducted worldwide regarding the quality of rehabilitation services for military personnel in order to reduce disability and return the wounded to a full life [1].

Combat trauma injuries that require further rehabilitation make up a specific share in the morbidity structure [1-3]. The quality and success of rehabilitation is a very important component of the recovery process [4-7]. The prediction of pain syndrome comes to the fore, since the intensity of pain is a factor that significantly affects the course of the rehabilitation period and affects the quality of life [3, 8, 9].

There are studies identifying disturbances of compensatory mechanisms, one of which is the centralization of blood circulation and impaired muscle perfusion at the level of the microcirculatory bed, which leads to a decrease in the perfusion index in adults, studies on determining the effectiveness of analgesic measures in anesthesiology, but concerning rehabilitation measures such studies are absent. The literature review presents the diagnostic capabilities of PI, an indicator of the capacity of volumetric peripheral blood flow, determined by photoplethysmography during pulse oximetry [10]. The normal values of the indicator and its characteristic changes under various pathological conditions in experimental studies and clinical practice in adults are indicated. However, no data were found in the available literature on the influence of the level of PI and muscle function in patients with combat trauma at the stage of rehabilitation.

Pain syndrome leads to such changes in the cardiorespiratory system, as vasospasm, increased heart rate, and respiratory rate above the permissible ones.

Patients who have to perform exercises do not always promptly report the onset of pain and its intensity, or may have problems with speech (aphasia) and so verbal communication is problematic for them. The most commonly used is the visual analog scale (VAS) [11, 12].

Individual differences were found in the quantitative assessment of pain. Thus, some patients assess pain in 10 scores only if it reaches such a degree of expression that they may lose consciousness. Others assess even mild pain in 10 scores, remaining calm and relaxed.

## AIM

Increasing the effectiveness of physical therapy in musculoskeletal injuries in the servicemen by substantiating the influence of perfusion on the level of pain syndrome when providing rehabilitation care to servicemen personnel with musculoskeletal injuries of traumatic origin.

Objectives: 1) to identify the features of the perfusion index in the wounded at the rehabilitation stage; 2) to determine the correlations between capillary filling and pain syndrome and adaptation; 3) to substantiate the diagnostic capabilities of the perfusion index in order to increase the effectiveness of rehabilitation care for servicemen.

## MATERIALS AND METHODS

In an open, single-center, prospective, cohort study, a comprehensive clinical and functional examination of 50 adult men receiving care in a rehabilitation department was conducted. These patients made up clinical group I. The control group (clinical group II) consisted of 15 healthy adult men. Inclusion criteria: men with combat injuries, presence of a signed informed consent to participate in the study, absence of pain before exercise, presence of one upper limb.

Research methods: clinical and anamnestic (determination of pulse rate, respiration, blood pressure, assessment of pain severity according to VAS, instrumental study of the perfusion index by the photoplethysmography method when conducting pulse oximetry using a pulse oximeter MasimoSet iSpO2 with an application for data transfer to an Apple iPhone 7 smartphone. Pulse oximeter sensors were applied to a healthy upper limb, the measurement time was 2 minutes after stabilization of the indicator. Statistical processing of the results was carried out using the STATISTICA 6.1® software product (StatSoftInc., serial number AGAR909E415822FA). To solve the tasks set and verify the initial assumptions, a set of statistical research methods was used, namely: for independent samples – Mann-Whitney test and Kruskal-Wallis test, to assess the dynamics – Wilcoxon signed-rank test for conjugation tables – $\chi 2$-test and exact test Fisher's test, to assess the degree of dependence between variables – Spearman's correlation.

The study was carried out within the framework of the scientific research work of the department «Medical, physiotherapeutic and occupational therapy support for sports, health and rehabilitation training» (state registration number UkrINTEI 0121U114435, implementation period 2022-2026).

The scientific research was carried out in compliance with the provisions of GCP (1996), Convention of the Council of Europe on the Protection of Human Rights and Biomedicine (dated April 4, 1997), the Declaration of Helsinki of the World Medical Association and the ethical principles of conducting scientific research involving humans (1964-2008), and the order of the Ministry of Health of Ukraine No. 690 dated September 23, 2009. (with changes made in accordance with the Order of the Ministry of Health of Ukraine No. 523 dated July 12, 2012)

## RESULTS

The average age of patients participating in the study was 38.8±7.2 years (clinical group I) and 35.6±8.1 years (clinical group II).

All subjects were male, had limb amputations. The number of days since the amputation was 37±8.37.

The perfusion index (PI) was measured three times: before the start of therapeutic exercises – measurement No.1, after 10 minutes from the start of therapeutic exercises (strength loads depending on the type of injury) – measurement No. 2 and 5 minutes after the end of therapeutic exercises – measurement No. 3, at the same time the severity of pain was assessed using the VAS scale.

Assessment of pain level in patients with trauma during rehabilitation exercises is a mandatory condition. A pain score of 5 and above requires pain relief or cessation of exercise, which worsens the effectiveness of rehabilitation.

All study participants were assessed using the VAS scale. During the study, exercises were performed to improve coordination and strength of the upper extremities.

Subsequently, patients in group I were divided into those who, during the load in the 2nd measurement, had a pain scale score less than 5 points on the VAS scale (n=19) – I (a) and those who had 5 or more points I (b) ( n=16). The analysis was carried out in both subgroups in the same way, with a pain score of 5 and above, the session was interrupted, the scores were measured and then the patient received anesthetic. The test data are given in Table 1.

The dynamics of the indicators shows that pain accompanies the entire period of performing the exercises, and persists after the end of the exercise. Three patients from the study had problems with speech and tremor of the limbs (contusion and dyslalia), which complicated the diagnosis. And 11 patients tried to hide the real intensity of pain (high motivation to continue session) and the state of the problem was detected when determining PI.

The VAS pain scale is a convenient, but not always reliable method of assessing the state of pain. The intensity of

**Table 1.** Pain score on the VAS scale in the study subjects, M±s

| Indicator | Measurement | Group I (a) n=19 | Group I (b) n=16 | $p_{Ia\text{-}Ib}$ < |
|---|---|---|---|---|
| VAS score | 1 | 1.4±0.7 | 1.9±1.1 | no |
| | 2 | 3.75 ±0.4 | 5.9 ±0.2 | 0.05 |
| | 3 | 3.1 ±0.9 | 4.7 ±1.5 | no |

*When comparing independent samples, the Mann-Whitney test was used ("no" – no significant difference was observed).*

*Source: compiled by the authors of this study*

**Table 2.** Dynamics of PI and arterial blood oxygen saturation

| Indicator | Measurement | I group (a) VAS less than 5 points | I group (b) VAS 5, and more points | II group | $p_{Ib-II<}$ |
|---|---|---|---|---|---|
| PI | 1 | 4.67±1.38 | | 3.49±0.34 | no |
| | 2 | 3.32± 0.33 | 2.7± 1.26* | 4.93±1.91 | 0.05 |
| | 3 | 4.1±0.8. | 3.54±1.91 | 4.3±1.24 | no |
| $SpO_2$ | 1 | 96±1.3 | | 97±2 | no |
| | 2 | 95±1.1 | 95±0.9 | 96±1.3 | no |
| | 3 | 97±2.2 | 96±2.0 | 98±3.4 | no |

*Difference between Ia and Ib – Mann-Whitney test; *p<0.05 by Wilcoxon signed-rank test. no – no difference observed.*

*Source: compiled by the authors of this study*

**Table 3.** Correlations between PI and disorders of the cardiovascular and respiratory systems in patients of group I

| Indicator | ρ | p |
|---|---|---|
| Marked changes in heart rate | | |
| 2 measurement | 0.463 | 0.05 |
| 3 measurement | 0.324 | 0.05 |
| Marked changes in respiratory rate | | |
| 2 measurement | 0.43 | 0.05 |
| 3 measurement | 0.46 | 0.05 |
| Completeness of exercise performance (repetition) | | |
| 2 measurement | 0.47 | 0.05 |
| 3 measurement | 0.43 | 0.05 |
| VAS scale score | | |
| 2 measurement | 0.67 | 0.05 |
| 3 measurement | 0.56 | 0.05 |

*Source: compiled by the authors of this study*

pain did not always depend on the severity of the lesion, it depended on the emotional state of the patient, his motivation to practice (a psychologist works with all patients).

The perfusion index in group I was 4.67±1.38 before the start of the exercises (3.49±0.34 in group II), during the exercises there was a decrease to 2.17±1.26, with pain syndrome on the VAS scale above 5 points and 3.32± 0.33 with pain syndrome below 4 points, which is 2.3 times and 1.5 times lower than in men of the control group, respectively; different dynamics of recovery after training was also observed in 3 measurements. Healthy and patients with pain up to 5 points had almost the same PI index, and with pain it was 1.2 times lower even after a short rest (Table 2).

Blood pressure in all patients was normal throughout the study.

Separately there were analyzed patients with very low PI indicators, those with PI below 1.72±1.15, this indicated severe vasospasm. They needed pain relief because pain score on the VAS was scale was higher than 5, more often being 6 or more.

These patients were at high risk of impaired adaptation to exercise (increased heart rate – above 90 percent of maximum, tachypnea – more than 30 respiratory movements per minute).

In patients with a perfusion index below 1.72±1.15, the exercise completion rate was analyzed separately, i.e. the number of repetitions of the exercise set by the physical therapist – they performed from 50 to 70 percent of the planned repetitions. Moreover, PI decreased 1-2 minutes before the patient began to complain of increased pain. The indicator was also convenient in patients who had speech problems. Arterial blood oxygen saturation ($SpO_2$) did not differ between groups I and II during the study and was within normal limits.

When conducting a correlation analysis, it was found that the PI indicator had a positive relationship with the

completeness of the exercises, and a negative one with VAS scores. Negative correlations between PI and heart rate, respiratory rate are considered reliable signs of disruption of adaptive mechanisms (Table 3).

Correlations between PI and VAS score prove the relationship between rehabilitation processes and blood flow restoration, namely capillary filling.

## DISCUSSION

Combat trauma injuries that require further rehabilitation make up a specific share in the morbidity structure [1, 3]. The quality and success of rehabilitation is a very important component of the recovery process [4-7]. And as scientists rightly point out, the prediction of pain syndrome comes to the fore, since the intensity of pain is a factor that significantly affects the course of the rehabilitation period and affects the quality of life [3, 8, 9]. Predicting pain syndrome with maximum objectivity is relevant, and the existing scales have certain limits of reliability [10, 12]. The literature review presents the diagnostic capabilities of the perfusion index, an indicator of the capacity of volumetric peripheral blood flow, determined by the photoplethysmography method during pulse oximetry [10]. It was interesting to determine the ability of the PI to predict the slowing of rehabilitation and impaired adaptation to the load, especially in patients with combat injuries [13, 14]. Identifying predictors of adaptation failure will help take a step towards solving this problem, and reduce significant stress [15].

## CONCLUSIONS

The paper presents a theoretical justification and a new solution to the current rehabilitation problem – the study of the relationship between perfusion (PI indicators) and pain intensity according to the VAS scale to increase the effectiveness of physical therapy for musculoskeletal injuries in the military.

The subjective VAS pain scale is a convenient, but not always reliable method for assessing the state of pain. The capillary filling index is reliable in assessing adaptation mechanisms and the quality of rehabilitation along with the traditional ones: heart rate and blood oxygen saturation. When the PI decreases below 1.75, it is possible to predict a decrease in muscle function and the need for pain relief.

The use of PI determination in patients undergoing rehabilitation with injuries is a non-invasive, simple, real-time method that allows for timely prediction of slowing rehabilitation and impaired adaptation to the load.

The results highlighted the feasibility of further research.

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*The work is a part of the research plan of Department of Physical rehabilitation, sports medicine and valeology Dnipro State Medical University «Medical, physiotherapeutic and occupational therapy support for sports, health and rehabilitation training (state registration number UkrINTEI 0121U114435, implementation period 2022-2026)».*

**CONFLICT OF INTEREST**
The Authors declare no conflict of interest

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**RECEIVED:** 09.04.2025
**ACCEPTED:** 08.09.2025

ORIGINAL ARTICLE

# Practical application of low temperatures in medicine

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## ABSTRACT

**Aim:** The aim of the study is to analyse which cryogenic temperatures have the most beneficial effect on muscle flexibility and strength, and whether this depends on body surface area.

**Materials and Methods:** The study group consisted of 250 men aged 25 to 35 (average age 30±5) who engaged in targeted and specialized physical training as part of their profession. These men belonged to special police and military units performing intervention, antiterrorism, and special missions.

**Results:** Analysing body surface area and selected motor characteristics with temperature produced therapeutic effects, while increasing the number of entries into the chamber yielded better results.

**Conclusions:** Only properly performed local and systemic cryotherapy treatment provides therapeutic effects. The methodology of treatments is established.

**KEYWORDS:** whole-body cryotherapy, cryogenics, local cryotherapy

Acta Balneol. 2025;67(5):333-339. doi: 10.36740/ABAL202505103

## INTRODUCTION

Cryotherapy is a form of supportive treatment that can be applied locally and systemically. Local cryotherapy, applied in the form of cold compresses, cold air or aerosols, lowers skin and tissue temperature, thereby reducing neuronal activity and tissue blood flow [1-3]. In clinical studies, cryotherapy demonstrated analgesic effects and reduced local swelling [4, 5]. Available experimental and clinical data on whole-body cryotherapy (temperatures below -110°C) demonstrates its positive effects when used appropriately [6-9]. However, the high rate of adverse events observed with this demanding method does not justify its routine use in clinical practice [5, 6, 10].

## AIM

The aim of the study is to analyse which cryogenic temperatures have the most beneficial effect on muscle flexibility and strength, and whether this depends on body surface area.

## MATERIALS AND METHODS

The study was conducted at the Medical Rehabilitation Center of the Ministry of Internal Affairs and Administration (PIM MSWiA) in Warsaw from March 2003 and continues to this day. The study group consisted of 250 men aged 25 to 35 (average 30 ± 5) who, due to their profession, were engaged in targeted and specialized physical training. These men belonged to the SOP, the Bureau of the Anti-Terrorist Organization, and the Soldiers of Grom. The subjects underwent cryotherapy in four experimental groups at three different temperature ranges: group A (the temperature in the chamber itself was -110°C (10 entries), group B (-130°C (10 entries), group C (-160°C) (10 entries), and group D (-110°C, -130°C, -160°C) – 10 entries at each temperature (30 in total) within the next six weeks. Group K was the control group, not using the whole-body cryostimulation treatments, for 6 consecutive weeks they were performing exercises on a stationary ergometer, similar to those recommended to people from the other study groups. Participation in the study was completely voluntary; each participant signed the Informed Consent Form and was assessed by a physician. Abdominal muscle flexibility and dynamic strength were assessed for each group member before and after completing the treatment series. Selected motor skills were assessed by: flexibility – measured by the depth of the forward bend of the torso from a straight sitting position, and abdominal muscle dynamic strength – measured by the number of squats performed from a supine position [11, 12]. The Bioethics Committee of the State Institute of Medicine of the Ministry of Affairs-and Administration in Warsaw approved the planned research related to whole-body cryotherapy(39/2005). A medical examination of the patient was the first step preceding the cryogenic chamber procedure. After the medical examination, each participant signed the Informed Consent Form to participate in the study and

to use the results for scientific purposes. Each examinee was prepared for the procedure by providing appropriate attire and footwear, breathing techniques were taught, and the proceedings before entering the chamber, during, and after the procedure were discussed. They were also informed aboutproceedings not recommended within the few hours before and after the procedure. The subjects of the study were randomly divided into four test groups and a control group. The first three test groups underwent a series of 10 treatments, each lasting 2 minutes, at one of the cryogenic temperatures: -110°C, -130°C, or -160°C. The fourth group received 30 treatments, each 10 entries at a different temperature: the first series at -110°C, the second at -130°C, and the last at -160°C. The control group did not undergo cryostimulation treatments. Immediately before entering the cryochamber, the subjects of the study had their blood pressure measured. Next, the group of five, for several seconds entered the first room, the vestibule, always at -60°C to acclimate their bodies to a low temperature. Afterwards, they entered the proper chamber , where the temperature was set appropriately for the given group, i.e., -110°C, -130°C, or -160°C. In the proper chamber, the subjects were walking in a circles for two minutes, not performing any additional exercises. The subjects of the study remained under constant supervision, as the chamber was equipped with video and audio communication system, used during routine procedures. Leaving the proper chamber they proceeded to the vestibule, and after closing the door to the proper chamber , they went outside. After leaving the cryogenic chamber, each participant was exercising on a stationary ergometer for 20 minutes (80-100 W, 1 W/kg body weight), under the supervision of a trained employee, as kinesiotherapy is an integral part of the treatment.

## RESULTS

Descriptive statistics were calculated for all the groups – measures of location, variability, and the degree of deviation from ideal symmetry. The study populations were then compared using these parameters. The distribution of the study samples was tested for normality using the W. Shapiro-Wilk test. Not all groups met the criteria for normality. Significance of mean differences was tested using the nonparametric Mann-Whitney or Kruskal-Wallis test. In assessing the effectiveness of individual therapeutic temperatures, the significance of differences in mean values of individual parameters across the study groups was tested using the Wilcoxon test. Changes in individual values, i.e., the difference in values after and before the study, were calculated separately for each participant and then for the entire group. Differences in mean values were also tested using the Mann-Whitney or Kruskal-Wallis test. For parameters with a non-normal distribution, if at least one parameter had a normal distribution, the Spearman correlation coefficient was calculated. The following scale was used for assessing the correlation coefficient (r) in the statistical analysis:

r=0 variables are not correlated,
0 <r<0.3 weak correlation,
0.3<r<0.5 average correlation,
0.5<r<0.7 high correlation,
0.7<r<0.9 very high correlation,
0.9<r<1 almost perfect correlation.

All statistical calculations were performed at a 95% confidence level ($p<0.05$). Clinical trial results were statistically processed using the licensed Statistica 5.0 PL package.

The following Figures 1, 2, 3, and 4 summarize the mean scores for the motor characteristics measured before and after a series of 10 treatments at specific cryogenic temperatures (groups A, B, C) or after a series of 30 treatments (group D). The figures also include the mean scores for the control group (group K), which did not ungergo treatments at cryogenic temperatures.

Figure 1 presents a graph of the mean flexibility scores for each study group and the control group. Statistical analysis showed that the increase in flexibility, measured by the depth of the forward bend from a straight sitting position, was statistically significant in each study group. The mean parameters for group A (-110°C) before the series of treatments were 17.1 and 19.46 ($p<0.001$), for group B (-130°C), 17.04 and 20.98 ($p<0.0001$), respectively, for group C (-160°C), 17.9 and 21.33 ($p<0.0001$), and for group D, 15.04 and 21.36 ($p<0.0001$). The mean results for the control group were 15.92 before the test and 16.26 after the test. These differences were not statistically significant. When comparing groups that underwent 10 treatments at the appropriate temperature, the greatest improvement in mean flexibility values – almost 4 cm – was observed after the application of a temperature of -130°C (group B), and the smallest improvement was observed after the application of a temperature of -110°C (group A). However, these differences are not statistically significant ($pABC = 0.16$). The greatest improvement in mean flexibility values – over 6 cm – was observed after a series of 30 treatments (group D). Statistical analysis revealed a difference between the results obtained by individuals in group D and the remaining results ($pAD<0.0001$, $pBD<0.01$, $pCD<0.001$, $pABCD<0.0001$). Therefore, it seems that the increase of the number of treatments positively affects the improvement of this motor characteristic. The mean flexibility test results obtained by the study groups were statistically significantly higher ($p<0.01$–$p<0.0001$) than those of the control group. The mean values of dynamic abdominal muscle strength, determined by the number of squats performed from a supine position in 30 seconds, are summarized in Fig. 2. The values before and after the series of treatments at individual temperatures were 32.38 and 37.74 for Group A, 34.32 and 38.86 for Group B, 35.30 and 38.38 for Group C, and 32.28 and 39.97 for Group D. A highly statistically significant improvement in abdominal muscle strength was observed in all groups at the $p<0.0001$ level. In the control group, the results before the observation were 32.06 and after the observation were 31.9; the differences were not statistically significant ($p=0.39$).

The greatest increase was observed in group D participants – 7.44, and the values obtained by the patients from this group were significantly higher than in the patients analysed

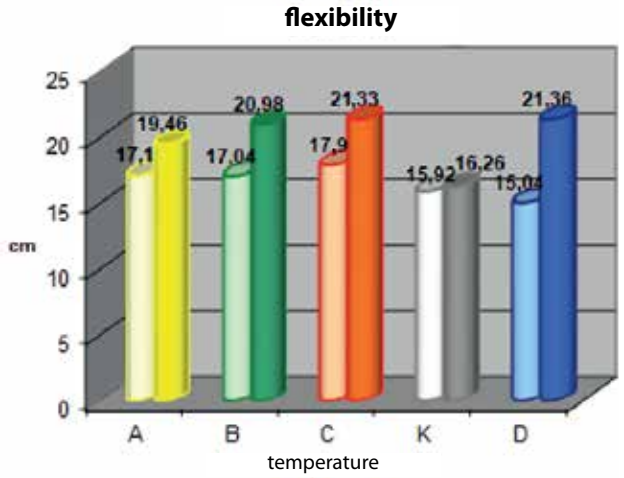


**Fig. 1.** Comparison of average flexibility scores

*Note: A -110°C – 10 entries into the cryogenic chamber.*
*B -130°C – 10 entries into the cryogenic chamber.*
*C -160°C – 10 entries into the cryogenic chamber.*
*D -110°C, -130°C, -160°C – 30 entries into the cryogenic chamber.*
*K – control group.*
*First values before, second after a series of treatments.*

*Source: compiled by the authors of this study*

after 10 treatments (pABCD<0.0001). A larger number of treatments in a series positively affects the improvement of dynamic abdominal muscle strength. In the test groups that received a series of 10 treatments, the greatest increase was observed in participants from group A – 5.36, and a similar increase in group B – 4.54. There were no statistically significant differences between the values of the increase in dynamic abdominal muscle strength in-groups A and B (pAB=0.55) patients. The difference in results between groups A and B was statistically significantly higher than the measurements in group C (pAC; pBC<0.05). The improvement of dynamic abdominal muscle strength parameters in each test group was statistically significantly greater than in the control group (p<0.0001).

A summary of the responses provided by the study groups to the satisfaction rating question is presented in Fig. 3. Participants completed Survey 2 after a series of entries to the cryogenic chamber, using a visual analog scale (VAS), where 0 represents no satisfaction, while 10 represents the highest level of satisfaction. The responses difference was statistically significant. (pABC<0.0001). Almost all participants in group A felt satisfied with the method used, usually rating it from 2 to 9, with the most common rating being 5 or 6. A similar distribution of responses was obtained in group B (pAB=0.14), but more participants (16%) reported no satisfaction with the study. However, participants in group C provided responses statistically significantly different from the other participants (pAC<0.001; pBC<0.01). If the respondent felt satisfied, most often chose level 7 or more, with 22% choosing level 10. At the same time, a significant percentage of respondents from group C – 16%, gave completely different answers, choosing 0, i.e. no satisfaction with the VAS scale used.

An analysis to determine possible relationships between the results of tests of selected motor skills was also conducted – the differences obtained before and after the treatments

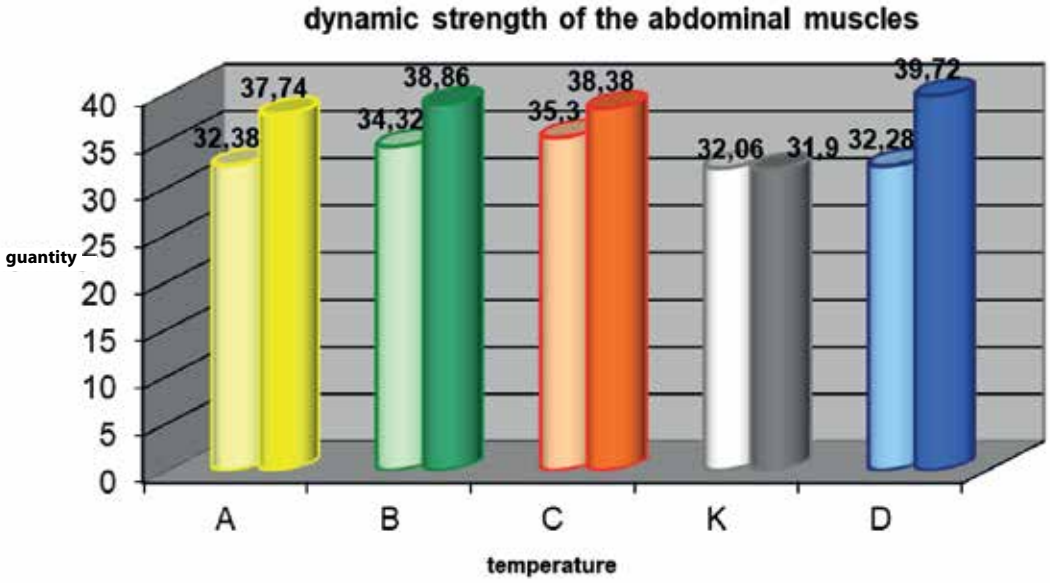


**Fig. 2.** Comparison of the average results of dynamic abdominal muscle strength

*Note: A -110°C – 10 entries into the cryogenic chamber.*
*B -130°C – 10 entries into the cryogenic chamber.*
*C -160°C – 10 entries into the cryogenic chamber.*
*D -110°C, -130°C, -160°C – 30 entries into the cryogenic chamber.*
*K – control group.*
*First values before, second after a series of treatments.*

*Source: compiled by the authors of this study*

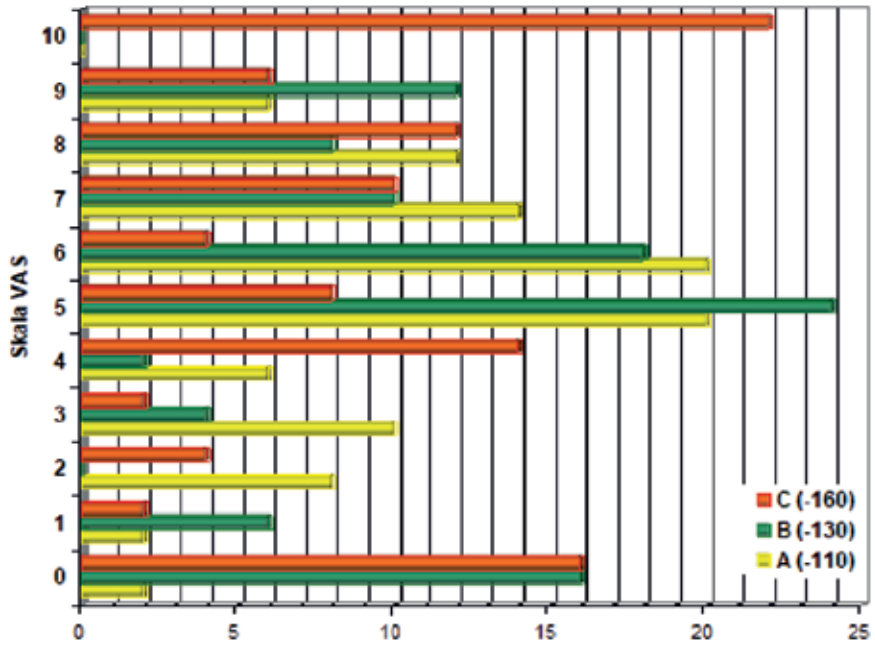


**Fig. 3.** Distribution of responses to the question about satisfaction on the visual analog scale (VAS) after a series of treatments.
*Source: compiled by the authors of this study*

– and the subjective satisfaction scores obtained using the VAS scale. No statistically significant relationships were found after applying appropriate correlation tests for groups A, B, and C. No relationships were found between changes in individual motor skills as a result of cryotherapy and anthropometric indicators such as height, weight, BMI (Body Mass Index), and body surface area calculated using the Isaksson formula.

For the purposes of this study, randomization into five study groups was performed. The results of anthropometric tests are presented in Table 1.

Statistical analysis did not show any correlation between the changes in individual motor features as a result of cryotherapy and anthropometric indicators such as height and weight (BMI) and body surface area calculated according to the Isaksson formula.

## DISCUSSION

The application of low temperature relieves pain, reduces swelling, and bleeding [13]. Modern technologies allow much lower temperatures than those achieved with snow or ice packs. The creation of cryofluids made the use of cold in medicine not to limit to localized, emergency treatment. Due to their low boiling point, cryofluids became useful in surgical treatment (cryosurgery), rehabilitation (cryotherapy), and diagnostics (magnetic resonance imaging – cooling a superconducting magnet with liquid helium). The availability of cryogenic agents influenced the development of one of the rehabilitation methods – cryotherapy. The term «cryotherapy» refers to various therapeutic activities aimed at lowering body surface temperature without damaging tissue. The goal of cryotherapy is to stimulate the body's physiological mechanisms under the influence of a strong cold stimulus to achieve a specific clinical effect.

Cryotherapy is divided into local cryotherapy, which involves a small area of the body, such as the elbow joint, and systemic cryotherapy, which involves the entire body. Local cryotherapy can be performed using various methods. These include compresses with ice bags, frozen silicone gel, or saline solution, partial immersion in ice water, ice massage, spraying with cooling sprays, contact cooling using a thermoelectric device, nitrogen vapor injection (the gas temperature at the nozzle outlet can range from -160°C to -196°C), nitrogen vapor and chilled air injection (the gas mixture temperature ranges from -100°C to -178°C), and cold air injection (temperature ranges from -30°C to -34°C) [1-5 ].

Local cryotherapy is clinically recognized and one of the most important therapeutic methods for indications requiring the local application of extremely low temperatures. An -innovation worth mentioning is the use of real-time thermal imaging during and after the procedure. As part of a completed project, the beneficiary of which was Metrum Cryoflex: «Innovative nozzle for local cryotherapy with an integrated infrared imaging system and support for assessing treatment effectiveness» (Project POIR.01.01.01-00-1192/17-02, implemented between 2019 and 2022 and financed by the National Centre for Research and Development), an LN2 cryotherapy nozzle was developed, equipped with a camera that collects temperature readings from the cryotherapy site. Using a FLIR Lepton 3.5 thermal imaging camera and a dedicated image analysis algorithm, the cryotherapy device generates real-time thermograms, which are interpreted by the software and presented graphically. Temperature graphs at measurement points allow the physiotherapist to continuously monitor cooling effectiveness and make decisions about whether to continue or terminate the treatment. The system also warns before

**Table 1.** Age and anthropometric indicators of the study groups

| Group | Parameters | Mean+/-SD | Range |
|---|---|---|---|
| Group A | age (years ) | 29.52+/-3,35 | 25.0-35.0 |
| | height (cm) | 181.52+/-5.92 | 170.0-195.0 |
| | body weight (kg) | 86.55+/-10.93 | 67.0-112.0 |
| | BMI | 26.2+/-2.38 | 22.13-31.69 |
| | body surface area ($m^2$) | 2.08+/- 0.16 | 1.81-2.40 |
| Group B | age (years ) | 29.22+/-3.17 | 25.0-35.0 |
| | height (cm) | 181.24+/-5.17 | 170.0-192.0 |
| | body weight (kg) | 86.74+/-9.16 | 72.0-112.0 |
| | BMI | 26.39+/-2.92 | 22.24-31.70 |
| | body surface area ($m^2$) | 2.08+/-0.13 | 1.88-2.42 |
| Group C | age (years ) | 29.52+/-3.27 | 25.0-35.0 |
| | height (cm) | 181.38+/-5.67 | 172.0-195.0 |
| | body weight (kg) | 86,89+/-10.63 | 72.0-112.0 |
| | BMI | 26.36+/-2.47 | 21.27-31.35 |
| | body surface area ($m^2$) | 2.08+/-0.15 | 1.86-2.42 |
| Group K | age (years ) | 30.5+/-3.12 | 25.0-35.0 |
| | height (cm) | 181.16+/-6.62 | 170.0-198.0 |
| | body weight (kg) | 87.98+/-9.82 | 70.0-112.0 |
| | BMI | 26.78+/-2.3 | 23.2-31.67 |
| | body surface area ($m^2$) | 2.09+/-0.15 | 1.8-2.48 |
| Group D | age (years ) | 29.54+/-3.04 | 25.0-35.0 |
| | height (cm) | 181.68+/-4.98 | 172.0-191.0 |
| | body weight (kg) | 88.2+/-8.03 | 70.0-103.0 |
| | BMI | 26.69+/-1.81 | 22.07-30.42 |
| | body surface area ($m^2$) | 2.1+/-0.12 | 1.86-2.31 |

*Note: A -110°C – 10 entries to the cryogenic chamber.*
*B -130°C – 10 entries to o the cryogenic chamber.*
*C -160°C – 10 entries to the cryogenic chamber.*
*D -110°C, -130°C, -160°C – 30 entries to the cryogenic chamber.*
*K – control group.*

*Source: compiled by the authors of this study*

critical temperatures (<12°C) are reached, significantly improving patient safety. Systemic therapy is possible thanks to technological advancements. The introduction of cryosaunas, freestanding cryochambers, and entry-exit cryochambers into medical practice [6-9, 13-20]. Freestanding cryochambers vary in design. Therefore, determining the optimal cryogenic temperature range that yields the best clinical results is an interesting question. Such work will enable describing-standard procedures for specific disease entities, as well as the principles of using cryotherapy in sports medicine – for the purposes of biological regeneration and the intensification of sports training. Research of the effects of cryogenic temperatures is particularly important due to the existing discrepancies between theoretical and empirical data. Based on a mathematical analysis of the influence of physical and anatomical factors, Baranow states that only within the temperature range of -133°C to -163°C, while maintaining good treatment tolerance, the best effects of low temperatures can be achieved, [18-20]. He also emphasizes, that only treatments performed at temperatures between -130°C and -160°C should be considered cryotherapeutic. Meanwhile, in the literature on whole-body cryotherapy, clinical studies can be found showing the beneficial effects of a temperature of -110°C, while the Japanese used temperatures below -170°C [15-17]. To this day, research is being conducted on the effects of cryostimulation on the human body, as well as on its side -effects and what should be done to minimize them. These studies apply to both healthy and sick people, the methodology is the same for all [21-24]. It is also important how we combine cryostimulation with other physiotherapeutic treatments and methods [25-27]. Sometimes other forms of therapy give better results or are less expensive [28].

## CONCLUSIONS

- The use of whole-body cryotherapy had a positive effect on the motor characteristics studied. Improvements in the motor characteristics studied occurred at each of the temperatures used (-110°C, -130°C, -160°C).
- It was shown that a temperature of -160°C did not result in the greatest improvement in the studied characteristics. Also, increasing the number of treatments in a series (up to 30) did not always lead to statistically significant improvement in the studied motor characteristics in comparison to the groups receiving only 10 treatments.
- Improvement in flexibility was similar, regardless of the temperature in the cryochamber during the treatments. Only increasing the number of treatments to 30 resulted in improvement.
- Mean values of dynamic abdominal muscle strength, measured by the number of squats performed from a straight supine position in 30 seconds, improved statistically significantly in all study groups. The greatest increase was observed in participants from Group D (30 repetitions), and the values were significantly higher than in patients studied after 10 sessions. The improvement in Groups A and B was similar, while in Group C (-160°C)-was statistically the lowest.
- Assessing the satisfaction of the patients, using a visual analog scale (VAS, revealed that most patients reported a high level of satisfaction after the treatments – an average of around 5 (maximum 10). Patients in groups A and B had similar ratings, with responses close to the average. However, patients in group C had many extreme responses – either they were very satisfied with the therapy or they did not notice its effects at all.
- Improvement in objective measurements of selected motor features has no significant correlation with subjective assessment of satisfaction.
- No correlation was found between changes in individual motor characteristics as a result of cryotherapy and anthropometric indicators such as height, body weight, BMI (Body Mass Index) and body surface area.

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**CONFLICT OF INTEREST**
The Authors declare no conflict of interest

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**RECEIVED:** 20.05.2025
**ACCEPTED:** 30.08.2025

 

ORIGINAL ARTICLE

# Enhancing functional recovery after upper abdominal surgery: the impact of backward walking training on postoperative rehabilitation

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## ABSTRACT

**Aim:** The objective of this study was to evaluate the effectiveness of backward walking training (BWT) as a rehabilitation strategy to improve functional capacity in patients undergoing upper abdominal surgery (UAS). By comparing the outcomes of patients receiving conventional physiotherapy with those incorporating BWT, this study aimed to determine whether BWT can enhance postoperative recovery and mobility.

**Materials and Methods:** A total of 42 participants were enrolled and randomly assigned to either Group A (BWT) or Group B (conventional physiotherapy with forward walking), with 21 participants in each group. Functional capacity was assessed using the Two-Minute Walk Test (2MWT) pre-intervention, post-intervention, and at a two-week follow-up. Data were analysed using paired and unpaired t-tests.

**Results:** Both groups showed significant improvements in 2MWT scores from pre-test to post-test ($p < 0.0001$). However, Group A exhibited greater functional gains (mean post-test: 83.800m, SD: 1.506) compared to Group B (mean post-test: 77.933m, SD: 0.128). A two-week follow-up assessment indicated that Group A retained 85% of their improvement (80.63m), whereas Group B retained 78% (75.19m). Between-group analysis revealed significantly greater improvements in Group A compared to Group B ($p < 0.0001$), with a large effect size (1.2; 95% CI: 0.9 - 1.5).

**Conclusions:** Incorporating BWT into postoperative rehabilitation protocols significantly enhances functional recovery in UAS patients compared to conventional physiotherapy alone. Future studies should explore long-term outcomes and optimal training protocols

**KEYWORDS:** functional capacity, backward walking training, post-operative rehabilitation, two-minute walk test, upper abdominal surgery

Acta Balneol. 2025;67(5):340-344. doi: 10.36740/ABAL202505104

## INTRODUCTION

Upper abdominal surgery (UAS) encompasses a wide range of major surgical procedures performed worldwide, with an estimated 234 million such operations carried out annually [1]. This category includes complex interventions such as liver resection, cholecystectomy, splenectomy, pancreatectomy, gastrectomy, and bariatric surgery, all involving incisions above the umbilicus [2]. These surgeries are critical for managing various serious medical conditions, yet they are associated with significant risks, particularly concerning postoperative complications.

Among the potential complications following UAS, pulmonary issues are of particular concern. Postoperative pulmonary complications (PPCs) are observed in up to 40% of patients who undergo UAS [3]. These complications not only lead to increased morbidity and mortality but also contribute substantially to higher healthcare costs. Older patients are particularly at risk, with evidence suggesting that they experience elevated mortality rates after major abdominal surgeries [4].

Following UAS, patients frequently encounter a range of respiratory and cardiovascular challenges. Common issues include reduced lung volumes, decreased functional residual capacity, and impaired ventilation. These respiratory problems are often compounded by cardiovascular effects such as reduced cardiac output and elevated heart rate, leading to a decline in overall functional capacity [5]. This decline manifests as difficulties in mobility, balance, and the performance of daily activities, significantly impacting the patient's quality of life and independence [6-8].

In response to these challenges, physiotherapy and early mobilization have emerged as crucial components of postoperative care. Early mobilization, defined as the initiation of physical activity as soon as feasible after surgery, has been shown to enhance recovery and mitigate complications [9,10]. Conversely, delayed mobilization is associated with poorer patient-reported outcomes, including reduced independence, functional performance, and overall health-related quality of life [11].

Given these considerations, the field of postoperative rehabilitation is evolving with the exploration of new techniques to optimize recovery. One promising innovative approach is backward walking training. While primarily studied in the context of neurological rehabilitation, backward walking has shown potential benefits, such as improved balance, proprioception, and muscular strength [12]. Additionally, research indicates that backward walking may offer metabolic efficiency advantages, which could be

particularly beneficial for patients recovering from UAS [13]. This research aims to investigate the impact of backward walking training on functional recovery following upper abdominal surgery. By exploring this novel rehabilitation technique, we seek to enhance postoperative outcomes, reduce complications, and improve the overall recovery experience for UAS patients. The potential benefits of this approach could represent a significant advancement in postoperative care, offering patients a more effective path to recovery and improved quality of life.

## MATERIALS AND METHODS

### STUDY DESIGN AND PARTICIPANTS

This experimental study was conducted at Saveetha Medical College and Hospital, Thandalam, Chennai. Participants were recruited based on specific inclusion and exclusion criteria. Power analysis was conducted using G*Power 3.1.9.7 software. Based on previous studies examining walking interventions in post-surgical patients, an effect size of 0.8 was anticipated. With $\alpha = 0.05$, power $(1-\beta) = 0.80$, and accounting for a 10% dropout rate, a minimum sample size of 21 participants per group was determined to be adequate for detecting clinically meaningful differences in functional capacity. Participants were randomized using a computer-generated sequence via the lottery method and concealed allocation (Fig. 1). The assessors of the 2MWT outcomes were blinded to group allocation. All participants provided informed consent before enrolment.

Inclusion Criteria:

Patients aged 25-60 years who underwent open upper abdominal surgery, including gastrectomy, liver resection, splenectomy, pancreatectomy, cholecystectomy, hernia repair, bariatric surgery, or Whipple's procedure under general anesthesia.

Patients mobilized out of bed by Post-Operative Day 2.

Both genders were included.

Exclusion Criteria:

1. Patients with a history of cerebrovascular accident (CVA), severe hypertension, cardiovascular disease, cerebellar or vestibular lesions.
2. Chronic alcoholics or those requiring assistive ambulation devices.
3. Patients with gait abnormalities or complications preventing safe participation.

### INTERVENTION PROTOCOL

Pre-operative education about post-surgery physiotherapy interventions were taught to the subjects and were made to perform the exercises prior to surgery. Participants received two sessions of physiotherapy each day, starting from Post-Operative Day 2 until Post-Operative Day 5. Each session lasted 30 minutes.

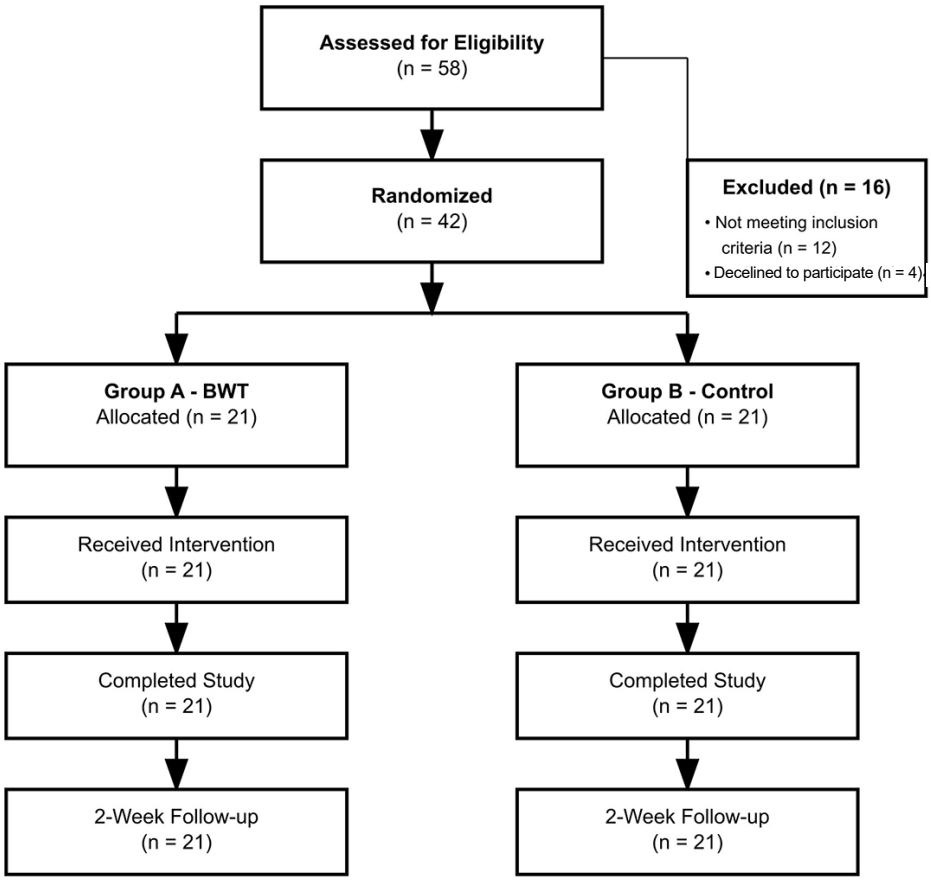


**Fig. 1.** Participant recruitment and allocation

*Source: compiled by the authors of this study*

Conventional Physiotherapy included: Active range of motion exercises for upper and lower limb, 10 repetitions for each movement of a joint; Diaphragmatic breathing exercises – 3 sets, 10 repetitions; Ankle pumps – 3 sets, 10 repetitions; Incentive spirometer

Group A (BWT): 20 minutes of conventional post-operative physiotherapy + 10 minutes of BWT (patients walked backward under therapist supervision).

Group B: 20 minutes of conventional physiotherapy + 10 minutes of forward walking on a level surface.

The Two-Minute Walk Test (2MWT) was used to assess functional capacity pre-intervention (Post-Op Day 2), post-intervention (Post-Op Day 5), and at a two-week follow-up.

STATISTICAL ANALYSIS

Data normality was assessed using the Shapiro-Wilk test. Descriptive statistics were presented as means ± standard deviations for continuous variables and frequencies (percentages) for categorical variables. Within-group comparisons were analyzed using paired t-tests, while between-group comparisons utilized independent t-tests. Effect sizes were calculated using Cohen's d, with 0.2, 0.5, and 0.8 representing small, medium, and large effects, respectively. Confidence intervals (95% CI) were calculated for all primary outcomes. Statistical significance was set at $p < 0.05$. All analyses were performed using SPSS version 26.0.

ETHICAL CLEARANCE

Approved by Instituitional Scientific Review Board (ISRB). ISRB Number: 01/004/2023/ISRB/SR/SCPT

## RESULTS

A total of 42 participants who underwent upper abdominal surgery were enrolled in the study and randomly assigned to two intervention groups: Group A (Backward Walking Training – BWT) and Group B (Conventional Physiotherapy with Forward Walking). Each group consisted of 21 participants, all of whom completed the intervention (Table 1).

The normality of data distribution was confirmed using the Shapiro-Wilk test ($p>0.05$ for all variables). Baseline characteristics showed no significant differences between groups, confirming successful randomization.

Table 2 presents the pre-test and post-test values of the Two-Minute Walk Test (2MWT) for both groups. At baseline, there were no statistically significant differences in functional capacity between the groups (Group A mean pre-test: 53.700m, SD: 0.753; Group B mean pre-test: 52.633m, SD: 0.712).

Upon completion of the intervention, both groups demonstrated significant improvements in 2MWT scores. Group A, which underwent BWT, exhibited a greater improvement in functional capacity, with a post-test mean of 83.800m (SD: 1.506), whereas Group B, which

**Table 1.** Participant Characteristics and Baseline Measurements

| Participant characteristics | | Group A n=21 | Group B n=21 |
|---|---|---|---|
| Mean age in years (SD)[a] | | 48.5 (5.2) | 49.2 (4.9) |
| BMI[b] in kg[c]/m[2d] (SD) | | 27.3 (2.1) | 27.5 (2.0) |
| Gender | Male | 12 | 10 |
| | Female | 09 | 11 |
| Comorbidities | Diabetes | 12 | 11 |
| | Hypertension | 07 | 09 |

[a]*SD – Standard Deviation*
[b]*BMI – Body Mass Index*
[c]*kg – Kilogram*
[d]*m – Metre*

*Source: compiled by the authors of this study*

**Table 2.** Pre-test and post-test values of 2MWT for Group A and Group B

| Groups | 2MWT[a] | Mean | SD | t-value | p-value |
|---|---|---|---|---|---|
| Group – A | Pre-test | 53.700 | 0.753 | 183.1828 | <0.0001 |
| | Post-test | 83.800 | 1.506 | | |
| Group – B | Pre-test | 52.633 | 0.712 | 138.5738 | <0.0001 |
| | Post-test | 77.933 | 0.128 | | |
| Post-test values of Group – A | | 83.800 | 1.506 | 17.7878 | <0.0001 |
| Post-test values of Group – B | | 77.933 | 0.128 | | |

[a]*2MWT – Two-Minute walk test*

*Source: compiled by the authors of this study*

received conventional physiotherapy with forward walking, showed a post-test mean of 77.933m (SD: 0.128). The within-group analysis revealed significant improvements from pre-test to post-test for both Group A (t-value: 183.1828, $p<0.0001$) and Group B (t-value: 138.5738, $p<0.0001$). The minimal clinically important difference (MCID) for 2MWT is approximately 14m, and both groups exceeded this threshold post-intervention.

Comparing the post-test values between the two groups, the between-group analysis indicated that Group A demonstrated significantly greater improvement in 2MWT scores than Group B (t-value: 17.7878, $p<0.0001$), suggesting that the addition of BWT to conventional physiotherapy was more effective in enhancing functional mobility.

A follow-up assessment at two weeks post-intervention showed that Group A maintained 85% (Mean- 80.63m) of their improvement, while Group B retained 78% (Mean-75.19m), indicating better long-term retention of gains in the BWT group.

## DISCUSSION

The purpose of the study was to determine the effectiveness of Backward Walking Training in terms of functional capacity in patients who underwent Upper abdominal surgery. The findings of this study demonstrate that backward walking training (BWT) significantly improves functional recovery in patients who underwent upper abdominal surgery compared to conventional physiotherapy alone. The observed improvements in the Two-Minute Walk Test (2MWT) suggest that BWT enhances postoperative mobility and endurance, offering a promising addition to standard rehabilitation protocols. The significant improvements in 2MWT scores observed in Group A may be attributed to the unique motor demands of backward walking, which enhance proprioception, core stability, and cardiopulmonary effort.

Consistent with findings in neurological rehabilitation, BWT in our study appears to activate posterior chain musculature and challenge balance mechanisms more than forward walking, leading to more pronounced functional improvements.

According to a study by Michaelsen et al. (2014) on the impact of backward walking training on walking ability following a stroke, walking on a treadmill backwards may enhance walking ability more than walking forwards in those who have had a stroke. They suggest that, in comparison to forward walking, reverse walking causes higher levels of lower limb muscle activation and postural problems. Consequently, compared to forward walking, it may enhance balance, coordination, spatiotemporal gait characteristics, and walking quality more [14].

Similarly, the studies by Rose et al. (2018) and Chang et al. (2021) found that adding backward walking to conventional therapy improved balance, gait, and cardiorespiratory fitness in stroke patients. The improvements seen with backward walking training may be related to the unique motor, balance, and coordination demands of backward locomotion. Backward walking requires trunk and pelvis control, proprioceptive input, and integration of sensory information which could explain the gains in functional mobility [15,16].

However, there is limited research specifically investigating backward walking in patients after abdominal surgery. The postoperative rehabilitation protocols after abdominal surgery typically involve early mobilization but do not routinely include backward walking as an intervention. This study provides initial evidence that adding backward walking training as an adjuvant to standard postoperative rehabilitation may enhance functional recovery in this population.

### LIMITATIONS

Despite promising results, the study has limitations.

1. Short intervention period limits generalizability.
2. Single-center study may reduce external validity.
3. No long-term follow-up beyond two weeks.
4. Participant motivation and subjective effort not controlled.

## CONCLUSIONS

In conclusion, this study demonstrates that incorporating backward walking training into postoperative rehabilitation significantly improves functional capacity in patients undergoing upper abdominal surgery. The findings suggest that BWT may offer greater benefits compared to conventional physiotherapy alone, particularly in enhancing mobility and recovery speed. While the results are promising, further research with larger sample sizes, extended intervention durations, and additional outcome measures is necessary to optimize rehabilitation protocols. Integrating BWT into standard postoperative care may provide a novel and effective approach to enhancing patient recovery following major abdominal surgeries.

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**CONFLICT OF INTEREST**

The Authors declare no conflict of interest


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**RECEIVED:** 22.05.2025
**ACCEPTED:** 28.08.2025

ORIGINAL ARTICLE

# Completeness of implementation of Individual Rehabilitation Plans and satisfaction with its results (according to a survey of people with disabilities after musculoskeletal injuries)

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## ABSTRACT

**Aim:** To analyze the completeness of Individual Rehabilitation Plans and satisfaction with its results (based on a survey of people with disabilities after musculoskeletal injuries).

**Materials and Methods:** According to the original author's program, a cross-sectional medical and sociological survey was conducted of 151 randomly selected people with disability after musculoskeletal injuries over the age of 18, residents of Ivano-Frankivsk region.

**Results:** It was found that 72.2% of respondents were dissatisfied with their rehabilitation. Individual Rehabilitation Plans of the vast majority (92.7%) were performed partially (60.0%) or not at all. The main reasons were financial limitations (50.0%) and improper communication from medical and rehabilitation settings (31.9%). Rehabilitation services were provided to respondents in insufficient quantities, although coverage increased from 9.3-13.3% in the acute period to 51.3-62.4% in the long-term period. A significant need for psychological consultation was identified (39.7%) against the background of the lack of information about the possibility of obtaining it (60.7%). In two-thirds of cases (64.8%) the surveyed persons are not sufficiently provided with assistive rehabilitation devices and in half of cases (52.3%) they are not informed about the social support services they are entitled to. To improve communication and coordination of all stakeholders in the long-term rehabilitation, it is proposed to identify a responsible rehabilitation manager at the community level, whose functions can be assigned to a public health specialist or to the head or responsible person of the primary health care facility.

**Conclusions:** Improving of the rehabilitation effectiveness requires enhancing communication and coordination between all stakeholders of the rehabilitation process.

**KEYWORDS:** musculoskeletal injuries, biopsychosocial model, community-based rehabilitation, rehabilitation management, Individual Rehabilitation Plan

Acta Balneol. 2025;67(5):345-351. doi: 10.36740/ABAL202505105

## INTRODUCTION

The problem of rehabilitation is still relevant. According to the World Health Organization (WHO), about 15% of the world's population lives with some form of permanent disability, of which more than 200 million have serious difficulties in functioning [1-3].

In Ukraine, the absolute number of people with disabilities is increasing from year to year, as is their rate in the population – from 3.0% in 1994 to 6.5% in 2020 [4].

Injuries are one of the leading causes of disability among the adult population both globally and in Ukraine in particular. Almost one billion people on Earth today live with the consequences of fractures, amputations, or other injuries [3, 5]. As a rule, the Years Lived with Disability due to trauma is highest at the social activity and working capacity age of 20-69 years, which emphasizes the burden of the problem and the importance of improving approaches to rehabilitation [3]. At the same time, as a result of the full-scale aggression of the russian federation against Ukraine, a significant increase in disability due to trauma after the war is predicted [6, 7].

However, the organization of rehabilitation services still faces numerous challenges, particularly in middle- and low-income countries, which results in only a small proportion of people in need of rehabilitation being able to receive it [8, 9]. In addition to problems with financing rehabilitation services, such barriers often include the lack of rehabilitation facilities and advanced technologies for rehabilitation activities, lack of coordination and data integration between stakeholders [10].

In 2021, with the approval of the Law "On Rehabilitation in Healthcare" [11], Ukraine began the process of transforming its rehabilitation system. According to the law, the organization of rehabilitation is based on the biopsychosocial model of daily functioning limitation, the rehabilitation strategy of health care and the International Classification of Functioning, Disability and Health. Rehabilitation care is provided by a multidisciplinary rehabilitation team from the moment a person has a limitation in daily functioning. However, still insufficiently effective coordination between stakeholders leads to fragmentation of the rehabilitation process, complications

in effective and comprehensive service delivery, and a negative impact on outcomes.

This emphasizes the need to improve the organization of rehabilitation after musculoskeletal injuries, considering medical, social and psychological aspects, as well as the needs and capabilities of patients.

## AIM

To analyze the completeness of Individual Rehabilitation Plans (IRP) and satisfaction with its results (based on a survey of people with disabilities after musculoskeletal injuries).

## MATERIALS AND METHODS

According to the original author's program, a cross-sectional medical and sociological survey was conducted of 151 randomly selected people with disability after musculoskeletal injuries over the age of 18, residents of Ivano-Frankivsk region, who agreed to participate in the research by signing the appropriate informed agreements. The survey was conducted at a medical and social examination facility, where the participants underwent re-examinations by a team of experts to determine the degree of loss of permanent disability. The questionnaire included the following blocks of questions: social and demographic characteristics of respondents; satisfaction with rehabilitation outcomes; barriers to rehabilitation effectiveness; types of medical and rehabilitation services received; need for psychological support; coverage of assistive rehabilitation devices; awareness of social support. In order to validate the questionnaire to determine the time for answering and the clarity of the questions, they were first tested and revised on 15 volunteers.

Out of the 151 individuals, 69.5% were male and 30.5% were female. Participants were recruited from both urban and rural areas, with 35.1% of the sample living in urban settings and 64.9% in rural areas. Age groups were divided as follows: 18-29 years (7.3%), 30-39 years (31.3%), 40-49 years (30.5%) and 50-59 years (30.5%).

The design and program of the research were reviewed and approved by the Ethics Committee of Ivano-Frankivsk National Medical University (Protocol No. 138/23 of 24.10.2023).

Data processing was carried out on the database created using Microsoft Excel by calculating rates of characteristics per 100 respondents and its standard error (±m). The reliability of the differences in data in the comparison groups (men-women, urban-rural, age groups) was assessed by the chi-square test ($\chi^2$).

## RESULTS

It was found that only a quarter of the respondents (27.8%) were fully satisfied with the results of his or her rehabilitation (Fig. 1). Most surveyed believed that they had achieved the expected effect partially (61.6%), and every tenth was completely dissatisfied (10.6%), especially among females: 19.6% vs. 6.7% of males ($p<0.05$).

The most important reasons for dissatisfaction with the results of rehabilitation measures were the lack of positive dynamics (62.5%) and the lack of conditions (facilities and specialists) for rehabilitation (25.0%). Among others, 6.3% of those dissatisfied complained about the lack of preferential vouchers for health resort treatment.

Only 7.3% of respondents indicated that they had fully implemented their IRP, significantly more common in urban areas than in rural areas ($p<0.05$) – 17.0% vs. 2.1%, respectively (Fig. 2). At the same time, the vast majority of surveyed assessed the completeness of their IRP as partial (68.0%), and one-fourth (24.7%) complained that they had not managed to complete it at all, in villages twice as high as in cities.

Among the respondents who did not fully perform the IRP, the main challenges were financial (50.0%) as well as organizational and communication (31.9% in total), namely:

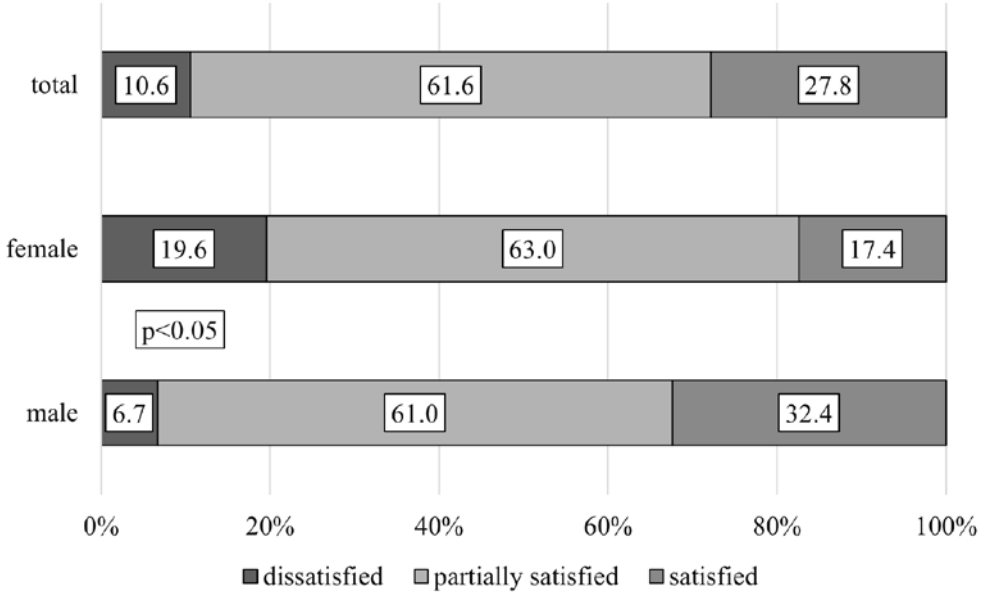


**Fig. 1** Satisfaction with the results of rehabilitation

*Source: compiled by the authors of this study*

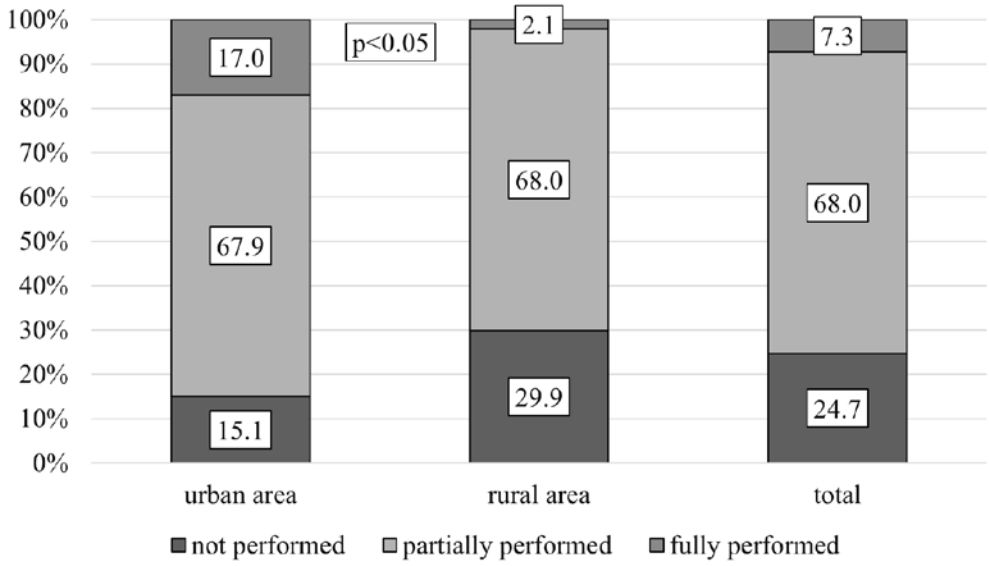


**Fig. 2.** Distribution of completeness of IRP implementation depending on place of residence

*Source: compiled by the authors of this study*

**Table 1.** Frequency of use of treatment and rehabilitation methods at different rehabilitation stages of persons with disabilities after musculoskeletal injuries

| Treatment method | Acute rehabilitation | | Post-acute rehabilitation | | Long-term rehabilitation | |
|---|---|---|---|---|---|---|
| | % | ±m | % | ±m | % | ±m |
| Surgery | 80.0 | 3.3 | 6.0 | 2.2 | 1.7 | 1.2 |
| Plaster cast | 25.3 | 3.6 | 7.8 | 2.5 | 0.0 | 0.0 |
| External fixation device | 14.7 | 2.9 | 2.6 | 1.5 | 0.9 | 0.9 |
| Skeletal traction | 9.3 | 2.4 | 0.9 | 0.9 | 0.0 | 0.0 |
| Therapeutic massage | 13.3 | 2.8 | 60.3 | 4.5 | 62.4 | 4.5 |
| Physical therapy | 9.3 | 2.4 | 38.8 | 4.5 | 51.3 | 4.6 |
| Electrophoresis | 6.7 | 2.0 | 32.8 | 4.4 | 29.9 | 4.2 |
| Magnetotherapy | 2.7 | 1.3 | 16.4 | 3.4 | 15.4 | 3.3 |
| Balneotherapy | 0.7 | 0.7 | 7.8 | 2.5 | 6.0 | 2.2 |
| Laser therapy | 0.7 | 0.7 | 3.4 | 1.7 | 5.1 | 2.0 |
| Paraffin therapy | 0.7 | 0.7 | 15.5 | 3.4 | 14.5 | 3.3 |
| Health resort treatment | 0.7 | 0.7 | 7.8 | 2.5 | 19.7 | 3.7 |
| Other | 5.3 | 1.8 | 12.9 | 3.1 | 9.4 | 2.7 |

*Source: compiled by the authors of this study*

20.3% did not know where to apply for rehabilitation services, 11.6% reported that no one told them about the importance of following the IRP. In addition, 8.7% noted that the nearest medical facility did not have the appropriate equipment and specialists.

When analyzing the specific amount of medical and rehabilitation services patients received during acute, post-acute and long-term rehabilitation (Table 1), it was found that right after the injury, the method of choice was surgery (66.5±3.9%). In addition, quite often patients were treated with a plaster cast (25.3±3.6%), an external fixation device (14.7±2.9%), skeletal traction (9.3±2.4%), and massage (13.3±2.8%). At the same time, only 9.3±2.4% of respondents were covered by physical therapy. Other rehabilitation services during this period were sporadic. However, it is noticeable that non-evidence-based procedures were prescribed: electrophoresis (6.7±2.0%), magnetotherapy (2.7±1.3%), etc.

In the post-acute period, rehabilitation services come to the fore: therapeutic massage (60.3±4.5%) and physical therapy (38.8±4.5%), as well as electrophoresis (32.2±4.4%), magnetotherapy (16.4±4.4%), and paraffin

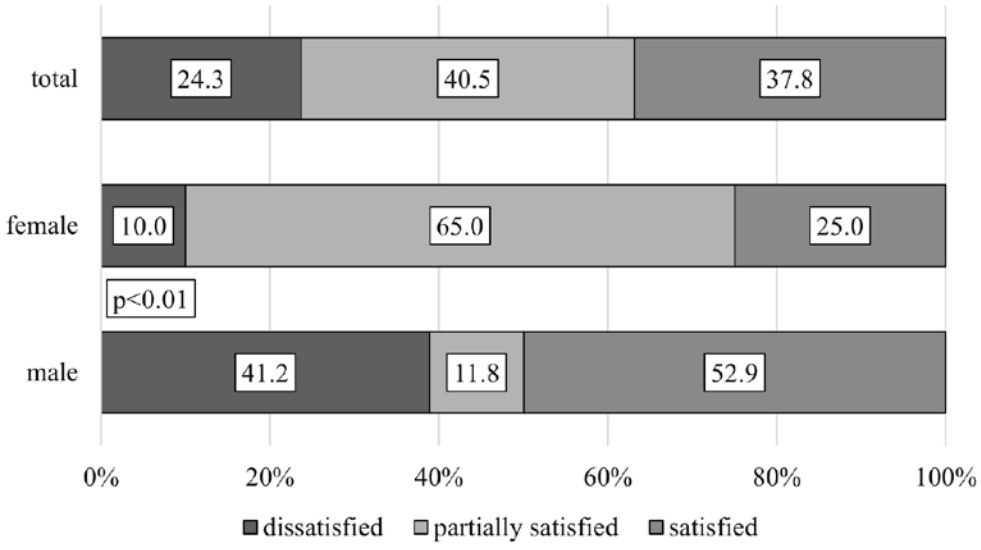


**Fig. 3.** The coverage of respondents' needs for assistive rehabilitation devices (per 100 people who needed it)

*Source: compiled by the authors of this study*

therapy (15.5±3.4%). About 10% (7.8±2.5%) of respondents said they had undergone health resort treatment and balneotherapy.

After the establishment of a permanent disability, i.e. during a long-term rehabilitation period, the respondents continued to receive mainly the same rehabilitation services. Of these, therapeutic massage remained a priority (62.4±4.5%). At the same time, the coverage of physical therapy (51.3±4.6%) and health resort treatment (19.7±3.7%) increased. Non-evidence-based procedures remained widespread: electrophoresis (29.9±4.2%), magnetotherapy (15.4±3.3%), paraffin therapy (14.5±3.3%), etc.

At the time of the survey, i.e. at the stage of long-term rehabilitation, almost 40% (36.0%) of respondents were taking non-steroidal anti-inflammatory drugs to relieve pain. However, almost half of the surveyed (46.7%) took non-evidence-based medications (nutritional supplements, vitamins, etc.). The use of sleeping pills and sedatives was quite common (22.7%). A possible reason for this is that almost 40% (39.7%) of respondents felt the need for psychotherapeutic consultation (from time to time – 29.8%, or constantly – 9.9%), among females twice as often as among males (65.2% vs. 28.6%, respectively, $p<0.001$). At the same time, the majority (60.7±4.0%) of interviewed did not know where to get it.

It was found that half (52.3%) of the respondents did not know what social support services they were entitled to in connection with their disability, and 39.7% were partially aware. Although about 60% (57.0%) of respondents needed assistive rehabilitation devices, only 43.0% of them applied for it to the relevant services, and 57.0% did not. At the same time, among those who applied for assistive rehabilitation devices, only about 40% (37.8%) received everything they needed (Fig. 3). About the same number (40.5%) partially met their needs. However, a quarter (24.3%) of them complained that they had not received anything, especially among males: 41.2% vs. 10.0% among females ($p<0.01$).

## DISCUSSION

Our study showed that a significant part of people with disabilities after musculoskeletal injuries (72.2%, including 82.6% of females and 67.7% of males) were completely or partially dissatisfied with their rehabilitation. As in other similar studies [8, 12, 13], the most common reasons for this were the subjective lack of positive dynamics and the lack of institutions or specialists providing such services.

On the other hand, it is impossible to achieve positive dynamics when the majority of respondents (92.7%) have incomplete (68.0%) or no IRP at all (24.7%). At the same time, it has been confirmed that the main barriers to this are usually financial limitations [13, 14], as well as inadequate organization of communication by medical and rehabilitation settings [15, 16]. In particular, a significant proportion of our respondents complained that they had not been warned about the importance of adherence to the IRP. And it is known that patient involvement and awareness of the services received is an important factor in the effectiveness of medical and rehabilitation care, as it increases adherence to the recommendations of medical and rehabilitation professionals [17, 18]. Moreover, joint goal setting is a fundamental aspect of patient-centered rehabilitation [19]. It is important to discuss with the patient the existing barriers and facilitators to receiving rehabilitation services, emphasizing the positive results that can be achieved [20].

Our study also confirmed that a significant factor in the implementation of the IRP is the territorial accessibility of rehabilitation services [21]. It was found that in urban areas the level of IRP implementation was significantly higher than in rural ones.

Regarding the specific list of services received by our respondents, it was found that in the acute period of rehabilitation, medical care was a priority, and rehabilitation services were rather sporadic. However, modern rehabilitation principles require that they should be apply as early as possible to the widest range of traumatized people, as

an early start of the rehabilitation process is one of the conditions for its success [17].

Our study found that in the subsequent periods of rehabilitation, the frequency of specialized treatments gradually decreased and the coverage of patients with rehabilitation services, including massage, physical therapy, and health resort treatment, increased.

At the same time, it is noteworthy that among the rehabilitation services provided, the percentage of prescriptions for non-evidence-based procedures (electrophoresis, magnetotherapy, paraffin therapy, laser therapy) was quite high, which is known to lead to unnecessary expenditures [22].

The study also revealed lacks in meeting the needs of respondents in psychological rehabilitation (39.7%), more so among females (65.2%) than males (28.6%). However, scientists have proven that mental health support has a positive impact and contributes to the effectiveness of rehabilitation, increased adherence to rehabilitation interventions, stable motivation to follow the recommendations of rehabilitation specialists, and an increase in the quality of life of rehabilitants [23].

Our study also found that almost half of the respondents did not know what social support services they were entitled to in connection with their disability and only a part of them were able to receive the necessary assistive rehabilitation devices. This indicates a lack of sufficient organizational support in social adaptation, a necessary component of the rehabilitation package [20].

As we can see the key problem of ensuring the continuity and comprehensiveness of rehabilitation services at all stages was the lack of effective communication and interaction. This is especially true for rehabilitation care in post-acute and long-term rehabilitation, which is usually provided at home or at the community level [11, 24, 25].

In our opinion, a possible solution to the established problems could be the appointment of a responsible rehabilitation manager at the community level whose main task would be to improve communication and coordination of all stakeholders of the rehabilitation process. International experience shows that this function is the best performed by a public health specialist, who in many countries is an employee of local government [26]. In case of such specialist's absence this function can be delegated to the head or responsible person of a primary health care facility [3].

LIMITATIONS

The study was conducted during the transitional period of the rehabilitation system reform, which could have affected the completeness of the implementation of the IRP, especially in the acute and post-acute periods.

PROSPECTS FOR FURTHER RESEARCH

Will be to develop a functional and organizational model for improving the process of rehabilitation of people after musculoskeletal injuries at the community level and to test it in the context of a significant increase in the number of injured people as a result of the full-scale aggression of the Russian federation.

## CONCLUSIONS

It was found that 72.2% people (82.6% among females vs. 67.7% of males) with disabilities after musculoskeletal injuries were dissatisfied with their rehabilitation, mainly due to the lack of positive dynamics (62.5%).

It was shown that Individual Rehabilitation Plans of the vast majority (92.7%) of respondents were performed partially (60.0%) or not at all (24.7%, 29.9% among rural residents vs. 15.1% among urban residents). The main reasons were financial limitations (50.0%) and improper communication from medical and rehabilitation settings (31.9%).

It was found that rehabilitation services were provided to respondents in insufficient quantities in all periods of rehabilitation, although coverage increased from 9.3-13.3% in the acute period to 51.3-62.4% in the long-term period. The list of medical and rehabilitation measures revealed a significant use of non-evidence-based medications (46.7%) and methods (14.5-29.9%).

A significant need for psychological consultation was identified (39.7%, 65.2% among females vs. 28.6% among males) against the background of the lack of information about the possibility of obtaining it (60.7%).

It is shown that in two-thirds of cases (64.8%) the surveyed persons are not sufficiently provided with assistive rehabilitation devices and in half of cases (52.3%) they are not informed about the social support services they are entitled to.

The system of rehabilitation after musculoskeletal injuries requires improvement at all stages: acute, post-acute and long-term rehabilitation. In particular, to improve communication and coordination of actions of all stakeholders in the long-term rehabilitation, it is proposed to identify a responsible rehabilitation manager at the community level, whose functions can be assigned to a public health specialist or (in case of his/her absence) to the head or responsible person of the primary health care facility.

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**CONFLICT OF INTEREST**
The Authors declare no conflict of interest

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A – Work concept and design, B – Data collection and analysis, C – Responsibility for statistical analysis, D – Writing the article, E – Critical review, F – Final approval of the article

**RECEIVED:** 14.04.2025
**ACCEPTED:** 08.08.2025

 

ORIGINAL ARTICLE

# Comparative effectiveness of hip – *versus* knee – dominant strengthening exercises in patellofemoral pain syndrome. A randomized controlled trial

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## ABSTRACT

**Aim:** To compare the effectiveness of hip-dominant *versus* knee-dominant strengthening exercises in individuals with patellofemoral pain syndrome (PFPS), it is essential to evaluate outcomes related to pain reduction, functional improvement, and strength enhancement. Hip-dominant exercises primarily target the gluteal muscles and lateral hip stabilizers, which can address proximal biomechanical deficits often linked to PFPS.

**Materials and Methods:** A randomized controlled trial was conducted with 40 participants diagnosed with PFPS, randomized into two groups: hip-dominant strengthening exercises (n=20) and knee-dominant strengthening exercises (n=20). The intervention lasted 8 weeks, and outcome measures included pain intensity (Visual Analog Scale [VAS]), knee-specific function (Kujala Anterior Knee Pain Scale), muscle strength (hip abductor and quadriceps strength), and the Global Rating of Change (GROC) scale.

**Results:** Both groups showed significant improvements in pain, function, and strength compared to baseline ($p<0.001$). However, the hip-dominant group exhibited a greater reduction in pain (VAS: $p=0.004$), higher improvements in function (Kujala: $p=0.001$), and more significant gains in hip abductor strength ($p<0.001$) compared to the knee-dominant group. Additionally, 85% of the hip-dominant group reported a clinically significant improvement on the GROC scale, compared to 60% in the knee-dominant group ($p=0.03$).

**Conclusions:** Hip-dominant strengthening exercises are more effective than knee-dominant exercises in reducing pain, improving knee function, and increasing muscle strength in individuals with PFPS.

**KEYWORDS:** hip-dominant exercises, knee-dominant exercises, proximal control, patellar tracking, physiotherapy

Acta Balneol. 2025;67(5):352-356. doi: 10.36740/ABAL202505106

## INTRODUCTION

Patellofemoral Pain Syndrome (PFPS) is one of the most common causes of anterior knee pain, particularly in physically active individuals, and is characterized by pain around or behind the patella, often exacerbated by activities such as squatting, stair climbing, or prolonged sitting [1]. The etiology of PFPS is multifactorial, involving altered biomechanics, muscle imbalances, and reduced neuromuscular control of the lower extremity [2].

Historically, rehabilitation approaches have emphasized quadriceps strengthening, particularly targeting the vastus medialis obliquus (VMO), based on the rationale that patellar maltracking is primarily due to quadriceps weakness [3]. While quadriceps-focused protocols remain widely used, growing evidence suggests that isolated knee exercises may not sufficiently address proximal contributing factors such as hip muscle weakness, which can influence femoral internal rotation and increase patellofemoral joint stress [4].

A shift in rehabilitation paradigms has led to increased interest in proximal interventions, particularly strengthening of the hip abductors, extensors, and external rotators. Dolak et al. [5] demonstrated that initiating rehabilitation with hip strengthening prior to quadriceps exercises led to earlier pain reduction in females with PFPS. Similarly, Şahin et al. [6] reported that combined hip and knee strengthening was superior to knee-only protocols in reducing pain and improving function.

Soleimani et al. [7] found that adding hip strengthening to conventional knee exercises produced significantly better outcomes in both pain and function compared to knee-only exercises, while Ismail et al. [8] reinforced this finding by showing enhanced results when hip strengthening was added to closed kinetic chain knee exercises. Systematic reviews also support the integration of hip exercises, with Thomson et al. [9] concluding that proximal-focused protocols result in superior outcomes for PFPS, especially in females.

More recent studies have explored variations of integrated approaches. Lee et al. [10] compared hip–knee and ankle–knee strengthening protocols and found both effective, though hip-focused interventions remained favorable for functional gains. Saad et al. [11] further differentiated between types of hip-focused exercises and emphasized the importance of individualized protocols, while Pompeo

et al. [12] suggested that distal segment training might be a viable alternative under specific conditions, although not necessarily superior to hip-based protocols.

Despite this growing body of evidence, few studies have directly compared the effectiveness of hip-dominant versus knee-dominant strengthening programs in isolation using a rigorous randomized controlled trial design. This gap is particularly relevant given the need to optimize resource allocation and exercise prescription in clinical settings. The present study aims to compare the effectiveness of a hip-dominant strengthening protocol versus a knee-dominant protocol in individuals with PFPS, evaluating outcomes in pain reduction, functional improvement, and muscle strength.

## MATERIALS AND METHODS

This study employed a single-blinded, two-arm randomized controlled trial design conducted over a period of 8 weeks. Participants were recruited from outpatient physiotherapy clinics and university health centers. Individuals aged between 18 and 40 years with a clinical diagnosis of patellofemoral pain syndrome (PFPS) were eligible for inclusion. The diagnosis was based on the presence of anterior or retropatellar knee pain lasting for at least four weeks, aggravated by at least two functional activities such as stair climbing, squatting, running, kneeling, or prolonged sitting. Participants were required to report a pain intensity score of at least 3 on a 10-point Visual Analog Scale (VAS) during aggravating activities. Exclusion criteria included a history of knee surgery, patellar dislocation or instability, ligamentous or meniscal injuries, systemic musculoskeletal disorders, or engagement in any lower limb strength training program in the previous six months. Written informed consent was obtained from all participants prior to inclusion in the study.

Eligible participants were randomly allocated into either a hip-dominant strengthening group or a knee-dominant strengthening group using a computer-generated random number sequence. Allocation was concealed using sealed opaque envelopes. While participants were aware of their assigned exercise protocol, the outcome assessor remained blinded to group allocation throughout the study to minimize bias.

Both groups participated in supervised physiotherapy sessions three times a week for eight consecutive weeks. Each session lasted approximately 45 to 60 minutes and included a standardized warm-up and cool-down period. The hip-dominant group performed exercises targeting the hip abductors, extensors, and external rotators, including side-lying hip abduction, clamshells, prone hip extension, monster walks with resistance bands, and single-leg bridges. Exercises were progressed based on symptom tolerance and proper form. Conversely, the knee-dominant group performed exercises focused on quadriceps strengthening, including straight leg raises, mini-squats (0-45°), terminal knee extensions with resistance bands, step-downs, and wall sits. All exercises were performed in pain-free or minimally painful ranges.

Outcome measures were assessed at baseline and at the end of the 8-week intervention period. The primary outcome was pain intensity measured using the Visual Analog Scale (VAS) during stair descent. Secondary outcomes included functional status assessed using the Kujala Anterior Knee Pain Scale, muscle strength of the hip abductors and knee extensors measured using handheld dynamometry, and patient-perceived global improvement assessed using the Global Rating of Change (GROC) scale.

Data were analyzed using SPSS version 26.0. Descriptive statistics were used to summarize baseline characteristics. Within-group changes were evaluated using paired t-tests, while between-group differences were analyzed using repeated-measures ANOVA and ANCOVA, adjusting for baseline values where appropriate. The level of significance was set at $p < 0.05$. Cohen's d was calculated to interpret effect sizes and assess clinical relevance.

## RESULTS

A total of 52 participants were initially screened for eligibility, out of which 40 met the inclusion criteria and were randomized into two equal groups: the hip-dominant strengthening group (n=20) and the knee-dominant strengthening group (n=20). All participants completed the 8-week intervention without any dropouts or adverse events. Baseline demographic and clinical characteristics were comparable between the groups, with no statistically significant differences in age, gender distribution, baseline VAS scores, Kujala scores, or muscle strength. 1.1 in the knee-dominant group (p=0.004) (Table 1). Similarly, functional improvement as measured.

Following the intervention, both groups demonstrated statistically significant improvements in all outcome measures compared to baseline ($p< 0.001$). The hip-dominant group showed a greater reduction in pain, with a mean decrease in VAS scores of 4.1±1.2, compared to 2.9± by the Kujala Anterior Knee Pain Scale was significantly higher in the hip-dominant group (mean increase: 22.4±6.5) compared to the knee-dominant group (mean increase: 15.3±5.7; p=0.001).

In terms of strength outcomes, participants in the hip-dominant group exhibited greater gains in hip abductor strength (mean increase: 27.8%±8.2) compared to the knee-dominant group (14.3%±6.7; $p<0.001$). Meanwhile, the knee-dominant group showed slightly greater improvement in quadriceps strength, though the difference between groups was not statistically significant (p=0.09).

On the Global Rating of Change (GROC) scale, 85% of participants in the hip-dominant group reported scores of +5 or higher, indicating moderate to large perceived improvement, compared to 60% in the knee-dominant group (p=0.03) (Table 1).

## DISCUSSION

The results of this randomized controlled trial indicate that hip-dominant strengthening exercises are more effective than knee-dominant exercises in reducing pain, improving function, and increasing strength in individuals

**Table 1.** Comparison of Outcomes Between Groups (Post-Intervention)

| Outcome Measure | Hip Group (n=20) | Knee Group (n=20) | p-value |
|---|---|---|---|
| VAS Pain Score (0-10) | 2.3 ± 0.8 | 3.6 ± 0.9 | 0.004 |
| Kujala Score (0-100) | 82.6 ± 7.4 | 75.2 ± 6.9 | 0.001 |
| Hip Abductor Strength (% change) | 27.8% ± 8.2 | 14.3% ± 6.7 | <0.001 |
| Knee Extensor Strength (% change) | 17.1% ± 6.1 | 20.6% ± 7.4 | 0.09 |
| GROC Score ≥+5 (% of participants) | 85% | 60% | 0.03 |

*Source: compiled by the authors of this study*

with patellofemoral pain syndrome (PFPS). The hip-dominant group exhibited greater reductions in pain, more significant improvements in function, and greater gains in hip abductor strength compared to the knee-dominant group, which aligns with the findings of several key studies in the field.

The significant reduction in pain observed in the hip-dominant group (p=0.004) supports the conclusions of Tyler et al. (2006), who highlighted the role of hip muscle function in alleviating PFPS symptoms. Their work suggested that addressing proximal muscle weakness, especially in the hip abductors and external rotators, helps stabilize the pelvis and lower extremities, reducing knee joint stress and alleviating pain during functional activities like stair climbing and squatting [5]. Our results corroborate this, suggesting that improving hip strength may be a crucial component of PFPS management, as it helps optimize lower limb mechanics and reduces pain.

In terms of functional outcomes, the hip-dominant group demonstrated significantly higher improvements in the Kujala Anterior Knee Pain Scale (p=0.001), which measures knee-specific function. This finding is consistent with the work of Rogan et al. (2019), who found that hip abductor muscle exercises were associated with substantial improvements in both pain and function in individuals with PFPS [6]. These improvements are likely due to enhanced control of the lower extremities during functional movements, such as squatting and stair climbing, which are commonly problematic in PFPS. The hip muscles contribute to the stabilization of the pelvis and lower limb, leading to better alignment and decreased knee joint stress during dynamic activities.

Our study also demonstrated greater increases in hip abductor strength in the hip-dominant group (p<0.001), which further supports findings from Hamada et al. (2017). They reported that hip and knee exercise programs had a carryover effect on functional performance in individuals with PFPS, with hip strengthening particularly contributing to improved postural control and lower limb mechanics [7]. This is crucial, as hip weakness can result in increased femoral internal rotation, which has been linked to abnormal patellofemoral joint loading and pain. By strengthening the hip abductors and extensors, the load on the knee is reduced, potentially mitigating PFPS symptoms.

On the other hand, the knee-dominant group showed a smaller but statistically significant improvement in knee extensor strength, although the difference between groups did not reach statistical significance (p=0.09). This is consistent with Kooiker et al. (2014), who found that quadriceps strengthening exercises alone resulted in modest improvements in pain and function in individuals with PFPS [8]. However, their systematic review also indicated that isolated knee exercises were less effective in improving long-term functional outcomes compared to integrated hip and knee strengthening approaches. This supports our hypothesis that knee strengthening alone may not be sufficient to fully address the underlying mechanical factors contributing to PFPS.

Additionally, a greater percentage of participants in the hip-dominant group reported clinically meaningful improvement (GROC≥+5) compared to the knee-dominant group (p=0.03). This is in line with Elliott et al. (2018), who conducted a systematic review and concluded that adding hip strengthening exercises to standard rehabilitation protocols led to more significant improvements in both pain and function in PFPS patients [9]. This suggests that incorporating hip exercises in PFPS rehabilitation provides a more comprehensive approach, addressing not only the knee joint but also the proximal stabilizing muscles.

Furthermore, the findings from the current study align with those of Lee et al. (2025), who also reported that integrated exercises targeting both the ankle, knee, and hip muscles resulted in improved gait and lower extremity function in individuals with PFPS [10]. Their study emphasizes the importance of a multi-joint approach to rehabilitation, which our results support, particularly with respect to the hip's role in maintaining proper lower limb alignment and function.

Despite the promising results, this study has several limitations. First, the sample size was relatively small, and future studies with larger sample sizes are needed to confirm the generalizability of these findings. Additionally, the follow-up period was limited to 8 weeks, and long-term follow-up is necessary to assess the sustained effectiveness of hip-dominant exercises in preventing recurrence of PFPS symptoms. The study also included only young adults (18-40 years), and it remains unclear whether the results can be generalized to older populations or individuals with more severe PFPS. Lastly, while the outcome assessor was blinded, the nature of the interventions meant that participants could not be blinded to their group allocation, which may have introduced bias.

## CONCLUSIONS

In conclusion, this study provides robust evidence supporting the effectiveness of hip-dominant strengthening exercises over knee-dominant exercises in reducing pain, improving function, and increasing strength in individuals with PFPS. Clinicians should consider incorporating hip-focused rehabilitation strategies, particularly in patients with persistent or recurrent PFPS, to optimize patient outcomes. Future research should investigate the long-term benefits of these interventions and explore their applicability in broader patient populations.

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**CONFLICT OF INTEREST**
The Authors declare no conflict of interest

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**RECEIVED:** 22.04.2025
**ACCEPTED:** 06.08.2025

ORIGINAL ARTICLE

# New approach for erythematotelangiectatic rosacea management with Nd:YAG 1064 laser therapy

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## ABSTRACT

**Aim:** To evaluate and to improve treatment methods of erythematotelangiectatic rosacea by applying a differentiated therapeutic approach.

**Materials and Methods:** For the study, 40 patients were selected with Fitzpatrick skin phototypes I–III who presented with visible vascular changes, sensations of heat, and persistent facial redness and were involved in the erythematotelangiectatic rosacea group. Digital image analysis was conducted at baseline and again one month after treatment to objectively assess treatment outcomes.

**Results:** Forty patients with erythematotelangiectatic rosacea were divided into two subgroups: azelaic acid gel and long-pulsed Nd:YAG 1064 nm laser therapy. At baseline, both groups showed comparable erythema severity (64,066.16 vs. 63,735.81 pixels). After one month, the erythematotelangiectatic rosacea group demonstrated a 48.72% reduction in erythema area (to 32,143.72 pixels), while the erythematotelangiectatic rosacea long-pulsed Nd:YAG group achieved an 87.24% reduction (to 8,137.24 pixels). Relative to total facial area, erythema decreased from 18.7% to 9.74% in erythematotelangiectatic rosacea and from 18.19% to 3.39% in long-pulsed Nd:YAG. Skin color normalization was also greater in the laser group (8.33% vs. 4.28%).

**Conclusions:** Both treatments improved symptoms, but Nd:YAG laser therapy provided significantly faster and more pronounced erythema clearance compared with topical therapy.

**KEYWORDS:** rosacea, erythematotelangiectatic rosacea, laser therapy, Nd:YAG 1064 laser, vascular lesions, facial erythema

Acta Balneol. 2025;67(5):357-361. doi: 10.36740/ABAL202505107

## INTRODUCTION

Erythematotelangiectatic rosacea (ETAR) is a chronic skin disorder characterized by persistent facial erythema, flushing, and visible telangiectasias. Although not life-threatening, its recurrent nature and cosmetic impact significantly reduce patients' quality of life [1]. The pathogenesis of ETAR involves vascular dysregulation, neurogenic inflammation, and environmental triggers, making treatment complex.

Conventional therapies such as topical agents and α-adrenergic agonists provide only temporary relief and have limited effect on persistent vascular changes. In this context, laser-based approaches are gaining importance [2]. The Nd:YAG laser, due to its deep penetration and selective targeting of dilated vessels, offers a promising option for long-term management of ETAR [3].

This study evaluates the effectiveness of high-energy Nd:YAG laser therapy as a means of improving treatment outcomes and optimizing therapeutic strategies for patients with erythematotelangiectatic rosacea.

## AIM

The main aim of the study is to optimize the treatment of rosacea by applying a differentiated therapeutic approach for erythematotelangiectatic rosacea (ETAR) using high-energy Nd:YAG laser therapy, and to evaluate its effectiveness through both subjective clinical assessment and objective digital image analysis.

## MATERIALS AND METHODS

The study included 103 patients with Fitzpatrick skin phototypes I–III who presented with visible vascular changes, sensations of heat, and persistent facial redness. All participants underwent a comprehensive clinical, laboratory, and instrumental evaluation to confirm the diagnosis of rosacea and exclude comorbidities that could influence the disease course or serve as contraindications for pharmacological or laser therapy.

Following dermatological examination and analysis of diagnostic results, 40 patients were selected and divided into Erythematotelangiectatic rosacea (ETAR) group (n = 40). Each main group was further subdivided based on treatment modality:

- ETAR – standard topical therapy with azelaic acid gel;
- ETAR-Nd – long-pulsed Nd:YAG 1064 nm laser therapy.

To objectively evaluate treatment outcomes, digital image analysis was performed both at baseline and one month after treatment. Erythema severity was assessed by analyzing the intensity of red coloration in standardized images captured under controlled lighting and spatial conditions [2]. Image

processing was carried out using ImageJ (Version 1.54k, September 15, 2024, accessible at https://imagej.net/ij/), a widely recognized software for quantitative image analysis. The analysis focused on quantifying red pixel counts in designated facial areas before and after treatment. The Pixels per Inch (PPI) metric was employed to measure the density of red pixels within specific zones, offering a detailed evaluation of erythema changes at high resolution.

The Kolmogorov-Smirnov test was utilized to assess the normality of data distribution. The reliability of findings was determined by calculating sampling errors, confidence intervals, and differences between results using Student's t-test. The t-value was computed using established formulas and compared against tabulated values to confirm statistical significance, which was set at $p < 0.05$.

Treatment of Dilated Capillaries, Telangiectasias, and Vascular Networks Without Signs of Plasma Component Extravasation in the ЕФТR Group was performed using vaporization in the long-pulse mode of the Nd:YAG Fotona laser system (1064 nm) (DualisSP II, Fotona, Slovenia). Pulses were applied pointwise in the projection of the visualized vessel under simultaneous cooling of the treatment area using the Zimmer CRYO6 air cooling system or an «ice pack.» The cold air stream provided cooling during laser energy irradiation, as well as for 5 seconds before and after processing each element, ensuring anesthesia and preventing negative thermal effects on the tissues.

## RESULTS

Evaluation of skin improvement with respect to erythema severity was based on quantitative analysis of changes in the intensity of the red color within a defined region of interest. A reduction in red channel intensity after treatment or external influence was interpreted as a decrease in the inflammatory process.

To assess dynamic changes, a delta-percentage method was applied using the formula:

$$\Delta = \left| \frac{[X_{fin} - X_{init}]}{X_{init}} \right| * 100,$$

where Xfin is the final value of the parameter and Xinit is the baseline value.

For the calculation of the relative reduction in erythematous area, the following formula was used:

$$\Delta S = \frac{S_1 - S_2}{S_1} * 100\%,$$

where $S_1$ is the erythematous area before treatment and $S_2$ is the erythematous area after treatment.

In addition to mean values, further analysis was performed by constructing histograms of red color distribution within the selected region. Improvement was reflected by a shift of the dominant peak toward lower intensities, indicating a reduction in erythema severity. Visualization of changes was also achieved using heat maps generated by applying LUT filters (e.g., "Red Hot" in ImageJ). Comparison of pre- and post-treatment maps provided qualitative confirmation of erythema reduction.

As an additional criterion, the Red/Green Ratio (R/G Ratio) was calculated, reflecting the dominance of redness relative to the baseline skin tone. A decrease in this ratio after treatment indicated normalization of skin condition.

Data in tables are presented as:

$$M \pm SD,$$

where M is the mean and SD the standard deviation.

The initial visual manifestations of erythema and couperosis, according to patients' medical histories, which data is provided in Table 1, primarily appear symmetrically on the cheeks (60%) (excluding isolated telangiectasias) and then spread to the lower and upper thirds of the face.

The clinical presentation of patients in the ETAR groups was characterized by less pronounced erythema, which was localized predominantly in the central part of the face in 50% of cases. The presence of telangiectasias – persistently dilated small blood vessels that are clearly visible through the skin – was detected in 25% of patients. The telangiectatic form exhibited less intense redness and was primarily characterized by vascular changes without a significant inflammatory reaction, as Fig. 1 presents.

In patients from the ETAR and ETAR-Nd groups, the pixel-based mean erythema area was 64,066.16 and 63,735.81, respectively, that shown on Table 2. A similar confirmation of the dominance of the vascular inflammatory component is demonstrated by the anthropometric parameter that characterizes the percentage of the erythematous area relative to the total facial area (S_percentage_of_affected_area). In the ETAR and ETAR-Nd groups, this parameter had mean values of 18.7 and 18.19.

According to the study design, patients in the ETAR group received pharmacotherapy, while in the ETAR-Nd group underwent laser therapy.

ETAR group: Treated with Skinoren gel 15% (LEO Pharma Manufacturing Italy S.R.L.), containing 0.15 g of azelaic acid per 1 g of gel, along with benzoic acid. The gel was applied to the facial skin twice daily. No systemic or local adverse effects related to the treatment were observed in these groups, nor were there cases of hypersensitivity to the active ingredient or any excipients in the gel or capsules. No systemic or local adverse effects related to the treatment were observed in the group, nor were there cases of hypersensitivity to the active ingredient or any excipients in the gel or capsules.

ETAR-Nd group: Treated with a long-pulsed ablative mode Nd:YAG 1064 nm laser, the gold standard for vascular vaporization.

Erythema is the primary clinical manifestation of rosacea, but its clinical evaluation lacks standardization. Therefore, digital photo documentation analysis was used for objective assessment of erythema severity dynamics (Fig. 2, 3).

After one month of treatment, all study groups showed positive dynamics. The erythema area significantly decreased in both ETAR group, though the effect in the latter was slower due to more pronounced inflammatory processes. Among patients receiving pharmacotherapy, the ETAR group showed a 48% improvement.

Laser therapy resulted an 87% reduction of erythema in the ETAR-Nd group. Overall, high-energy laser therapy led to

**Table 1.** General characteristics of the study groups

| Indicator, Unit of Measurement | Groups | | |
|---|---|---|---|
| | ETAR | ETAR-Nd | $P_{(ETAR:ETAR-ND)}$ |
| Number, n | 20 | 20 | |
| Age, years | 40±5,5 | 39±4,9 | p > 0,05 |
| Gender, males, n (%) | 3 (15,0) | 4 (20,0) | p > 0,05 |
| TC, mmol/L | 4,25 ± 0,79 | 4,3 ± 0,81 | p > 0,05 |
| LDL-C, mmol/L | 2,39 ± 0,63 | 2,4 ± 0,62 | p > 0,05 |
| TG, mmol/L | 3,15 ± 0,21 | 4,16 ± 0,271 | p > 0,05 |
| BMI, kg/m$^2$ | 23,5 ± 4,10 | 24,0 ± 4,19 | p > 0,05 |
| ESR, mm/hour | 6,76 ± 4,29 | 8,05 ± 3,68 | p > 0,05 |
| D-dimer, ng/L | 0,26 ± 0,18 | 0,29 ± 0,15 | p > 0,05 |
| SBP, mmHg | 120,4±5,2 | 128,3±6,36 | p > 0,05 |
| HbA1c, % | 4,8±0,58 | 4,6±0,71 | p > 0,05 |
| Glucose, mmol/L | 5,4±0,75 | 5,1±0,86 | p > 0,05 |
| Hemoglobin, g/L | 131,2±6,85 | 128,4±7,22 | p > 0,05 |
| Erythrocytes, 10$^{12}$/L | 4,2±0,89 | 4,4±0,77 | p > 0,05 |

*Source: compiled by the authors of this study*


**Fig. 1.** Erythema area in a patient from the ETAR group in the digital image

*Picture taken by the authors*

a 79%-87% improvement compared to pharmacotherapy, which achieved a 22%-48% improvement, as shown on Table 3.

An additional parameter, chosen to eliminate anthropometric error, was the ratio of erythema area to the total facial area for each patient in the study groups. A significant reduction in this parameter was achieved with all treatment methods (Table 4).

Treatment with standard pharmacotherapy showed a reduction in the ETAR group from 18.7% to 9.74%. Laser therapy resulted in a decrease from 18.2% to 3.4% in the ETAR-Nd group. This suggests that the proposed laser therapy methods can be considered as an alternative or complement to standard modern pharmacotherapy.

## DISCUSSION

This study demonstrated that high-energy Nd:YAG laser therapy is significantly more effective than conventional topical treatment in reducing erythema in patients with erythematotelangiectatic rosacea (ETAR). Objective pixel-based image analysis confirmed a marked decrease in erythematous area and intensity after laser therapy, while only minimal, non-significant changes were observed with azelaic acid [5].

These results align with previous reports indicating that laser and light-based modalities, particularly Nd:YAG at 1064 nm, provide superior outcomes for vascular

**Table 2.** Comparative characteristics of digital erythema indices in the studied groups

| Groups | ETAR | ETAR-Nd | P |
|---|---|---|---|
| S, Pixels | 64066,16 ± 8913,73 | 63735,81 ± 9527,02 | p > 0,05 |
| S_percentage_of affected_area, % | 18,7 ± 11,57 | 18,19 ± 12,43 | p > 0,05 |

*Source: compiled by the authors of this study*


**Fig. 2.** Visual data characterizing the dynamics of the erythema area in a patient from the ETAR group
*Picture taken by the authors*


**Fig. 3.** Digital data characterizing the dynamics of the erythema area in a patient from the ETAR group
*Picture taken by the authors*

**Table 3.** Changes in mean total erythema area in the study groups after one month of treatment

| Groups | S1, Pixels | S2, Pixels | ΔS, % | p |
|---|---|---|---|---|
| ETAR | 64066,16 ± 8913,73 | 32143,72 ± 1775,76 | 48,72 | p<0,05 |
| ETAR-Nd | 63735,81 ± 9527,02 | 8137,24 ± 11973,3 | 87,24 | p<0,05 |

*Source: compiled by the authors of this study*

**Table 4.** Characteristics of the mean erythema area ratio relative to the total facial area in the study groups

| Groups | S_selected_area, Pixels | S1_percentage_ of affected_area, % | S2_percentage_ of_affected_area,% | p |
|---|---|---|---|---|
| ETAR | 332185,64 ± 211033,23 | 18,7 ± 11,57 | 9,74 ± 7,21 | p<0,05 |
| ETAR-Nd | 216786,33 ± 274759,65 | 18,19 ± 12,43 | 3,39 ± 3,54 | p>0,05 |

*Source: compiled by the authors of this study*

manifestations of rosacea due to their ability to selectively target deeper dermal vessels. In contrast, topical agents primarily control inflammation but have limited effect on persistent telangiectasias and chronic vasodilation [6].

The strengths of this study include the use of digital imaging for objective quantification, reducing subjectivity in outcome assessment. Limitations include the relatively short follow-up period and modest sample size, which may not fully reflect long-term efficacy and safety.

## CONCLUSIONS

The proposed objective digital erythema assessment system using photofixation and image analysis with ImageJ software (measurement unit – Pixels, PPI) is a reliable method for comparative evaluation of clinical changes before and after treatment. The use of the long-pulsed Nd:YAG 1064 nm mode resulted in an 87.24% reduction in erythema area compared to a 48.72% reduction with retinoid therapy.

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### CONFLICT OF INTEREST

The Authors declare no conflict of interest


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**RECEIVED:** 10.05.2025
**ACCEPTED:** 28.08.2025

 

ORIGINAL ARTICLE

# The impact of positive therapy on the restoration of the psycho--emotional state and somatic health of a person during the war

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## ABSTRACT

**Aim:** The aim is to investigate the impact of positive therapy on the indicators of psycho-emotional state and somatic health of a person during the war.

**Materials and Methods:** In 2023-2024, the research of the psycho-emotional state and somatic health of people was conducted based on on-site sessions of free psychotherapy. The research involved 63 people aged 22 to 45. Gender, education, family and financial status were not criteria for selecting respondents. Research methods: bibliosemantic, diagnostic, medical and biological, statistical.

**Results:** The effectiveness of positive psychotherapy as a method of overcoming negative psycho-emotional states in respondents during the war and improving their somatic health has been proven. It has been established that the use of positive therapy contributes to a significant ($p < 0.001$) improvement in the emotional state (by 1.80 points), increase in self-esteem (by 1.72 points), reduction of stress (2.62 points) and increase in stress resilience (by 3.47 points). It has been found that after the use of positive therapy, the respondents somatic health improved: the number of people with a satisfactory level decreased to 34.9 %, with a poor level – to 11.2 %, and the number of the respondents with an average and good level of health increased to 20.6 % and 33.3 %, respectively.

**Conclusions:** Positive therapy helps people better cope with emotional difficulties and swings, strengthens their self-image and self-confidence during the war, maintains psycho-emotional stability, and improves somatic health. Engaging in such practices helps develop positive thinking, the ability to appreciate yourself, and find joy in everyday life.

**KEYWORDS:** somatic health, war, martial law, psycho-emotional state, positive therapy

Acta Balneol. 2025;67(5):362-368. doi: 10.36740/ABAL202505108

## INTRODUCTION

The perception of the course of internal and external armed conflicts often negatively affects the psycho-emotional state of an average person and leads to severe psycho-emotional disorders, which, in turn, cause various somatic problems [1]. Among the different methods of psychological assistance, positive psychotherapy proves to be very effective in the context of correcting psycho-emotional states during hostilities and martial law [2, 3]. This approach aims to maintain psychological well-being, preserve mental health and develop positive resources in difficult periods of social challenges and crisis situations.

With the outbreak and exacerbation of existing armed conflicts around the world, including in Ukraine, the issue of maintaining and preserving the somatic and mental health of people exposed to stress factors caused by war is becoming acute. Scholars [4-6] argue that numerous psychological problems, such as anxiety, post-traumatic stress disorder, and other negative emotional states always accompany the period of martial law. These problems can affect people's quality of life, social adaptation, and general psychological and physical condition. In this context, the study of the possibilities of correcting psycho-emotional states and somatic health with the help of positive psychotherapy is of particular importance [7, 8]. Therefore, the development of effective methods and programs of psychotherapeutic support for people experiencing stress provoked by war and various traumatic events can help improve their psychological state and ability to overcome the consequences of perceiving a military conflict.

As rightly noted by researchers [9], the current understanding of the psycho-emotional problem and the identification of effective psycho-correctional approaches to improving the mental states of individuals is often incomplete. Usually, any atypical situation radically changes the usual way of life, making significant adjustments to people's psycho-emotional backgrounds, necessitating adaptation to new living conditions. It is important to note that such adaptation can be both successful and lead to the development of anxiety disorders. The practice of multicomponent positive psychological care based on the individual's consciousness has demonstrated its effectiveness in both clinical and non-clinical settings [10, 11]. First, some aspects of cognitive and behavioral therapy

deserve attention, which contribute to strengthening psychological resilience and developing self-regulation mechanisms in response to stressful situations provoked by war. At the same time, according to some scientists [7], the positive processes of psychotherapy are significantly influenced by the individual's satisfaction and symptomatic improvement of their mental health. One can also agree with the scientific standpoint [3, 12, 13] that positive therapy is a multicomponent model that promotes corrective changes in the individual by developing satisfaction and forming a true meaning of life in complex and crisis conditions. Hence, the use of effective methods and the development of a therapeutic care program for people experiencing stress and traumatic events in martial law can help maintain and preserve their somatic health and psycho-emotional state, increase the level of adaptation and ability to overcome the consequences of war.

## AIM

The aim is to investigate the impact of positive therapy on the indicators of psycho-emotional state and somatic health of a person during the war. Tasks: 1) to substantiate the feasibility of introducing positive therapy methods to correctional work in the context of war; 2) to investigate the indicators of psycho-emotional state and somatic health of people experiencing military conflict in Ukraine before and after therapeutic work.

## MATERIALS AND METHODS

### PARTICIPANTS

In 2023-2024, psycho-emotional states and somatic health research of people during martial law was conducted based on on-site sessions of free psychotherapeutic care (locations in Kyiv and Chernihiv (Ukraine), inside railway stations). This made it possible to collect data in conditions that were safe and accessible to patients, despite the restrictions associated with martial law. The primary diagnosis initially involved establishing verbal psychological contact (in order to determine the essence of the problem, readiness to receive psychotherapeutic help in the future), as well as conducting express diagnostics of the person's psychoemotional state at the time of the consultation on a ten-point scale (where 6 or more points were the criterion for inclusion in the group of subjects and indicated the need to pay special attention to the person). This allowed, among the 92 people who sought help during the specified period, to identify 63 individuals with the most pronounced symptoms of mental and somatic health. At this stage, diagnostic methods were used in working with patients to confirm their health status. So, the research involved 63 people aged 22 to 45 years. The exclusion criterion was the personal desire of the research participant to withdraw from the study. Gender characteristics, level of education, family and financial status were not criteria for identifying respondents, and therefore were not taken into account within the framework of the study. After the initial diagnosis, a set of positive therapy methods was chosen for the respondents, which allowed us to see the actual situation of the somatic and mental health of the subjects. The next stage was remote psycho-correctional and therapeutic work with the subjects over the next 3 months.

### RESEARCH METHODS

The following methods were used to achieve the research aim: bibliosemantic, diagnostic, medical and biological, and statistical. The bibliosemantic method was used to conduct an analytical review of scientific sources on the outlined issues. 30 sources from the databases MedLine, Web of Sciences Core Collections, Scopus, Index Copernicus were investigated. The choice of literature sources (criterion) was based on the results of previous studies on the negative impact of war on the individuals, as well as the importance of positive therapy in restoring the psycho-emotional state and maintaining the somatic health of a person. The literature review covered the timeframe of 2019-2025. The key words for selecting literature sources were: war trauma, correction, mental health, psycho-emotional state, physical health, positive psychotherapy, motor activity.

The diagnostic method involved the use of two methods to assess the mental health of people during martial law: "Wiesbaden Inventory for Positive Psychotherapy and Family Therapy (WIPPF)" [15], "Self-Assessment of Stress Resilience" [16]. The WIPPF is a reliable and valid tool for studying current abilities, areas of conflict processing, and fundamental emotional attitudes. Through the survey, respondents determine the balanced state of their lives and the harmonization of their current abilities. This questionnaire helps to identify a person's level of positive resources and stress resilience. The questionnaire contains 88 statements that provide four levels of assessment: completely agree (4 points), partially agree (3 points), partially disagree (2 points), and completely disagree (1 point). As part of the assessment of the subjective significance of personal characteristics, the relevance for our research was: section 2 (conflict reactions manifested in the four areas of the balance model) and section 3 (subjectively perceived parameters of the attitude model) [16].

The method for self-assessment of stress resilience (S.Cowan and G. Williamson) is used to determine how emotionally resilient a person is and helps to realize possible risks. The participant is offered 18 questions, each of which must be answered by selecting one of three options: "very rarely", "from time to time", or "often". After the answers are chosen, the scores for each answer are summed and the total is compared to different ranges of scores to determine the stress resilience level. If a participant scores between 51 and 54, their level of stress resilience is rated as "very low." Other score ranges also define the level of stress resilience from "very low" to "very high". This method helps you understand your psychological resilience and consciously work to improve or maintain it.

The medical and biological method involved assessing patients' somatic health state using V.P. Voitenko's methodology referred to as "Health Self-Assessment" [14]. According to this methodology, a questionnaire was used,

which contains 27 questions that provide for a positive (1 point) or negative (0 points) answer from the respondent. The level of somatic health was considered ideal if the sum of points ranged from 0 to 3 points, good – 4-7 points, average – 8-13 points, satisfactory – 14-20 points, poor – 21-27 points.

STATISTICAL ANALYSIS

The statistical method was used to process the data obtained. The reliability of the difference between the indicators presented in percentages was determined using Pearson's Chi-square ($\chi^2$) criterion. The reliability of the difference between the indicators presented as average value was determined using Student's test (t). The reliability of the difference was set at $p<0.05$. The results were presented as X±m, where X is the arithmetic mean and m is the standard error of the arithmetic mean. All statistical analyses were performed using SPSS software.

The research was carried out in accordance with the requirements of the Regulations on academic integrity at the National Academy of Internal Affairs and followed the regulations of the World Medical Association Declaration of Helsinki. Prior consent to participate in the study was obtained from all respondents.

## RESULTS

To restore the somatic health and psycho-emotional state of people during martial law, we developed and tested a program of correctional work using positive therapy. Restorative measures were applied to all research participants, with special attention paid to the respondents with a poor level of somatic health and a high level of destructive emotional states.

The use of positive therapy included a five-stage algorithm of activities. The first stage is distancing, aimed at shifting the client's attention from the problem to less disturbing topics to reduce internal tension and prepare for further work. This is achieved through methods such as moving from the content to the counseling process, positive reinterpretation, cross-cultural approach, and metaphors. The second stage provided the detailed study of the client's problem situation to help them consider it from different perspectives. This is done using methods such as the energy balance model, analysis of micro and macro events in the client's life, and work with actual abilities and role models. The third stage – situational encouragement – is about providing psycho-emotional support to the client to give them the strength to continue working. This includes relying on the client's resources and potential, and should provide concrete, not fake, support. The fourth stage, verbalization, involves working directly on solving the client's problem and activating the principle of self-help. Methods used here include the 5-step problem-solving algorithm, training on actual abilities, working with concepts, and body techniques. The fifth stage, which describes interaction to develop new behaviors, uses methods such as role-playing and psychodrama. The last step in using positive therapy is to expand the system of goals to avoid the recurrence of traumatic situations in the client's life and develop skills to overcome difficulties independently. At this stage, the clients are encouraged to make plans and define their short- and long-term future in the context of the problems already solved, guided by the principle of balance. They can also formulate their motto or write a letter to themselves in the future. In addition, the clients make agreements with themselves to implement the action plan, discuss possible obstacles and ways to overcome them, adjust their reactions to external and internal factors and determine their lifestyle. The specialist is a guiding factor, showing faith in the client and supporting their constructive decisions. Thus, the principles of self-help, balance and hope are realized.

To analyze the indicators of the psycho-emotional state, the average values were calculated on the scales "Emotional State", "Self-Esteem", "Stress" of the Wiesbaden Inventory for Positive Psychotherapy and Family Therapy (WIPPF) and the method of "Self-Assessment of Stress Resilience" (Table 1).

Indicators on the "Emotional State" scale show a significantly ($p<0.001$) positive dynamics of the respondents' emotional state under the influence of positive therapy. The difference is 1.80 points. Despite the stressful conditions of martial law, people under the influence of positive therapy find

**Table 1.** Results of assessing the indicators of the psycho-emotional state of the respondents (n=63) before and after the use of positive therapy during the war (Mean±m), points

| Indicators of the psycho-emotional state | Research stages | | Reliability of the difference | |
|---|---|---|---|---|
| | Before | After | t | p |
| "Wiesbaden Inventory for Positive Psychotherapy and Family Therapy" method | | | | |
| "Emotional State" scale | 15.75±0.31 | 17.55±0.29 | 4.21 | <0.001 |
| "Self-Esteem" scale | 14.81±0.27 | 16.53±0.28 | 4.42 | <0.001 |
| "Stress" scale | 14.87±0.35 | 12.25±0.32 | 5.52 | <0.001 |
| "Self-Assessment of Stress Resilience" method | | | | |
| Stress Resilience | 21.68±0.44 | 25.15±0.41 | 5.77 | <0.001 |

*Notes: Mean – arithmetical mean; m – error of arithmetical mean; t – Student's t-test value; p – confidence interval.*

*Source: compiled by the authors of this study*

**Table 2.** The ratio of somatic health levels in the respondents (n=63) before and after using positive therapy during the war, %

| Somatic health levels | Research stages | | Reliability of the difference | |
|---|---|---|---|---|
| | Before | After | $\chi^2$ | p |
| Good level | 15.9 | 20.6 | 1.721 | >0.05 |
| Average level | 28.6 | 33.3 | | |
| Satisfactory level | 39.7 | 34.9 | | |
| Poor level | 15.8 | 11.2 | | |

*Note: $\chi^2$ – Pearson's Chi-square criterion value; p – confidence interval.*

*Source: compiled by the authors of this study*

ways to adapt and have a sufficient level of psychological resilience. An individual approach to therapeutic work plays a significant role. Although the data shows a general trend, it is essential to consider individual differences in experiences and reactions to martial law. Personal characteristics, life experience, and access to resources can significantly affect the psycho-emotional state of the persons under study.

Assessment of the respondents' psycho-emotional state indicators using the "Self-Esteem" scale shows a relatively high level of self-esteem among the survey participants after psychotherapy. The average value has significantly improved by 1.72 points ($p<0.001$), indicating that most respondents positively perceive their value and competence even under challenging circumstances. This may indicate the presence of substantial internal resources that allow people to adapt to difficult conditions. A high indicator of self-esteem can act as a defense mechanism that helps people better cope with emotional difficulties and swings.

The indicators on the "Stress" scale reveal a significant ($p<0.001$) decrease in the level of stress in the respondents by 2.62 points and correspond to a moderate level after the use of positive therapy. Moderate stress levels in wartime reflect the respondents' adaptive coping mechanisms and the effectiveness of psychological assistance.

Assessment of the level of stress resilience of the respondents under the influence of positive therapy shows a significant ($p<0.001$) improvement – the difference between the initial and final data is 3.47 points. The results indicate a relatively substantial level of stress resilience of the respondents. The research participants demonstrate a moderate level of ability to adapt to the stressful conditions of war. At the same time, it is imperative to consider individual characteristics when developing psychological assistance and support programs. In particular, this may affect the development of specific program activities to build coping skills, increase resilience, and improve self-regulation.

The analysis of the respondents' somatic health indicators before using positive therapy showed that at the beginning of the research, the vast majority had a satisfactory level (39.7%) and average (28.6%) level of somatic health. At the same time, a significant proportion (15.8%) had a poor level. After the use of positive therapy, the ratio changed in the direction of improving the somatic health of the respondents: the number of people with a satisfactory level decreased to 34.9%, with a poor level – to 11.2%, and the number of the respondents with an average and good level of health increased to 20.6% and 33.3%, respectively (Table 2).

This indicates the effectiveness of positive therapy not only in improving the psycho-emotional state of the respondents, but also their somatic health.

## DISCUSSION

As the results of the assessment of psycho-emotional state indicators and the analysis of the respondents' somatic health demonstrate, the impact of positive therapy on personal recovery in war conditions is rational and appropriate, as evidenced by a significant improvement in the studied indicators of the respondents (difference between baseline and final data). This is primarily due to the fact that wars and hostilities around us always significantly impact a person, leading to changes and deterioration in their health. Military actions radically change the usual way of life, making significant adjustments to the psycho-emotional background of people, which necessitates adaptation to new conditions of existence [17]. That is why special attention should be paid to somatic health and the specifics of the manifestation of psycho-emotional states of people [18]. The data we obtained on personality changes show that adaptation to unusual (atypical) conditions of war can be both successful and lead to the formation of anxiety disorders. At the same time, ordinary people demonstrate a moderate level of ability to adapt to the stressful conditions of war.

In the context of a person's stay in martial law, personal manifestations, their peculiarities and mechanisms of development play an essential role. Relevant personal reactions include, in particular, feelings of stupor, fear, hysteria, anxiety, panic, confusion, guilt, tense expectation of a disaster, loss of faith, avoidance of unpleasant sensations, desire for revenge, etc. In the problematic (sometimes extreme) conditions of life of many people during the war, a relatively common negative emotional state for civilians is a feeling of constant anxiety and worry [19]. These symptoms and manifestations affect the course of their lives, which requires proper qualified psychological assistance. After all, as the results show, primarily in terms of "Emotional state" and "Stress" ($p<0.001$), properly organized

therapeutic work contributes to the positive dynamics of the respondents' emotional state.

According to researchers [2, 3, 20], positive psychotherapy should play a significant role in addressing adverse health conditions and improving psycho-emotional well-being during war. The possibilities and methods of positive therapy contribute to strengthening psychological resilience and developing self-regulation mechanisms in response to stress during martial law [21]. The results of our research also prove this, as the dynamic changes from using such tools during correctional and therapeutic work demonstrate a positive effect. At the same time, the research forms a holistic understanding of the impact of war on the somatic and psycho-emotional state of the individual, identifying the key problems and challenges people face in the context of a military conflict.

Based on the study, researchers [22, 23] found a correlation between the psycho-emotional state and the somatic health of the individual. According to some researchers [22, 23], the revealed dependence indicates that an increase in the level of emotional discomfort reduces the potential physical resources of the individual. The impact of martial law peculiarities on the somatic health and psycho-emotional state of people only emphasizes their vulnerability, which is accompanied by disorganization of behavior under the influence of potent stressors and extreme situations. Taking into account the empirical data obtained, an increase in emotional discomfort is associated with a decrease in self-esteem. This may indicate the importance of maintaining a positive self-perception and self-confidence in martial law conditions to support overall psycho-emotional well-being. Instead, the high level of self-esteem that can be achieved through positive therapy can act as a defense mechanism that helps people better cope with emotional difficulties and swings.

The development of stress resistance can be key to reducing the negative impact of crises on an individual's somatic and psycho-emotional state [24-26]. Practical recommendations for psychological assistance should include strategies for improving stress resistance, including activating the individual's resistance to stressors and negative phenomena. We suppose that qualitatively organized correctional and therapeutic work by specialists will contribute to the process of restoring (preserving) the somatic and mental health of people and acquiring skills to work with this problem [1]. In particular, the five-stage algorithm of positive therapy measures we used contributed to the development of stress coping skills, increased resilience, improved self-regulation, and restored the somatic health of the subjects. This is proved by the results of this research and confirms the opinion of many scholars on the subject matter [5, 6, 10,13,17, 27-30].

## CONCLUSIONS

The effectiveness of positive psychotherapy as a method of overcoming negative psycho-emotional states in respondents during the war and improving their somatic health has been proven. It has been established that the use of positive therapy contributes to a significant ($p<0.001$) improvement in the emotional state (by 1.80 points), increase in self-esteem (by 1.72 points), reduction of stress (2.62 points) and increase in stress resilience (by 3.47 points). The importance of an individual approach to working with each person, considering their unique experience and needs, is emphasized. This approach can significantly influence the formation of specific program measures to develop skills to counteract the stressful phenomena of war and improve self-regulation. Special attention should be paid to the development of skills for introspection and self-reflection, which allows an individual to better understand their emotional states and effectively manage them.

It has been found that after the use of positive therapy, the respondents' somatic health improved: the number of people with a satisfactory level decreased to 34.9%, with a poor level – to 11.2%, and the number of the respondents with an average and good level of health increased to 20.6% and 33.3%, respectively. This demonstrates the effectiveness of positive therapy not only in improving the psycho-emotional state of the respondents, but also their somatic health. The proposed program of corrective work was developed taking into account the specifics of the destructive impact of war on the personality. The main goal was not only to eliminate the existing negative consequences of war, but also to prevent their recurrence through the development of personal resilience.

Thus, positive therapy helps people better cope with emotional difficulties and swings, strengthens their self-image and self-confidence during the war, maintains psycho-emotional stability, and improves somatic health. Positive therapy is provided by meditation techniques, breathing exercises, self-regulation methods, and auto-training, which promotes the development of positive thinking, the ability to appreciate oneself, and finding joy in everyday life.

PROSPECTS FOR FURTHER RESEARCH.

We plan to study the impact of the developed positive therapy program on the dynamics of somatic and mental health indicators of combatants.

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**CONFLICT OF INTEREST**
The Authors declare no conflict of interest

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**RECEIVED:** 29.03.2025
**ACCEPTED:** 22.07.2025

ORIGINAL ARTICLE

# Efficacy of intensive *versus* non intensive physiotherapy in children with autism

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## ABSTRACT

**Aim:** This study aims to evaluate the efficacy of intensive *versus* non-intensive physiotherapy in improving motor skills and overall functional outcomes in children with ASD.

**Materials and Methods:** A total of 40 children aged 3 and above were selected using simple random sampling. Participants were required to meet specific inclusion criteria, such as being diagnosed with ASD and having mild to moderate motor skill impairments. Children with severe intellectual disabilities, medical conditions preventing physical activity, recent surgeries, or significant injuries were excluded from the study. Children undertaking medication for psychological and behavioral control are not included in this study.

A systematic review of existing literature was conducted, focusing on studies that assessed the impact of physiotherapy interventions on motor skills in children with ASD. Both intensive versus non-intensive therapy programs were included. Data was extracted and analyzed to compare the outcomes of these two approaches.

**Results:** The results indicated that intensive physiotherapy, involving 60-minute sessions four times a week, produced more substantial improvements in both motor and behavioural domains compared to non-intensive physiotherapy, which co insisted of 30-minute sessions twice a week. Children in the intensive group showed a significantly greater reduction in ADOS-2 scores, reflecting improved social communication and restricted behaviours. The mean decrease in ADOS-2 scores for the intensive group was 5.2 points ($p<0.01$), whereas the non-intensive group showed a decrease of 2.8 points ($p<0.05$). Similarly, the intensive group demonstrated more pronounced improvements in motor skills, as indicated by the GMFM, with a mean increase of 13.4 points ($p<0.001$), while the non-intensive group showed a smaller improvement of 5.7 points ($p<0.05$).

**Conclusions:** Physiotherapy, whether intensive or non-intensive, is effective in enhancing motor skills and overall functional performance in children with ASD. Intensive physiotherapy appears to offer greater benefits in severe cases, while non-intensive therapy remains a valuable option for broader developmental gains. Further research is recommended to optimize these interventions and tailor them to individual needs.

**KEYWORDS:** developmental disabilities, autism spectrum disorder, motor skills development, intensive rehabilitation, non-intensivet therapy

Acta Balneol. 2025;67(5):369-373. doi: 10.36740/ABAL202505109

## INTRODUCTION

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition characterized by challenges in communication, social interaction, and the presence of restricted and repetitive behaviors[1]. Among children with ASD, motor skill deficits are commonly observed, significantly impacting their functional abilities and overall quality of life. These motor impairments often manifest in both gross and fine motor skills, which are crucial for daily activities and social participation [2]. As such, the role of physiotherapy, both intensive versus non-intensive, has gained considerable attention as a therapeutic approach to address these deficits and improve overall motor function in children with ASD.

Physiotherapy interventions for children with ASD encompass a variety of techniques aimed at enhancing motor skills, including structured exercise programs, sensory integration, and motor training activities [3]. The effectiveness of these interventions has been widely studied, with evidence suggesting that tailored physical exercise programs can lead to significant improvements in gross motor skills, balance, coordination, and overall physical fitness. Intensive rehabilitation programs, characterized by high frequency and duration of sessions, have shown particular promise in addressing more severe motor delays, and they may also have ancillary benefits such as reducing sleep disorders in children with motor impairments.

Non-intensive physiotherapy, while less frequent or rigorous, also plays a crucial role in the management of ASD [4]. It offers flexibility and accessibility, making it a viable option for children who may not tolerate or require intensive interventions. Research indicates that even less intensive programs can yield positive outcomes, particularly when combined with other therapeutic approaches [5]. Moreover, the incorporation of motor interventions within broader therapeutic frameworks, including occupational therapy and multi-therapy approaches, highlights the holistic benefits of physiotherapy in enhancing not only motor skills but also socialization, communication, and behavioural outcomes in children with ASD [6].

Overall, the integration of intensive versus non-intensive physiotherapy within the treatment regimen for children with ASD holds significant potential for improving their motor and functional performance, thereby contributing to their overall development and quality of life [7]. Despite the potential benefits of both intensive versus non-intensive physiotherapy, the evidence base supporting their efficacy in children with ASD remains limited and somewhat conflicting. While some studies have reported positive outcomes with intensive therapy, demonstrating improvements in motor function, balance, and coordination, others have found comparable benefits with non-intensive approaches. Additionally, factors such as the child's age, severity of ASD symptoms, and individual response to therapy may influence treatment outcomes.

Furthermore, the optimal dosage and duration of physiotherapy interventions for children with ASD have yet to be determined[8]. Questions regarding the sustainability of gains achieved through intensive therapy and the long-term impact on functional outcomes also warrant further investigation.

In light of these considerations, there is a need for rigorous research examining the comparative effectiveness of intensive versus non-intensive physiotherapy approaches in children with ASD. By elucidating the strengths and limitations of each approach, healthcare providers can better tailor treatment plans to meet the unique needs of individual children with ASD [10], ultimately enhancing their physical function, participation, and quality of life.

**AIM**

This study aims to evaluate the efficacy of intensive versus non-intensive physiotherapy in improving motor skills and overall functional outcomes in children with ASD.

## MATERIALS AND METHODS

A randomized control trial was conducted to evaluate the efficacy of intensive versus non-intensive physiotherapy interventions in children with Autism Spectrum Disorder (ASD). A total of 40 children aged 3 and above were selected using simple random sampling. Participants were required to meet specific inclusion criteria, such as being diagnosed with ASD and having mild to moderate motor skill impairments. Children with severe intellectual disabilities, medical conditions preventing physical activity, recent surgeries, or significant injuries were excluded from the study. Children undertaking medication for psychological and behavioral control are not included in this study. During the study period, the food consumption of all the participants were monitored in same energy levels to prevent bias.

Participants were randomly divided into two groups: an experimental group and a control group, using a closed envelope method. The experimental group received sensory integration therapy combined with gross motor, while the control group participated in physical and developmental activities. Each treatment session lasted 30 minutes and was conducted daily over a 12-week period. Pre-treatment assessments using the ADOS-2 Scale were performed [11], and the same assessments were repeated after the 12-week intervention as post-test evaluations. The primary outcome measures included changes in the ADOS-2 scale and GMFM scale scores to assess the efficacy of the interventions [12].

Treatment Protocols Intensive Physiotherapy Group The intensive intervention will aim to provide higher frequency and duration of sessions, focusing on motor skill improvement. The goal is to target motor deficits in both gross and fine motor skills while maintaining engagement through structured and individualized activities. Session Duration: 60 minutes per session. Frequency [13] 4 sessions per week for 12 weeks (48 sessions in total). Content of Sessions: Warm-up (5-10 minutes): Gentle stretching and relaxation techniques, such as deep breathing exercises, joint mobilizations, or light walking to prepare the child for physical activity. Motor Skill Development (40-45 minutes): Gross Motor [14] Activities aimed at improving balance, coordination, strength, and endurance. Examples include obstacle courses, balance board exercises, hopping, and climbing activities. Fine Motor: Tasks involving hand-eye coordination, dexterity, and strength. Activities include play dough manipulation, threading beads, pegboards, and building with blocks. Cool Down (5-10 minutes): Relaxation techniques such as slow stretches or breathing exercises to help the child calm and reflect on the session. Therapist's Role: Each session will be led by a licensed physiotherapist with experience in ASD [15], who will adapt the activities based on the child's response and progress. Frequent positive reinforcement (e.g., verbal praise or rewards) will be used to encourage engagement and success. Non-Intensive Physiotherapy Group The non-intensive intervention will offer a less frequent treatment schedule, focusing on providing moderate support in motor skill development without overwhelming the child [16]. Session Duration: 30 minutes per session. Frequency: 2 sessions per week for 12 weeks (24 sessions in total). Content of Sessions: Warm-up (5 minutes) – gentle stretching and joint mobility exercises, adapted to each child's needs; Motor Skill Development (20 minutes) – Gross Motor: Simplified activities such as walking on a line, short-distance running, and basic jumping exercises to focus on basic motor function without high intensity, and Fine Motor – tasks such as stacking blocks, finger painting, or simple puzzles to engage the child in lower-intensity fine motor activities [17]; Cool Down (5 minutes) – Gentle relaxation exercises like breathing or stretching to aid in muscle recovery and relaxation. Therapist's Role [18]. A licensed physiotherapist will guide the child through exercises, offering support and motivation while maintaining an appropriate pace for each individual's comfort level [19].

## RESULTS

The randomized control trial was conducted to assess the efficacy of intensive versus non-intensive physiotherapy interventions in improving motor skills and behavioural outcomes in children with Autism Spectrum Disorder (ASD). A total of 40 children, aged 3 years and above, were enrolled

and randomized into two groups: the intensive physiotherapy group (n=20) and the non-intensive physiotherapy group (n=20). The study lasted 12 weeks, with both groups undergoing daily or bi-weekly physiotherapy sessions as outlined in the treatment protocols. The primary outcome measures included the changes in scores on the ADOS-2 Scale and GMFM Scale.

BASELINE CHARACTERISTICS

At baseline, there were no significant differences between the two groups in terms of age, gender, motor skill impairments, or ADOS-2 scores. The mean age of participants was 5.3 years (±1.2 years) across both groups, with an approximately equal gender distribution (45% male, 55% female). All children had mild to moderate motor skill impairments, as per the inclusion criteria.

INTERVENTION FIDELITY

Both groups adhered to the treatment protocols with high fidelity. The intensive group attended an average of 46 out of 48 sessions (96% adherence), while the non-intensive group attended an average of 22 out of 24 sessions (92% adherence).

ADOS-2 SCALE RESULTS

The ADOS-2 Scale measures social communication and restrictive behaviours, which were assessed at baseline and post-treatment (Table 1).

**Intensive Group**: A significant reduction in the ADOS-2 scores was observed, indicating improvements in social communication and behaviour. The mean pre-treatment ADOS-2 score was 18.4 (±4.6), and the post-treatment score was 13.2 (±3.8), representing a mean change of -5.2 ($p<0.01$).

**Non-Intensive Group**: The ADOS-2 scores also improved, though to a lesser degree. The mean pre-treatment ADOS-2 score was 19.1 (±4.3), and the post-treatment score was 16.3 (±4.0), representing a mean change of -2.8 ($p<0.05$).

GMFM SCALE RESULTS

The Gross Motor Function Measure (GMFM**)** assesses gross motor skills, including balance, coordination, and mobility (Table 1).

**Intensive Group**: The intensive group showed significant improvements in gross motor skills, with a pre-treatment mean GMFM score of 45.3 (± 10.2) and a post-treatment mean score of 58.7 (± 8.5). The mean change was +13.4 ($p<0.001$).

**Non-Intensive Group**: The non-intensive group also showed improvements, with a pre-treatment GMFM score of 46.2 (± 9.8) and a post-treatment score of 51.9 (± 9.6). The mean change was +5.7 ($p<0.05$).

## DISCUSSION

This randomized controlled trial evaluated the efficacy of intensive versus non-intensive physiotherapy interventions in children with Autism Spectrum Disorder (ASD), with significant findings regarding improvements in motor skills and behavioural outcomes. The results indicated that intensive physiotherapy, involving 60-minute sessions four times a week, produced more substantial improvements in both motor and behavioural domains compared to non-intensive physiotherapy, which co (Ji YQ, 2003) insisted of 30-minute sessions twice a week. Children in the intensive group showed a significantly greater reduction in ADOS-2 scores, reflecting improved social communication and restricted behaviours. The mean decrease in ADOS-2 scores for the intensive group was 5.2 points ($p<0.01$), whereas the non-intensive group showed a decrease of 2.8 points ($p<0.05$). Similarly, the intensive group demonstrated more pronounced improvements in motor skills, as indicated by the GMFM, with a mean increase of 13.4 points ($p<0.001$), while the non-intensive group showed a smaller improvement of 5.7 points ($p<0.05$).

These results highlight the importance of the intensity and frequency of physiotherapy interventions in achieving significant improvements in both motor and behavioural outcomes for children with ASD. There are similar that reported similar results Ji YQ 2023 conducted a systemic review and meta analysis and found that exercise intervention have moderate to large benefits in functional motor skills[20]. Srinivasan S 2024 done a pilot RCT comparing general movement vs creative movement interventions both led to a medium to large improvement in gross motor performance including coordination strength and walking endurance [21].

**Table 1.** Pre-treatment and Post-treatment scores of ADOS-2 and GMFM scales for both the intensive and non-intensive physiotherapy groups

| Outcome Measure | Group | Pre-treatment Score | Post-treatment Score | Mean Change | Statistical Significance |
|---|---|---|---|---|---|
| ADOS-2 Scale (Social Communication & Restrictive Behavior) | Intensive Group | 18.4 (± 4.6) | 13.2 (± 3.8) | -5.2 | $p < 0.01$ |
| | Non-Intensive Group | 19.1 (± 4.3) | 16.3 (± 4.0) | -2.8 | $p < 0.05$ |
| GMFM (Gross Motor Function Measure) | Intensive Group | 45.3 (± 10.2) | 58.7 (± 8.5) | +13.4 | $p < 0.001$ |
| | Non-Intensive Group | 46.2 (± 9.8) | 51.9 (± 9.6) | +5.7 | $p < 0.05$ |

*Source: compiled by the authors of this study*

Significant improvement in fine manual control, body coordination and overall skills were found in the study done by Jin YR 2023 in finding the efficacy of motor interventions on functional performance among preschool children with ASD [13]. Ruggeri A 2020 found that many interventions such as motor skill interventions, motor activity interventions, physical education and swimming intervention improved motor abilities of children with ASD. Each intervention develops different motor ability in the children they also found visual instruction has more response that other ways of teaching [23]. Ben hassen 2023 found that Psychomotor rehabilitation for ASD children can help them to improve their motor skills, including PC in different conditions. These improvements may have a positive impact on daily activities and allow them to perform these activities with greater ease and confidence. In addition, by enhancing motor skills, ASD children may increase their self-confidence, social participation, and emotional well-being [22].

Despite the positive findings, this study had some limitations, such as the relatively small sample size and the short duration of the intervention. Future studies could explore the long-term effects of intensive and non-intensive physiotherapy interventions and assess additional outcome measures to capture broader aspects of functioning, such as cognitive and emotional development. The energy level of the food consumed by both the groups during the intervention period is not taken into account. Moreover, it would be beneficial to examine the sustainability of improvements over time to better understand the lasting impact of these interventions on children with ASD.

In conclusion, while both intensive and non-intensive physiotherapy interventions led to improvements in children with ASD, the intensive physiotherapy approach showed more significant gains. This suggests that increasing the frequency and duration of therapy may enhance outcomes, providing valuable insights for clinicians and caregivers aiming to optimize treatment strategies for children with ASD.

## CONCLUSIONS

This study suggests that intensive physiotherapy interventions focusing on motor skill development yield greater improvements in both motor skills and behavioural outcomes in children with Autism Spectrum Disorder compared to non-intensive interventions. The intensive group showed superior results in both the ADOS-2 and GMFM scales, suggesting that higher frequency and duration of therapy may be more effective in enhancing the developmental progress of children with ASD.Further research with larger sample sizes and longer follow-up periods is recommended to confirm these findings and explore the long-term benefits of intensive physiotherapy for children with ASD.

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**CONFLICT OF INTEREST**

The Authors declare no conflict of interest

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**RECEIVED:** 07.04.2025
**ACCEPTED:** 08.09.2025

 

ORIGINAL ARTICLE

# Toward professional readiness: psychophysiological predictors of efficiency in rehabilitation students

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## ABSTRACT

**Aim:** The aim of the study was to carry out a professional evaluation of the work process and to establish the relationship between psychophysiological functions of the organism that ensure high professional success of rehabilitation specialists

**Materials and Methods:** A job-related assessment was conducted, incorporating psychophysiological evaluation, expert analysis, and dynamic observation of rehabilitation specialists, including physicians in physical and rehabilitation medicine, physiotherapists, occupational therapists, and their assistants. A specially designed questionnaire with 57 items was utilized to evaluate the professional significance of various psychophysiological functions. Statistical analysis, including descriptive statistics, cluster analysis, and correlation analysis, was performed using the Statistica 6.1 software package to determine the interrelations among key psychophysiological characteristics.

**Results:** The study identified a set of core psychophysiological functions essential for rehabilitation professionals, including reaction speed, endurance, coordination, sensory perception, and cognitive abilities. Cluster analysis revealed three primary competency groups: (1) higher nervous activity and attention, (2) visual sensory system and movement coordination, and (3) sensory-motor integration and cognitive functions. The correlation analysis demonstrated strong interdependencies among these attributes, with significant relationships observed between higher nervous activity and key visual sensory functions.

**Conclusions:** The research highlights the necessity of an integrated approach to professional training for rehabilitation specialists. A structured understanding of psychophysiological functions can help refine educational curricula and enhance practical training methodologies. The findings emphasize the importance of individualized training strategies tailored to the functional demands of specific rehabilitation professions

**KEYWORDS:** rehabilitation, professional competence, psychophysiology, occupational therapy, physical therapy modalities

Acta Balneol. 2025;67(5):374-381. doi: 10.36740/ABAL202505110

## INTRODUCTION

In the context of professional education for rehabilitation-related specialties, the identification and scientific substantiation of specific psychophysiological functions that underpin successful professional performance is of critical importance. Modern training programmes must not only deliver theoretical knowledge and practical skills but also ensure that students develop the functional capabilities necessary for high-efficiency work in complex rehabilitation environments. One effective tool for achieving this is the professionogram – a structured, evidence-based profile that outlines the functional requirements of a given profession. Within this framework, particular emphasis is placed on psychophysiograms, which detail the psychophysiological attributes essential for professional efficiency, such as motor coordination, sensory perception, cognitive endurance, and attentional control [1, 7-11].

By analysing these functions, it becomes possible to assess students' professional readiness and tailor educational strategies to support the development of capacities that directly influence performance. Such an approach is especially relevant in rehabilitation disciplines, where the integration of sensory, cognitive, and neuromotor systems is vital to patient care [2, 4, 7, 9, 12].

## AIM

The aim of the study was to carry out a professional evaluation of the work process and to establish the relationship between psychophysiological functions of the organism that ensure high professional success of rehabilitation specialists.

## MATERIALS AND METHODS

The present scientific study was conducted at the premises of Vinnytsia National Pirogov Memorial Medical University, Vinnytsia State Mykhailo Kotsiubynskyi Pedagogical University, and the Vinnytsia Socio-Economic Institute of the Open International University of Human Development "Ukraine". Over the period 2023-2025, a total of 312 medical faculty students – 156 female and 156 male – were observed under academic supervision. The participants were enrolled in the professional educational programmes "Therapy and Rehabilitation" and "Medicine". These programme profiles constituted the principal inclusion and exclusion criteria for assigning individuals to the respective comparison groups.

It should be noted that the "Therapy and Rehabilitation" educational programme is oriented towards the theoretical and practical training of highly qualified and labour-market-competitive specialists in the field of therapy and rehabilitation. Graduates are expected to work either independently within multidisciplinary rehabilitation teams or under supervision, implementing interventions aimed at restoring the functional integrity of various human body systems, including psychological dimensions of life activity. Emphasis is placed on practice-based learning and the application of rehabilitation strategies tailored to achieving specific rehabilitation goals and addressing patients' individualised needs.

By contrast, the "Medicine" programme aims to ensure that students acquire the competences necessary to apply their theoretical knowledge, practical skills, and professional understanding –across humanities, basic sciences, and clinical disciplines – in solving standard professional tasks associated with medical practice. The scope of this programme includes the diagnosis and management of conditions according to established symptom and syndrome classifications, the handling of physiological states and diseases requiring specific clinical management strategies, emergency care, laboratory and instrumental diagnostics, as well as the performance of essential medical procedures.

As part of the scientific research, a job-related psychophysiological assessments were carried out for rehabilitation-related professions such as doctors of physical and rehabilitation medicine, physiotherapists, occupational therapists, physiotherapy assistants and occupational therapy assistants. The methodologies employed included medical-sociological analysis, expert evaluation, and dynamic observation of professional activity.

Expert evaluation of the professional activities of rehabilitation specialists, who form the core of a multidisciplinary rehabilitation team, was carried out in several key stages:

1. Identifying the primary rehabilitation profiles subject to study.
2. Developing a specialised questionnaire for scoring the professional importance of psychophysiological functions for the defined specialities.
3. Selecting a panel of experienced experts with at least 5-10 years of professional experience in the studied field or those teaching relevant subjects in higher education institutions.
4. Conducting a job-related psychophysiological examination.
5. Performing statistical analysis and interpretation of the obtained data.

For these purposes, a specially designed expert evaluation questionnaire consisting of 57 questions was used to determine the level of professional significance of psychophysiological functions. The data obtained during the expert evaluation were validated through dynamic observation of professional activities.

Statistical analysis was conducted using the standard package for multivariate statistical analysis, "Statistica 6.1" (Licence No. VXXR901E245722FA). The study applied descriptive statistics, cluster analysis, and correlation analysis. The reliability of the obtained results was determined using both parametric and non-parametric methods, including Student's t-test and Pearson's chi-square test, with subsequent significance assessment (p).

The implementation of any classification-based procedures (such as cluster and correlation analysis), including the development and scientific substantiation of psychophysiograms for core rehabilitation-related professions, necessitates the application of a range of multivariate statistical analysis techniques. Specifically, cluster analysis facilitates the identification of patterns in the grouping of research objects and their primary characteristics into distinct sets and subsets, i.e., clusters, which represent homogeneous units within the multidimensional space of examined features. This requires the application of k-means methodology (divisive method, MacQueen algorithm) or agglomerative-hierarchical methods. In our case, the k-means methodology is considered the most appropriate. Thus in the cluster analysis of key psychophysiological characteristics, spatial classification of these characteristics was performed using the k-means method (divisive method, McQueen algorithm) in a multidimensional space of the studied factors. Correlation analysis established the functional interconnections of the obtained data based on Pearson (r) and Spearman (rs) correlation coefficients, determining their significance levels (p).

## RESULTS

In the course of the conducted research, a psychophysiological assessments of rehabilitation-related professions (physician in physical and rehabilitation medicine, physiotherapist, occupational therapist etc.) was carried out, and its role in ensuring the effective training of rehabilitation specialists was determined.

It was established that the professionally significant psychophysiological functions of key rehabilitation professions, which define the primary components of their psychophysiogram, include indicators of simple and differentiated visual-motor reaction speed, balance and mobility of neural processes, endurance of the nervous system, strength of excitation and inhibition processes, as well as resistance to monotony effects. Additionally, parameters such as visual acuity, differentiated light sensitivity, visual field volume, critical flicker fusion frequency, and visual

perception speed were identified. Other key characteristics include differentiated musculoskeletal sensitivity, dexterity and coordination of finger movements, coordination of hand movements, combined coordination of hand movements, hand coordination with and without visual control, movement tempo, combined coordination of hand and foot movements, muscular endurance, and hand muscle strength. Moreover, attention-related indicators, including volume, switching, distribution, stability, and concentration, as well as semantic working memory, operational and practical thinking, and spatial imagination, were found to be critical.

In particular, when examining the representation of specific properties of the visual sensory system within the psychophysiographic structure of core rehabilitation-related specialities, it should be noted that, in all cases, the leading positions within the structure are occupied by visual acuity and differential light sensitivity (first level of importance); followed by critical flicker fusion frequency, visual perception speed, and visual field size (second level of importance); and, finally, by colour discrimination and differential colour discrimination (third level of importance) (Table1).

Conversely, when analysing the representation of specific properties of the somatosensory analyser within the psychophysiographic profiles of the main rehabilitation specialities, it is important to highlight that, in all cases, primary importance is attributed to joint–muscle sensitivity and differential joint–muscle sensitivity (first level of importance); followed by indicators of coordination of movements of various types and origins (second level of importance); and, finally, by measures of muscular endurance and upper limb strength (third level of importance) (Table 2).

The presence of these psychophysiological functions within the psychophysiogram structure of core rehabilitation-related professions is of significant theoretical importance. It highlights both the commonality and unity of most of these functions, as well as certain structural particularities of specific functions. Consequently, this underscores the necessity of considering these factors in the process of developing scientifically justified strategies for improving the professional training of future rehabilitation specialists, both at the educational stage and during direct professional practice.

Equally significant as the development of such professional profiles and psychophysiograms is the establishment of interconnections between individual professionally significant psychophysiological functions. These functions shape and maintain the working dynamic stereotype, which is determined using multivariate statistical analysis procedures such as cluster and correlation analysis.

An analysis of the obtained expert assessments regarding the degree of development of psychophysiological functions – reflecting the functional state of higher nervous activity, the visual sensory system, and other sensory systems, the somatosensory analyser, as well as characteristics of attention, memory, thinking, and imagination – demonstrates that the cluster structure of leading groupings, based on the k-means methodology, for professions such as physician in

**Table 1.** Professionally Important Psychophysiological Functions (Indicators of the functional state of the visual sensory system) required for the effective acquisition of core rehabilitation-related specialists, which constitute the foundation of their psychophysiograms.

| | Physician in Physical and Rehabilitation Medicine | Physical Therapist | Occupational Therapist | Physical Therapist Assistant | Occupational Therapy Assistant |
|---|---|---|---|---|---|
| Indicators of the functional state of the visual sensory system | Visual acuity (5.00 points)<br>Differentiated light sensitivity (5.00 points)<br>Critical Flicker Fusion frequency (5.00 points)<br>Visual perception speed (5.00 points)<br>Visual field volume (4.90±0.10 points)<br>Differentiated color discrimination (4.60±0.22 points)<br>Color discrimination (4.50±0.13 points)<br>Dark and light adaptation (4.60±0.16 points)<br>Spatial adaptation (4.40±0.16 points) | 1.Visual acuity (5.00 points)<br>2.Differentiated light sensitivity (5.00 points)<br>3.Critical Flicker Fusion frequency (5.00 points)<br>4.Visual perception speed (5.00 points)<br>5.Visual field volume (4.90±0.10 points)<br>6.Color discrimination (4.30±0.21 points)<br>7.Differentiated color discrimination (4.10±0.17 points)<br>8.Spatial adaptation (4.20±0.13 points)<br>9.Dark and light adaptation (3.90±0.10 points) | 1.Visual acuity (5.00 points)<br>2. Differentiated light sensitivity (5.00 points)<br>3. Critical Flicker Fusion frequency (5.00 points)<br>4. Visual perception speed (5.00 points)<br>5. Visual field volume (5.00 points)<br>6. Color discrimination (4.30±0.21 points)<br>7.Differentiated color discrimination (4.10±0.17 points)<br>8. Spatial adaptation (4.30±0.15 points)<br>9. Dark and light adaptation (3.90±0.10 points) | Visual acuity (5.00 points)<br>Differentiated light sensitivity (5.00 points)<br>Critical Flicker Fusion frequency (5.00 points)<br>Visual perception speed (5.00 points)<br>Visual field volume (5.00 points)<br>Differentiated color discrimination (4.10±0.17 points)<br>Color discrimination (4.30±0.21 points)<br>Spatial adaptation (4.30±0.15 points)<br>Dark and light adaptation (3.90±0.10 points) | Visual acuity (5.00 points)<br>Differentiated light sensitivity (5.00 points)<br>Critical Flicker Fusion frequency (4.70±0.15 points)<br>Visual perception speed (4.80±0.13 points)<br>Differentiated color discrimination (3.70±0.15 points)<br>Color discrimination (3.70±0.15 points)<br>Visual field volume (3.60±0.16 points)<br>Spatial adaptation (3.90±0.23 points)<br>Dark and light adaptation (3.10±0.23 points) |

**Table 2.** Professionally Significant Psychophysiological Functions (Indicators of the functional state of the somatosensory analyzer) required for the effective acquisition of core rehabilitation-related specialties, which constitute the foundation of their psychophysiograms

| | Physician in Physical and Rehabilitation Medicine | Physical Therapist | Occupational Therapist | Physical Therapist Assistant | Occupational Therapy Assistant |
|---|---|---|---|---|---|
| Indicators of the functional state of the somatosensory analyzer | 1.Differentiated musculoskeletal sensitivity (5.00 points)<br>2.Musculoskeletal sensitivity (5.00 points)<br>3. Hand movement coordination (4.90±0.10 points)<br>4.Combined hand movement coordination (4.90±0.10 points)<br>5.Hand movement coordination without visual control (4.80±0.13 points)<br>6.Movement tempo (4.70±0.15 points)<br>7.Dexterity and coordination of finger movements (4.50±0.16 points)<br>8.Hand movement coordination under visual control (4.70±0.15 points)<br>9.Combined coordination of hand and leg movements (4.00±0.14 points)<br>10. Hand muscle strength (3.90±0.10 points)<br>11.Hand muscle endurance (3.90±0.17 points) | 1.Differentiated musculoskeletal sensitivity (5.00 points)<br>2.Musculoskeletal sensitivity (5.00 points)<br>3.Dexterity and coordination of finger movements (5.00 points)<br>4. Hand movement coordination (5.00 points)<br>5.Combined hand movement coordination (5.00 points)<br>6.Hand movement coordination without visual control (5.00 points)<br>7.Hand movement coordination under visual control (5.00 points)<br>8.Movement tempo (5.00 points)<br>9.Combined coordination of hand and leg movements (4.60±0.16 points)<br>10.Hand muscle endurance (4.20±0.13 points)<br>11.Hand muscle strength (4.10±0.17 points) | 1.Differentiated musculoskeletal sensitivity (5.00 points)<br>2.Musculoskeletal sensitivity (5.00 points)<br>3.Dexterity and coordination of finger movements (5.00 points)<br>4.Hand movement coordination (5.00 points)<br>5.Combined hand movement coordination (5.00 points)<br>6.Hand movement coordination without visual control (5.00 points)<br>7.Hand movement coordination under visual control (5.00 points)<br>8.Movement tempo (5.00 points)<br>9.Combined coordination of hand and leg movements (4.50±0.16 points)<br>10.Hand muscle endurance (4.20±0.13 points)<br>11.Hand muscle strength (4.10±0.17 points) | 1.Differentiated musculoskeletal sensitivity (5.00 points)<br>2.Musculoskeletal sensitivity (5.00 points)<br>3.Dexterity and coordination of finger movements (5.00 points)<br>4.Hand movement coordination (5.00 points)<br>5.Combined hand movement coordination (5.00 points)<br>6.Hand movement coordination without visual control (5.00 points)<br>7.Hand movement coordination under visual control (5.00 points)<br>8.Movement tempo (5.00 points)<br>9.Combined coordination of hand and leg movements (4.50±0.16 points)<br>10.Hand muscle endurance (4.20±0.13 points)<br>11.Hand muscle strength (4.10±0.17 points) | 1.Differentiated musculoskeletal sensitivity (5.00 points)<br>2.Musculoskeletal sensitivity (5.00 points)<br>3.Dexterity and coordination of finger movements (5.00 points)<br>4.Hand movement coordination (5.00 points)<br>5.Combined hand movement coordination (5.00 points)<br>6.Hand movement coordination without visual control (5.00 points)<br>7.Hand movement coordination under visual control (5.00 points)<br>8.Movement tempo (5.00 points)<br>9.Hand muscle endurance (4.50±0.10 points)<br>10.Combined coordination of hand and leg movements (4.50±0.16 points)<br>11.Hand muscle strength (4.10±0.17 points) |

physical and rehabilitation medicine, physiotherapist, and occupational therapist, was characterised by the presence of three primary clusters, namely:

1. The "functional capabilities of higher nervous activity and attention" cluster (Cluster № 1), encompassing characteristics of simple and differentiated visual-motor reaction speed, balance and mobility of neural processes, strength of excitation and inhibition processes, nervous system endurance, as well as attention-related indicators such as volume, switching, distribution, stability, and concentration.
2. The "functional capabilities of the visual sensory system, movement coordination, and attention" cluster (Cluster № 2), which integrates indicators of visual acuity, differentiated light sensitivity, visual field volume, critical flicker fusion frequency, and visual perception speed. Additionally, it includes indicators of differentiated musculoskeletal sensitivity, dexterity and coordination of finger movements, coordination of hand movements with and without visual control, movement tempo, combined coordination of hand and foot movements, muscular endurance, and hand muscle strength, as well as attention-related parameters such as volume, switching, distribution, stability, and concentration.
3. The "functional capabilities of other sensory systems, memory, thinking, and imagination" cluster (Cluster № 3), comprising characteristics of differentiated tactile sensitivity, proprioceptive sensitivity, and spatial-auditory orientation, alongside indicators of semantic working memory, operational and practical thinking, and spatial imagination.

Simultaneously, for the forms of occupation such as physiotherapy assistant and occupational therapy assistant, a certain redistribution of the content within the identified cluster groupings was observed. Consequently, the structure still included three primary clusters, but with slightly different content:

1. The "functional capabilities of higher nervous activity" cluster (Cluster № 1), incorporating characteristics of simple and differentiated visual-motor reaction speed, balance and mobility of neural processes, strength of excitation and inhibition processes, and nervous system endurance.
2. The "functional capabilities of the visual sensory system, movement coordination, and attention" cluster (Cluster № 2), which consolidates indicators of visual acuity, differentiated light sensitivity, visual field volume, critical flicker fusion frequency, and visual perception speed. It also includes differentiated musculoskeletal sensitivity, dexterity and coordination of finger movements, coordination of hand movements with and without visual control, movement tempo, combined coordination of hand and foot movements, muscular endurance, and hand muscle strength, as well as attention-related parameters such as volume, switching, distribution, stability, and concentration.
3. The "functional capabilities of other sensory systems, memory, thinking, and imagination" cluster (Cluster № 3), comprising characteristics of differentiated tactile sensitivity, proprioceptive sensitivity, and spatial-auditory orientation, along with indicators of semantic working memory, operational and practical thinking, and spatial imagination.

The structural features of the identified cluster groupings are presented in Fig. 1 and 2.

The data obtained through correlation analysis procedures confirm the previous results. Firstly, it was found that the highest number of statistically significant correlations

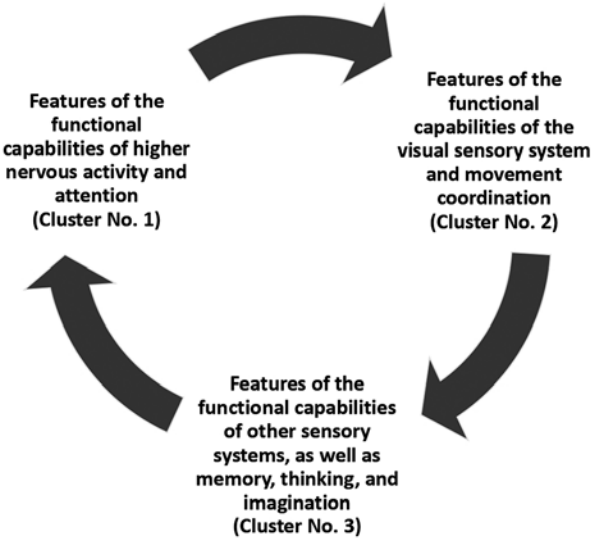


**Fig. 1.** The structure of the main clusters of psychophysiological functions characteristic of such specialties as a physician in physical and rehabilitation medicine, a physical therapist, and an occupational therapist

*Source: compiled by the authors of this study*

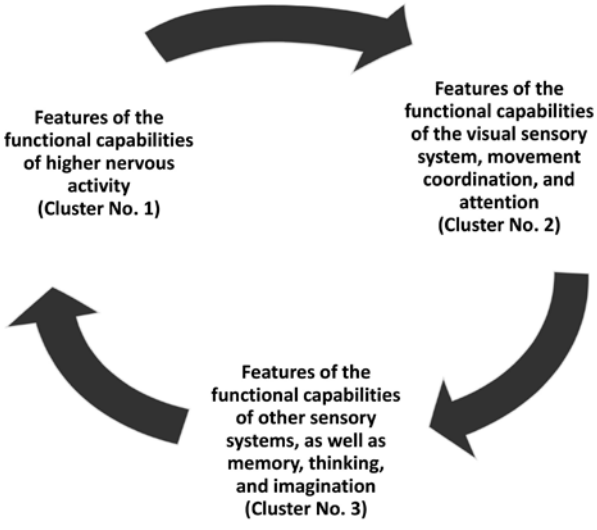


**Fig. 2.** The structure of the main clusters of psychophysiological functions characteristic of such form of occu pationas a physical therapist assistant and an occupational therapist assistant

*Source: compiled by the authors of this study*

($p<0.05$-$0.001$) between the characteristics of the functional state of higher nervous activity, which indicate a high level of psychophysiological readiness for performing core activities of rehabilitation specialists, is characteristic of such professions as a physician in physical and rehabilitation medicine (38 correlations), physiotherapist (35 correlations), and occupational therapist (33 correlations). The lowest number was observed for physiotherapy assistant (27 correlations) and, primarily, occupational therapy assistant (25 correlations). Similarly, correlations between specific indicators reflecting the functional state of the visual sensory system were most prevalent in professions such as a physician in physical and rehabilitation medicine (46 correlations), physiotherapist (44 correlations), and occupational therapist (41 correlations), with slightly fewer for physiotherapy assistants (38 correlations) and occupational therapy assistants (36 correlations). Correlations between indicators reflecting the functional state of the somatosensory analyser were highest for a physician in physical and rehabilitation medicine (48 correlations), physiotherapist (52 correlations), and occupational therapist (55 correlations), while the lowest numbers were observed for physiotherapy assistants (42 correlations) and occupational therapy assistants (40 correlations).

Secondly, when considering individual rehabilitation-related professions, it is essential to note that the highest number of significant ($p<0.05$-$0.001$) correlations related to the functional state of the higher nervous system were associated with characteristics of simple and differentiated visual-motor reactions, balance and mobility of neural processes, endurance of the nervous system, and resistance to monotony effects. The highest number of significant ($p<0.05$-$0.001$) correlations in the functional state of the visual sensory system was linked to indicators such as critical flicker fusion frequency, differentiated light sensitivity, visual perception speed, visual field volume, and differentiated colour perception. Additionally, the highest number of significant ($p<0.05$-$0.001$) correlations in the functional state of other sensory systems was associated with characteristics of differentiated tactile sensitivity, proprioceptive sensitivity, and spatial-auditory orientation. Furthermore, the highest number of significant correlations in the functional state of the somatosensory analyser was observed in indicators such as differentiated musculoskeletal sensitivity, hand movement coordination, combined coordination of hand movements, hand movement coordination without visual control, movement tempo, finger dexterity and coordination, hand movement coordination under visual control, and muscular endurance of the hands. Finally, the highest number of significant ($p<0.05$-$0.001$) correlations in the functional characteristics of attention, memory, and thinking were associated with attention volume, switching, distribution, stability, and concentration, as well as semantic working memory, practical thinking, and spatial imagination.

## DISCUSSION

While performing a psychophysiographic analysis of the collected data – an approach for which the modern literature offers no direct counterparts (only distant analogues [2, 3] addressing other branches of medical practice) – it should be emphasized that, for the leading rehabilitation-oriented specialties, the professionally significant psychophysiological functions include the following characteristics of higher nervous activity and sensory systems:

- speed of simple and discriminative visual motor reactions;
- balance and mobility of neural processes;
- nervous-system endurance;
- strength of excitation and inhibition processes and resistance to monotony;
- visual-system indices such as visual acuity, differential light sensitivity, visual-field extent, and critical flicker--fusion frequency;
- differential muscle-joint (proprioceptive) sensitivity;
- dexterity and coordination of finger and arm movements;
- muscular endurance and arm strength;
- attentional volume, shifting, distribution, stability, and concentration.

In reviewing these results, one must first note the considerable diversity of professionally important psychophysiological functions whose high development ensures maximal task performance by rehabilitation specialists. This finding is consistent with earlier studies on other medical professions – particularly in dentistry and general medicine [2, 3] – and, crucially, holds true even under pronounced stress conditions [1].

This situation was evidenced by the almost complete "unanimity" of indicators, confirming their undeniable necessity for inclusion both in the structure of the psychophysiograms being developed and in the diagnostic algorithms being substantiated to train highly qualified rehabilitation specialists and ensure their coordinated work within a multidisciplinary rapid response team, which provides comprehensive socio-psychological support to victims during medical care delivery.

At the same time, attention was drawn to a certain "internal diversity" of the established features, particularly the tendency toward a slight decrease in the expression level of higher nervous activity indicators reflecting the strength of excitation and inhibition processes in the central nervous system among representatives of different form of occupation, primarily assistants to specialised physicians.

Thus, based on the analysis of the functional capabilities of higher nervous activity, it was evident that in the structure of psychophysiograms of core rehabilitation-related specialities, the leading positions were occupied by simple and differentiated visual-motor reaction speed (first level of importance), balance and mobility of neural processes, and nervous system endurance (second level of importance), as well as the strength of excitation and inhibition processes in higher nervous activity (third level of importance).

It is also undeniable that one of the most important components of psychophysiograms for rehabilitation physicians includes data obtained through expert assessments of the

development level of psychophysiological functions reflecting the functional state of the visual sensory system. In this regard, the leading positions were occupied by indicators of visual acuity and differentiated light sensitivity (first level of importance), critical flicker fusion frequency, visual perception speed, and visual field volume (second level of importance), as well as characteristics of colour differentiation and differentiated colour perception (third level of importance).

Finally, when examining the representation of specific properties of the somatosensory analyser within the psychophysiogram structure of core rehabilitation-related professions, it was evident that, in all cases, the leading positions were occupied by indicators of musculoskeletal sensitivity and differentiated musculoskeletal sensitivity (first level of importance), indicators of coordination of various types of movements and their genesis (second level of importance), as well as muscular endurance and hand muscle strength (third level of importance).

These findings were also confirmed by the results of cluster and correlation analyses, which identified specific target criteria for psychohygienic, psychocorrectional, and psychophysiological interventions. These criteria were delineated separately for such professions as a physician in physical and rehabilitation medicine, physiotherapist, and occupational therapist (Group 1) and separately for such forms of occupation as physiotherapy assistant and occupational therapy assistant (Group 2).

## CONCLUSIONS

In the course of the conducted research, it was identified that the professionally significant psychophysiological functions of key rehabilitation-related specialities, which determine the primary components of their psychophysiogram, include indicators of simple and differentiated visual-motor reaction speed, balance and mobility of neural processes, nervous system endurance, strength of excitation and inhibition processes, as well as resistance to monotony effects. Additionally, characteristics such as visual acuity, differentiated light sensitivity, visual field volume, critical flicker fusion frequency, and consequently, the lability of the visual sensory system and visual perception speed were considered. Other significant features included differentiated musculoskeletal sensitivity, dexterity and coordination of finger movements, hand movement coordination, combined hand movement coordination, hand coordination with and without visual control, movement tempo, combined coordination of hand and foot movements, muscular endurance, and hand muscle strength. Furthermore, key indicators related to attention capacity, switching, distribution, stability, and concentration, as well as semantic working memory, operational and practical thinking, and spatial imagination were identified as critical.

According to the results of cluster analysis procedures, the structure of the leading groupings of the examined psychophysiological functions for professions such as a physician in physical and rehabilitation medicine, physiotherapist, and occupational therapist was characterised by the presence of three primary clusters:

1. Cluster "Functional capabilities of higher nervous activity and attention" (Cluster № 1).
2. Cluster "Functional capabilities of the visual sensory system, movement coordination, and attention" (Cluster № 2).
3. Cluster "Functional capabilities of other sensory systems, memory, thinking, and imagination" (Cluster № 3).

At the same time, for physiotherapy assistant and occupational therapy assistant, three primary clusters were also identified but with slightly different content:

1. Cluster "Functional capabilities of higher nervous activity" (Cluster №1).
2. Cluster "Functional capabilities of the visual sensory system, movement coordination, and attention" (Cluster № 2).
3. Cluster "Functional capabilities of other sensory systems, memory, thinking, and imagination" (Cluster № 3), which includes characteristics of differentiated tactile sensitivity, proprioceptive sensitivity, and spatial-auditory orientation, as well as indicators of semantic working memory, operational and practical thinking, and spatial imagination.

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**CONFLICT OF INTEREST**
The Authors declare no conflict of interest

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A – Work concept and design, B – Data collection and analysis, C – Responsibility for statistical analysis, D – Writing the article, E – Critical review, F – Final approval of the article

**RECEIVED:** 30.05.2025
**ACCEPTED:** 08.09.2025

 

REVIEW ARTICLE

# On the potential use of radon waters from the Khmilnyk resort for the treatment of dental diseases

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## ABSTRACT

**Aim:** To explore the therapeutic potential of radon-rich waters from the Khmilnyk resort in Ukraine for the treatment and prevention of periodontal diseases.
**Materials and Methods:** A literature review was performed using PubMed and Google Scholar databases, covering research published between 1970 and 2023 related to radon balneotherapy, particularly in dentistry.
**Conclusions:** Balneotherapy, particularly with low-dose radon exposure, is known for its anti-inflammatory, analgesic, and antioxidant effects. Although radon waters have been widely used in the treatment of cardiovascular and musculoskeletal disorders, their application in dental care, especially for chronic periodontal inflammation, remains underexplored. The Khmilnyk resort, with its unique radon-mineral composition and long-standing therapeutic tradition, offers promising perspectives for integration into dental practice. Radon therapy may improve blood circulation in periodontal tissues, stimulate cellular regeneration, and enhance oral immunity.
The use of Khmilnyk radon waters could become an effective adjunct in periodontal treatment. Further clinical trials are warranted to validate optimal protocols and safety measures.

**KEYWORDS:** radon waters, balneotherapy, dentistry, PubMed, Google Scholar, Medline

Acta Balneol. 2025;67(5):382-387. doi: 10.36740/ABAL202505111

## INTRODUCTION

Balneotherapy is a clinically effective complementary approach in the treatment of low-grade inflammation- and stress-related pathologies. The biological mechanisms by which immersion in mineral-medicinal water and the application of mud alleviate symptoms of several pathologies are still not completely understood, but it is known that neuroendocrine and immunological responses – including both humoral and cell-mediated immunity – to balneotherapy are involved in these mechanisms of effectiveness; leading to anti-inflammatory, analgesic, antioxidant, chondroprotective, and anabolic effects together with neuroendocrine-immune regulation in different conditions [1]. Hydrotherapy stimulates blood circulation and phagocytosis, helps activate the body's antioxidant system. [2-4]. In dentistry, periodontal diseases remain the most common and constantly require the search for new treatment methods. Hydrotherapy in dentistry is primarily used in the treatment of periodontal diseases. Its therapeutic effect lies in stimulating blood circulation in periodontal tissues, driven by the biochemical composition of the water (mineral, sea, or sulfuric water), water pressure (1-3 atm), and thermal influence (37-45°C). Hydrotherapy promotes inflammation reduction and exudate resorption. It is employed in cases of chronic inflammation of the gums, deeper periodontal layers, and atrophic changes. Hydrotherapy enhances blood flow and phagocytosis. Trace elements present in mineral waters particularly benefit the gingival epithelium, acting as catalysts in biochemical detoxification processes. However, scientific data on the use of radon waters in dentistry remains limited. From existing literature, it is known that radon waters are used in periodontal disease hydrotherapy in the form of rinses, drinking courses, and inhalations. For radon therapy, water is sourced from natural springs, boreholes, and less commonly, uranium mines [5].

## AIM

To analyze the potential of using radon waters from the Khmilnyk resort for the treatment and prevention of periodontal diseases.

## MATERIALS AND METHODS

A literature review was conducted using the PubMed and Google Scholar databases, covering studies published between 1970 and 2023 concerning radon water therapy, especially for dental diseases. The data were analyzed to identify the most common dental conditions treated with this form of physical medicine. Publications containing the following keywords were selected: balneology, dentistry, radon waters. Out of 50 articles reviewed, 25 were selected that contained relevant information directly related to the topic.

## REVIEW AND DISCUSSION

According to historical records, the Khmilnyk resort is located on the northwestern edge of the Ukrainian

Crystalline Shield, which represents an outcropping of the Earth's most ancient crystalline platform.

The granites and other massive rocks of the Ukrainian Crystalline Shield, which formed in geological antiquity, have been subject to long-term weathering processes – rain, wind, heat, and cold. The resulting fractured granite, crisscrossed with numerous interconnected fissures, has created favorable conditions for the formation of underground waters through the infiltration of atmospheric precipitation, floodwaters, and meltwaters into the depths of the granite layers.

As these subterranean waters percolate through the rock, they become enriched with various salts, minerals, and gases, acquiring new chemical properties. In addition to common minerals and salts, the waters also absorb trace amounts of naturally occurring radioactive elements found in granite. These elements impart radioactive characteristics to the water. According to the Institute of Geological Sciences of the National Academy of Sciences of Ukraine, the locations of radioactive water deposits within the Ukrainian Crystalline Shield often coincide with regions rich in granite formations.

These geological features – structural composition, terrain, and climate – determine the hydrogeological profile of groundwater deposits. When drilling into granite massifs, naturally occurring fissures are encountered, facilitating the upward movement of water into the borehole. This is precisely how the therapeutic waters of Khmilnyk, enriched with health-promoting components, were first obtained from granite formations.

The Southern Bug River, which splits into two branches, creates an island-like area within the city. Historically, residents of this part of Khmilnyk faced a persistent shortage of potable water. Attempts to extract water from traditional wells consistently failed. At depths of 5-7 meters, drillers encountered dense rock layers that were impossible to penetrate manually. The small amounts of water that did emerge were yellowish in color, unpalatable, and extremely hard, rendering it unfit for drinking. Consequently, deeper aquifers had to be tapped to meet the community's needs.

In 1934, in a search for potable water within the city center, the Ukrainian Geological Exploration Trust drilled its first borehole, labeled No. 1E. At a depth of 65 meters, the water obtained was yellowish, saline in taste, and highly mineralized, making it unsuitable for either drinking or technical purposes.

From April 1935 to 1938, researchers from the Institute of Geological Sciences of the National Academy of Sciences of Ukraine conducted detailed chemical and physicochemical analyses of water from borehole No. 1E. The water appeared yellowish, odorless, with a slightly astringent, salty taste. It had a temperature of 10°C and a specific gravity of 1005-1006. Freshly collected water was clear but became cloudy upon settling, producing a precipitate composed of calcium, magnesium, iron carbonates, and other compounds.

Chemical and radiological studies of the mineral spring water revealed the presence of radon (a radium decay product), carbon dioxide, nitrogen, oxygen, potassium, sodium, calcium, magnesium, manganese, iron, bicarbonates, chloride, sulfates, and rare gases such as helium, argon, xenon, and krypton. Organic substances were also found, including bitumens, humic acids, petroleum-based acids, as well as a variety of trace elements. Some of these components form a surface film that slows the rapid volatilization of therapeutic gases during balneological procedures.

According to data from the Institute of Geological Sciences of NAS Ukraine, the gaseous composition of the water includes: carbon dioxide (92.73%), nitrogen (7.2%), helium (0.068%), and xenon and krypton (0.044%).

The chemical composition of the mineral water from borehole No. 11 is represented by the Kurlov formula:

$$\mathrm{Rn17\ nKu/л\ CO^2_{0,5}\ M_{2,5}\ \frac{HCO_3 54 SO^4_{\ 27}}{Ca51\ (Na\ +\ K)\ 45}\ t^{\circ}\ -9^{\circ}C}$$

Based on the research conducted by an expedition comprising staff from the Institute of Geological Sciences of the National Academy of Sciences of Ukraine and the Ukrainian Research Institute of Balneology, the following conclusions were drawn: the water discovered in Khmilnyk can be classified as carbonated, radon-rich, and mineralized. It contains a significant amount of manganese, which undoubtedly adds balneological value; given the described characteristics and adequate discharge rates, external therapeutic application is feasible, provided it is carried out under strict medical supervision.

Experimental and clinical studies conducted by researchers at the Ukrainian Research Institute of Balneology have confirmed the therapeutic value of the mineral water from the borehole No. 1E. The radon water-bearing area in Khmilnyk was officially recognized as a health resort by Resolution No. 1376 of the Council of People's Commissars of the Ukrainian SSR, dated October 10, 1938. The spring was put into practical use [6].

Subsequent extensive studies carried out by the Central Research Institute of Balneology and Physiotherapy, the Ukrainian Research Institute of Rehabilitation and Balneology, and Vinnytsia National Pirogov Memorial Medical University have established that both existing and newly discovered sources of mineral water possess comparatively high therapeutic properties. Based on their hydrogeological origin and ionic composition, certain mineral water sources in Khmilnyk are considered unique due to their distinctive combination of dissolved components, with no analogues among known mineral waters across the European territory of the country [3].

Between 1934 and 1960, six wells were drilled on the island part of Khmilnyk, all tapping into carbonated radon-rich mineral water. This water has since been used for therapeutic purposes by the Regional Physiotherapy Hospital, Railway Clinical Hospital No. 2, the „Southern Bug" sanatorium, and the „Radon" sanatorium. The deposit has been designated the „Khmilnyk therapeutic water deposit."

Given the high therapeutic value and proven effectiveness of these mineral waters, the Ukrainian Republican Council

for Trade Union Resort Management decided to clearly delineate the radon mineral water distribution zone in Khmilnyk, with the aim of evaluating future development prospects for the resort. Hydrogeological investigations conducted by specialists from the Ukrainian office „Ukrgeokoptazhminvod" led to the identification of new promising radon water deposits in the resort area, with substantial discharge capacity.

Drilling operations were carried out between 1952 and 1962 on the southwestern outskirts of the city and in the „Lisna dacha" area. A total of 21 wells were drilled, yielding nitrogen-radon water. These newly discovered wells were collectively named the Novo-Khmilnyk Deposit.

Research on the chemical composition and physicochemical properties of the therapeutic waters from the new deposit, conducted by the Institute of Geological Sciences of the National Academy of Sciences of Ukraine, revealed the water to be clear, odorless, fresh-tasting, slightly mineralized, with a typical color and a temperature of 9°C. Chemically, the water is radon-rich, with a bicarbonate-calcium-sodium-magnesium composition and a mineralization level of 0.7 g/L. Additionally, it contains trace amounts of iodine, bromine, copper, zinc, nickel, cobalt, silver, manganese, metaboric acid, and silicic acid.

The chemical composition formula of the therapeutic water from the Novo-Khmilnyk deposit (borehole No. 5RK):

$$Rn88nKu/\text{л}M_{0,7}\ \frac{HCO_3 95}{Ca63\ Na18\ Mg27}\qquad t^\circ\ -9^\circ C$$

The nitrogen-radon waters of the Novokhmilnyk deposit are currently used for therapeutic purposes by several health institutions, including the inter-farm sanatorium „Podillia," the „Khmilnyk" Sanatorium of the Ukrainian Trade Union Health Resort Association (AO „Ukrprofzdravnytsia"), the Military Clinical Sanatorium, and the Maternal and Child Rehabilitation Center „Berezova Roscha".

Hydrogeological and chemical-radiological studies conducted in the vicinity of the Khmilnyk resort have identified two main types of therapeutic waters: carbonated radon mineral waters with low radon content and weakly mineralized waters with low to moderate levels of radon. The concentration of radon in various boreholes ranges from 50 to 100 nCi/L.

The total reserves of carbonated radon waters at the Khmilnyk deposit are estimated at 5.5 million $m^3$ per day. The sanitary condition of these therapeutic waters is satisfactory. A reduced concentration of deuterium – known to stimulate biological activity – has been detected in these water types [6,7].

In 1989, the Nobuzh Geological Survey Team, while conducting additional exploration, discovered another radon water deposit in the southern part of the resort (Holodkynskyi site).

Subsequent investigations revealed that this new deposit contains weakly mineralized hydrocarbonate-calcium-magnesium water with radon concentrations ranging from 60 to 180 nCi/L. The borehole discharge reaches 1800 $m^3$/day.

It is important to emphasize that, prior to the discovery of borehole No. 1E in Khmilnyk, no known sources suitable for radon balneotherapy had existed in Ukraine. Currently, radon-bearing sources have been found in Zhytomyr, Kyiv, Kirovohrad, and other regions of Ukraine, where radon therapy clinics operate successfully. However, due to its long-standing practice and accumulated expertise, the Khmilnyk resort remains the leading facility in the country providing radon balneotherapy.

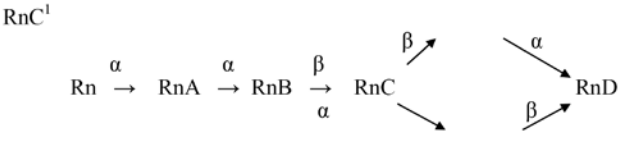
The favorable combination of therapeutic components in the radon waters, picturesque natural surroundings, mild climate, proximity to rivers and forested areas, convenient location with good transportation links, and the high efficacy of treatments have made Khmilnyk the most prominent radon health resort in Ukraine [6].

According to literature sources, radon (radon-220) is the principal therapeutic agent in radon waters. It is a primary isotope of the chemical element with atomic number 86 in the Periodic Table of Dmytro Mendeleev and is a decay product of radium. Radon was discovered in 1900 by physicists E. Rutherford and E. Dorn.

Radon belongs to the group of inert, or so-called noble gases, which are chemically non-reactive. It is widely distributed in nature – present in atmospheric air, mineral and freshwater sources, and all natural environments that contain dispersed radium.

The presence of radioactive elements in the air, water, soil, food, and the human body forms the natural background radiation, which is not only harmless but also essential for the maintenance of normal biological functions. As academician V.I. Vernadskyi wrote in 1935, a deficiency or absence of specific natural radioactive elements in the diet may disrupt metabolic processes and potentially lead to serious health disorders.

During the decay of radon, a series of new radioactive isotopes are formed – namely Radium A, Radium B, and Radium C. These are unstable daughter products that settle on surfaces, forming an active layer where further radioactive decay continues. As previously mentioned, this process results in the release of three types of radiation. Radium A decays by emitting alpha particles and produces a new radioactive atom, Radium B, which further decays by emitting beta particles and gamma rays, leading to the formation of Radium C, $C^1$, $C^{11}$, and the stable isotope Radium D (Lead-210). The decay chain of radon and its daughter products can be expressed by the following formula:




Due to their limited penetration ability, alpha and beta particles are absorbed by water, and only those alpha rays located in the immediate vicinity of the body's surface exert a therapeutic effect. Gamma radiation, on the other

hand, is not absorbed by water due to its high penetration capacity. However, the quantity of gamma particles present in radon water is so negligible that they can practically be disregarded.

The influence of natural factors, including radon water, on the human body is considerably more complex than that of pharmacotherapy.

It has been established that the primary active agent in radon therapy is alpha radiation emitted by radon and its short-lived decay products.

The mechanism of ionizing radiation at the molecular and cellular levels has been extensively studied by prominent scientists, including biologists, physiologists, and physicians. According to Professors I.I. Gusarov, P.G. Tsarfis, and A.N. Obrosov, two main types of ionizing effects on cellular molecules are distinguished: direct ionization, which occurs directly in biologically significant macromolecules such as DNA, RNA, and enzymes; indirect ionization, which involves the ionization of water molecules within cells. Irradiation of water leads to the formation of free radicals – potent oxidants such as $OH^-$, $HO_2$, $H_2O_2$, and $O_2$, as well as the powerful reducing agent atomic hydrogen. These radicals interact with vital biopolymers (e.g., proteins, nucleic acids) and other cellular structures [8-10].

Thus, ionization results in the generation of hydroxyl radicals, hydrogen peroxide, and other strong oxidants within cells, intensifying oxidative processes in the body.

At the Khmilnyk health resort, treatment traditionally involves very low doses of radon. A typical therapeutic course of 15 baths with radon concentrations of 12-15 nCi/L is equivalent to approximately one month of natural background radiation exposure. Compared to the doses used in clinical radiology for oncological treatment, the ionizing radiation doses in radon therapy might initially appear insignificant.

Nevertheless, long-term clinical practice confirms the high efficacy of low-radon-content baths, as demonstrated by both short- and long-term medical observations. Numerous scientific institutes specializing in balneology and physiotherapy also attest that, while the radiation doses administered in radon therapy are minimal, they are sufficient to exert a significant therapeutic effect on the body – not only from a dosimetric perspective but also from a clinical standpoint [11].

Over the past 20-25 years, radiobiological literature has accumulated considerable data on the favorable, stimulatory effects of low doses of ionizing radiation.

Treatment with low-radon-content baths activates the body's antioxidative defense mechanisms by generating compounds rich in "free" electrons. These compounds neutralize molecules with unpaired electrons, thereby restoring normal redox balance and yielding positive clinical outcomes.

Consequently, low-radon baths exhibit marked antioxidant, anti-inflammatory, desensitizing, and analgesic properties. They stimulate the secretion of glucocorticoid hormones from the adrenal cortex, which supports their broad application in the treatment of musculoskeletal disorders, hypertension, atherosclerosis, and other cardiovascular conditions. Additionally, they have a pronounced sedative effect, promote deeper sleep, and reduce pain symptoms. Extensive experience in treating elderly patients at radioactive health resorts demonstrates that radon therapy normalizes overall body tone, enhances work capacity, improves skin elasticity, and restores capillary circulation. Radon water will likely hold a prominent place among future therapeutic and preventive tools in gerontology for combating premature aging [12].

Radon baths, inhalations, and irrigations are employed at the Khmilnyk resort for the treatment of various diseases. Radon penetrates the body through intact skin and the respiratory tract, enters the bloodstream, and is subsequently distributed throughout the organism. The temperature of the water, along with dissolved gases (such as carbon dioxide found in certain Khmilnyk sources), facilitates more rapid absorption of radon and its decay products into bodily tissues.

When radon water is applied externally, all physicochemical stimuli, including those caused by radioactive radiation, primarily affect the skin – a large and significant receptor zone. Under the influence of ionizing radiation, the skin undergoes biophysical and biochemical changes, including alterations in metabolic processes and the formation of various vasoactive substances. These reactions result in changes in skin temperature, tactile sensitivity, and pain perception.

Due to the skin's close connection with internal organs and tissues, the biophysical and biochemical changes triggered by radon baths can influence biological and metabolic processes in different body systems.

Ionizing radiation from radon water has a specific impact on the nervous system. Radon baths most commonly induce inhibitory processes in the central nervous system, reducing pain symptoms and normalizing sleep patterns [6-7].

Clinical observations conducted at several leading medical institutions have confirmed that radon water plays a significant role in maintaining mineral homeostasis within the oral cavity. Therefore, the use of radon water for inhalations and mouth rinses is highly important [13].

The alpha radiation emitted by radon contained in water is believed to be a critical factor in regulating inflammatory processes and maintaining oral homeostasis. Researchers argue that these doses exhibit a phenomenon known as „hormesis" [1, 14-16].

Inhalations and rinsing with radon water in cases of periodontitis have been shown to reduce, and eventually eliminate, advanced inflammatory processes. A clinical trial conducted at the Tskaltubo resort involved 150 participants, including 120 patients and 30 healthy individuals (control group). The results demonstrated that radon water inhalations and rinses significantly contributed to the reduction and eventual resolution of oral inflammation in patients with periodontitis. The authors assert that the unique properties of Tskaltubo mineral water represent a valuable component in the treatment of early-stage periodontal disease [13].

Radon water's pronounced anti-inflammatory, desensitizing, and analgesic effects are widely applied in the treatment of periodontitis of various etiologies. In recent years, radon therapy has also been used in the rehabilitation of patients with maxillofacial injuries, as it promotes accelerated bone callus formation [14, 15].

The therapeutic benefits of radon baths are characterized by their mild action, sedative effect, and a broad range of applicable dosages. Notably, adverse reactions to radon therapy are rare. Radon waters are generally well tolerated by patients and can mitigate the intensity of other, more potent balneotherapeutic factors. This compatibility enables their use in combination with other forms of balneo- and physiotherapy [16-18].

In addition to reflex responses, hormonal entry into cells, dissociation of corticosteroid-protein and other protein complexes, as well as changes in homeostasis have been observed. Simultaneously, there is neurogenic mobilization of the hypothalamic-pituitary-adrenal system and the release of glucocorticoids [19, 20].

Radon baths exert a more pronounced influence on the pituitary-adrenal axis than carbon dioxide-hydrogen sulfide baths. They stimulate the secretion of ACTH and cortisone, activate the glucocorticoid and mineralocorticoid functions of the adrenal cortex, enhance intracellular steroid metabolism, and suppress autoimmune processes. These changes lead to the development of protective and compensatory mechanisms and the restoration of impaired physiological functions, which ultimately determine the therapeutic efficacy of spa treatment.

The effectiveness of radon therapy can also be attributed to the fact that stimulation of the adaptive-defense response continues beyond the treatment period, persisting for several months or even years.

Thus, radon treatment provides a prolonged analgesic, anti-inflammatory, and desensitizing effect in a wide range of conditions [21, 22].

Long-term clinical observations and specialized studies have demonstrated that, when administered in appropriate doses, radon-rich waters act as physiological stimuli. They regulate neurohumoral processes, restore intracellular metabolism, and normalize secretory, enzymatic, and trophic functions [12-14].

While the radon waters at the Khmilnyk resort are used to treat cardiovascular, musculoskeletal, and neurological disorders [22-24], there is no available literature on their application in dental disease treatment. However, at other balneological resorts, radon therapy has been successfully implemented in the management of periodontal diseases [5, 11, 13].

## CONCLUSION

The use of radon-rich waters represents a promising method for the treatment of oral diseases. It may enhance the outcomes of standard endodontic disinfection of root canals and periodontal therapy. Further clinical trials are needed to determine the most effective and safe parameters for radon therapy, but current clinical outcomes are highly encouraging. We consider the application of Khmilnyk resort radon waters in dentistry to be a promising direction for future research and clinical practice.

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## CONFLICT OF INTEREST

The authors declare no conflict of interest

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A – Work concept and design, B – Data collection and analysis, C – Responsibility for statistical analysis, D – Writing the article, E – Critical review, F – Final approval of the article

**RECEIVED:** 20.06.2025
**ACCEPTED:** 06.08.2025

 

REVIEW ARTICLE

# Multidisciplinary approaches involving clinical pharmacists in the cardiac rehabilitation of patients with chronic coronary syndrome in Ukraine

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**ABSTRACT**

**Aim:** This study is to investigate the impact of pharmacists' interventions in the clinical practice of rehabilitation of patients after acute coronary syndrome with subsequent scientific and applied substantiation of the functional fulfillment of pharmacists' roles as part of multidisciplinary teams.

**Materials and Methods:** Foreign and Ukrainian publications of scientometric databases Scopus, Web of Science, Cochrane, PubMed, ESC, AHA, ADA sites. European, American and Ukrainian regulatory and legal support for the rehabilitation of patients after acute coronary syndrome with the participation of pharmacists as part of multidisciplinary teams. The methods used were narrative search using keywords, dialectical, synthesis, content analysis, visualization.

**Conclusions:** The functional content of pharmacists' roles as part of multidisciplinary teams in the process of cardiac rehabilitation of patients after acute coronary syndrome has been scientifically substantiated. The need to develop and implement clinical pharmacology guidelines in cardiology for specific nosologies, tailored for community and clinical pharmacists, has been identified. It is recommended to update the curricula in postgraduate training of pharmacists and clinical pharmacists in accordance with ESC/AHA standards.

**KEYWORDS:** Treatment adherence, chronic coronary syndrome, pharmaceutical care, multidisciplinary team, cardiac rehabilitation, drug-drug interaction

Acta Balneol. 2025;67(5):388-396. doi: 10.36740/ABAL202505112

## INTRODUCTION

About 80% of all premature deaths in the world are caused by non-communicable diseases, among which cardiovascular and cerebrovascular diseases (such as heart attacks and strokes), cancer, chronic respiratory diseases (such as chronic obstructive pulmonary disease and bronchial asthma) and milestone diabetes play a major role [1]. One of the areas of activity of the World Health Organization for 2023-2030 is the development of preventive and therapeutic measures to reduce premature mortality from non-communicable diseases (Target 3.4) [1], among which measures aimed at the rehabilitation of patients after complications and recurrences of cardiovascular diseases play an important role [2].

The incidence of cardiovascular diseases remains high in the European Union, where the number of patients who underwent inpatient treatment for diseases of the circulatory system in 2021 was 8.6 million [3].

Coronary heart disease (CHD) is the leading cause of death among men and women in Ukraine (as of 2021) [4]. Analyzing statistics on the mortality rate from ischemic heart disease among countries in the world, Ukraine ranks fourth [4].

The results of the observational study EUROASPIRE V (n = 2759), in which participated 27 European countries, including Ukraine, showed an unsatisfactory level of adherence to lifestyle changes and pharmacotherapy among patients with very high cardiovascular risk [5].

Increasing measures aimed at preventing cardiovascular and cerebrovascular diseases, improving screening of risk factors, covered by the European Union initiative "Healthier Together", can contribute to reducing disability and premature mortality, as well as improving the quality of life of such patients and lead to a decrease in the burden and costs of healthcare [6].

To address these issues, the clinical guidelines of the European Society of Cardiology (ESC) [7] and the American Heart Association (AHA) [8] emphasize interprofessional collaboration within multidisciplinary teams of healthcare professionals, including physicians of various specialties, nurses, pharmacists, medical psychologists, social workers, etc.

The effectiveness of clinical pharmacists' interventions in rehabilitation programs for patients with acute coronary syndrome has been demonstrated in improving adherence to pharmacotherapy, reducing adverse reactions on medicines and promoting lifestyle changes, all of which contribute to fewer repeat hospitalizations and a reduction in premature mortality [9-11].

Therefore, it is relevant to study the impact of pharmaceutical care on improving adherence to treatment in the clinical practice of rehabilitation of patients after acute coronary syndrome with the subsequent determination

of the functional content of the roles of Good Pharmacy Practice (GPP) of pharmacists and their participation in multidisciplinary teams.

## AIM

The purpose of this study is to investigate the impact of pharmacists' interventions in the clinical practice of rehabilitation of patients after acute coronary syndrome with subsequent scientific and applied substantiation of the functional fulfillment of pharmacists' roles as part of multidisciplinary teams.

## MATERIALS AND METHODS

The materials for the scientific substantiation of the impact of pharmacists' interventions on the clinical practice of rehabilitation of patients after acute coronary syndrome were foreign scientific studies, European, American and Ukrainian regulatory and legal support for the rehabilitation of patients after acute coronary syndrome with the participation of pharmacists as part of multidisciplinary teams.

The search and analysis of the Ukrainian regulatory and legal documents were carried out using the narrative search method using the keywords: "medical guarantees program" (60 documents), "cardiac rehabilitation" (1 document), "pharmaceutical assistance" (4 documents), "cardiovascular diseases" (4 documents) as of April 04, 2025 on the website of the Verkhovna Rada of Ukraine in the "Legislation" section, subsection "Regulatory and legal framework of Ukraine". The inclusion criteria comprised regulatory and legal documents that were in effect at the time of writing the article, pertaining to research conducted over the past decade. A total of 69 documents were selected. In addition, on the website of the State Expert Center of the Ministry of Health of Ukraine, in the section "Standardization in the field of health care", in the subsection "Standardization of medical care" in the register of "Medical and technological documents", a search was carried out for regulatory and legal documents using the keywords "ischemic heart disease" (3 documents), "arterial hypertension" (3 documents), "type 2 diabetes" (3 documents), "heart failure" (3 documents), "atrial fibrillation" (3 documents), "pharmacist's protocol for dispensing reimbursed medicines to patients with cardiovascular diseases" (1 document), "acute coronary syndrome" (2 documents). The inclusion criteria consisted of regulatory and legal documents that were valid at the time the article was written, relating to research carried out over the past five years. A total of 18 documents were selected. The exclusion criteria were identical documents with different dates of amendments. A total of 87 regulatory and legal documents were analyzed.

Considering that the basis for the development of Ukrainian standards for providing medical care to patients with cardiovascular diseases are the clinical recommendations of the ESC, AHA, and the American Diabetes Association (ADA), we examined the websites of these organizations and selected relevant clinical recommendations for providing medical care to patients with chronic coronary syndrome, arterial hypertension, atrial fibrillation, heart failure and type 2 diabetes. Using content analysis, the pharmaceutical component in international and Ukrainian standards for providing medical care was identified.

In addition, an information search was conducted by using a narrative review and keywords: "cardiovascular pharmaceutical care" (1569 documents), "pharmacological care model" (205 documents), "pharmacist intervention in cardiac rehabilitation" (2 documents), "pharmacist intervention in ischemic heart disease" (4 documents), "pharmacist intervention in case of chronic coronary syndrome" (2 documents) in the scientometric databases Scopus, Web of Science, PubMed, Cochrane library in English and using the visualization program VOSviewer [12]. The inclusion criteria included open-access, full-text scientific publications published exclusively in English, strictly addressing the research topic within the past five years. A total of 1,782 documents were extracted. The exclusion criteria included annotations, duplicate publications, reviews, books, paid-access scientific publications, and publications that were only indirectly related to the selected research topic. After applying the exclusion criteria, 22 clinical trials, meta-analyses, randomized controlled trials, and systematic reviews involving pharmacists in the rehabilitation of patients after acute coronary syndrome were analyzed.

After analyzing regulatory documents and scientific research and using the synthesis method, we generalized the methods used worldwide for the further formation of a holistic approach to the participation of pharmacists in multidisciplinary teams in the rehabilitation of patients after acute coronary syndrome.

By using the dialectical method, contradictions in the existing model of providing pharmaceutical care to patients after acute coronary syndrome were identified, which became the basis for modeling part of the model of pharmaceutical care for patients with ischemic heart disease with comorbid conditions as a single cycle of the continuous process of providing medical care.

Following the identification of the functional components of pharmacists' roles in accordance with the principles of Good Pharmacy Practice, applied research methods were utilized to evaluate the feasibility of integrating these defined functions into real-world clinical practice. In addition, a clinical case involving the participation of a clinical pharmacist was analyzed to further elucidate the advantages and potential barriers associated with the implementation of a multidisciplinary approach to cardiac rehabilitation in patients with coronary artery disease and comorbidities.

The practical implementation of the proposed approaches in cardiac rehabilitation of a multidisciplinary approach with the involvement of a clinical pharmacist was considered on the example of a patient who previously provided informed consent to the processing and use of data for scientific purposes. A patient was randomly selected from the clinical population after providing informed consent for the processing and use of personal data for scientific purposes.

Levels of depression and anxiety were evaluated using the Hospital Anxiety and Depression Scale (HADS)

(Zigmond & Snaith, 1993). Scores were interpreted as follows: <7 points indicated a normal range, while ≥8 points suggested the presence of subclinical or clinical anxiety (HADS-A) or depression (HADS-D). Treatment adherence was assessed using the Medication Adherence Rating Scale (MARS-5) (Thompson et al., 2000), which also allowed for the estimation of medication-taking duration. Pharmacotherapy monitoring was conducted in accordance with the methodology established by the National Health Service (NHS) England [27].

The study was conducted in accordance with the Declaration of Helsinki of the World Health Organization "Ethical Principles of Medical Research with the Participation of Human Subjects" (International Ethical Guidelines for Biomedical Research Involving Human Subjects, 2016).

## REVIEW

Using the VOSviewer visualization program with the keywords "cardiac rehabilitation" and "pharmaceutical care" made it possible to identify a new trend in scientific research on the impact of pharmacist interventions on the rehabilitation of patients after acute coronary syndrome (seven publications), aimed at lifestyle correction, improving adherence to pharmacotherapy and risk factors: total cholesterol, blood pressure, blood plasma glucose (Fig. 1) [12].

The results of the analysis of international documents indicate a reorientation of pharmaceutical services from pharmaceutical provision of medicines to pharmaceutical care [14]. Thus, the European Resolution CM/Res (2020)3 on the implementation of pharmaceutical care for the benefit of patients and Health services stipulates that pharmacists are obliged to supervise the following:

1. rational pharmacotherapy, taking into account polypharmacy in medicines prescriptions for cardiovascular diseases with concomitant conditions;
2. contribute to reducing the occurrence of undesirable adverse reactions and medicines interactions, taking into account medicines metabolism;
3. appropriate use of medicines by patients, which will subsequently positively affect adherence to treatment;
4. modification of risk factors for cardiovascular diseases [13].

Of particular interest are the American clinical guidelines on pharmaceutical care for patients after acute coronary syndrome [15] and on the prevention of acute coronary syndrome under the supervision of pharmacists [15]; Australian clinical protocols and recommendations for rehabilitation and recovery programs for patients with cardiovascular risk (Queensland) [16]; British guidelines on the possibilities of optimizing pharmacotherapy [29]. It should be noted that the listed clinical guidelines for pharmacists are a clarification of the functional content of the roles of GPP and the separation of the functions of pharmacists as part of multidisciplinary teams in the care of patients with chronic coronary syndrome in accordance with the ESC [7] and AHA [8] clinical guidelines and algorithms for the provision of appropriate pharmaceutical care.

According to the results of the analysis of Ukrainian regulatory documents in healthcare institutions, the position of clinical pharmacist [17] with defined functional responsibilities is envisaged [18; 19]. However, the quality standards of pharmacy services are of a recommended nature [19], and the Law of Ukraine "On Medicinal Products" with defined functions of pharmacists comes into force after the end of martial law in Ukraine [18]. In addition, according to the order of the Ministry of Health [17], the position of clinical pharmacist in healthcare institutions does not provide for the participation of a clinical pharmacist in multidisciplinary teams, which contradicts the concept

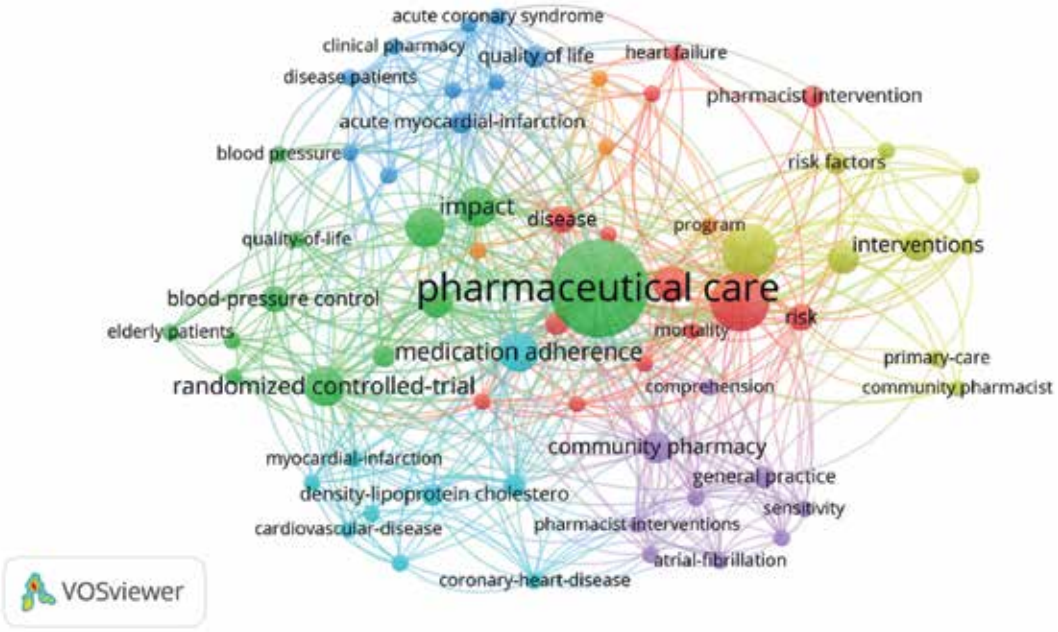


**Fig. 1.** Scientific works distributed within the cluster networks by keywords "cardiac rehabilitation", "pharmaceutical care" [12]

of "pharmaceutical care" in the new version of the Law of Ukraine "On Medicinal Products" [18].

The results of the analysis of foreign scientific publications indicate the effectiveness of the influence of pharmacist interventions on adherence to treatment, control of safe use of medicines and risk factors for patients with chronic coronary syndromes [20] as part of multidisciplinary teams and in the periods before and after exacerbation of coronary syndrome. Interventions of clinical pharmacists in monitoring pharmacotherapy of patients with chronic coronary syndromes showed a decrease in the occurrence of repeated cardiovascular events by 30% and mortality by 2% [21].

In addition, clinical pharmacists, as members of cardiac rehabilitation medical teams, participate in educating patients on the proper and safe use of medications, aiming to minimize the risk of side effects [9].

Considering the fact that patients with acute coronary syndrome have long-term risks of recurrent cardiovascular events, a special role is assigned to the intervention of pharmacists together with the medical team in ensuring continuity of care and cardiac rehabilitation [22]. In an open, prospective, controlled, non-randomized clinical trial, the intervention of clinical pharmacists in interprofessional interaction with the medical team showed an improvement in treatment adherence within the patients with acute coronary syndromes by 49.3% compared with the control group (18.8%), and in solving drug-related problems (60%) [23]. A systematic review and meta-analysis of randomized clinical trials (n = 8933 patients with cardiovascular disease) showed improvements in blood pressure, glycated hemoglobin, low-density lipoprotein cholesterol, and adherence to pharmacotherapy among patients with cardiovascular disease in the context of primary prevention and pharmacist-led control of modifiable risk factors [22].

Therefore, summarizing the results of the analysis of foreign and Ukrainian regulatory documents and scientific publications, the functional fulfillment of the roles of pharmacists in good pharmacy practice (Table 1) in the rehabilitation of patients after acute coronary syndrome is highlighted [13].

Considering the above-described activities in which pharmacists can participate as members of a multidisciplinary team, and for the practical implementation of the proposed model, we conducted an analysis of clinical cases during the patient rehabilitation process with the involvement of a clinical pharmacist. The clinical case analysis with the involvement of a Clinical pharmacist provided insights into the feasibility of implementing pharmacists' functions in clinical settings, highlighting both the benefits and the challenges encountered in practice.

## CLINICAL CASE

A 52-year-old white woman applied for correction of pharmacotherapy due to complaints that appeared during the last 2 weeks of periodic increase of blood pressure during the day, headache, swelling of the lower legs, periodic weakness, increased shortness of breath (on the MRC scale from 2 to 3 degrees of severity). The patient leads a sedentary lifestyle, has mainly canned foods and semi-finished products in her diet, does not smoke and has no allergies to medications.

The diagnoses include hypertension, ischemic heart disease, and stenting (1 BMS in the anterior interventricular branch of the left coronary artery). She also has heart failure with reduced left ventricular ejection fraction (LVEF) and chronic obstructive pulmonary disease (COPD).

**Table 1.** Functional content of the Roles of pharmacists of good pharmacy practice in the rehabilitation of patients after acute coronary syndrome [13]

| Clinical hospital pharmacists | Pharmacist assistants, pharmacists, pharmacovigilance professionals |
|---|---|
| Modification of CVD risk factors | Modification of CVD risk factors |
| Monitoring of prescribed and over-the-counter medicines (OTC) | Patient screening |
| Checking for medicines compatibility | Monitoring of prescribed and over-the-counter (OTC) medicines |
| | Checking for medicines compatibility |
| Pharmacovigilance | Pharmacovigilance |
| Supervision of polypharmacy | Supervision of polypharmacy |
| Coordination of pharmacotherapy | Coordination of pharmacotherapy |
| Educating patients about the drug regimen | Educating patients about the drug regimen |
| Monitoring of the effectiveness of pharmacotherapy together with the doctor | Monitoring of the effectiveness of drug therapy in cooperation with a primary care physician |
| Monitoring adherence to treatment together with the doctor | Monitoring adherence to treatment |
| Providing healthcare institutions with medicines | Providing patients/consumers with medicines |
| | Dispensing medicins under the reimbursement program |

At the time of admission, she was taking nebivolol 2.5 mg per day, losartan 25 mg per day, atorvastatin 40 mg per day, acetylsalicylic acid 100 mg per day, and salbutamol 200-400 mcg per day in spray form.

Objectively: BMI = 24, waist circumference 78 cm. Increased BP figures were detected – 150/99 mm Hg. Art., signs of decompensation of heart failure with EFLV (decrease in EFLV from 46% to 30%) and negative dynamics of lipid profile indicators with an increase in the level of total cholesterol (from 4.0 mmol/l to 5.7 mmol/l,) and low-density lipoprotein (LDL) (from 1.77 mmol/l to 3.65 mmol/l). According to the results of the HADS questionnaire, there are signs of depression (12 points).

After interviewing the patient by a clinical pharmacist, it was found out: the patient leads a sedentary lifestyle, eats a large amount of canned vegetables, does not smoke, and has no allergies to medications.

Monitoring of adherence to pharmacotherapy showed that the patient periodically refuses therapy with losartan 25 mg/day due to disappearing episodes of BP drop. Sometimes forgets to take atorvastatin 40 mg per day. Episodically took salbutamol 100 mcg (1 inhalation 1 time per day) in the form of a spray, but began to use it more often after increasing shortness of breath (2-4 inhalations per day), as she perceived these symptoms as signs of exacerbation of chronic lung disease.

In monitoring the effectiveness of pharmacotherapy, carried out by the doctor in collaboration with the clinical pharmacist, negative dynamics according to echocardiography (Echo-CG) data were taken into account by comparing the latest results from the medical record with those obtained at the start of treatment, as well as the negative dynamics of lipid profile indicators.

## DISCUSSION OF PHARMACOTHERAPY CORRECTION IN A CLINICAL CASE

According to the ESC clinical guidelines [7], the patient is classified as having high cardiovascular risk and has not achieved the target blood pressure (BP) values of <130/80 mm Hg. The current combination therapy of nebivolol 2.5 mg/day and losartan 25 mg/day is not considered optimal. For improved BP control and to achieve target values, it is recommended to reassess the dosages of the prescribed medications or consider fixed-dose combinations that include a diuretic agent (e.g., indapamide or hydrochlorothiazide) [25].

For the improvement of the patient with heart failure with reduced left ventricular ejection fraction and disease progression, the use of angiotensin II receptor and neprilysin inhibitors should be considered regardless of the presence of concomitant type 2 diabetes. In addition, the use of mineralocorticoid receptor antagonists and sodium-glucose co-transporter 2 inhibitors is also recommended in accordance with ESC clinical guidelines [25]. In addition, the use of carvedilol should be considered, as it has additional benefits in the treatment of heart failure with reduced ejection fraction [25].

For the correction of dyslipidemia, intensification of lipid-lowering therapy with the maximum dose of a statin should be considered, in this case atorvastatin 80 mg with ezetimibe 10 mg to accordance with ESC guidelines [7]. In the future, it is possible to use a PSK9 inhibitor (in Ukraine, this drug is registered on the pharmaceutical market, but it has been defective for a long time).

Considering the fact of the patient's acute Q-wave myocardial infarction with urgent stenting, in accordance with ESC recommendations, the use of antiplatelet therapy with acetylsalicylic acid at a dosage of 75 mg or 100 mg, or clopidogrel 75 mg, is prescribed [7].

After consultation with a psychiatrist, sertraline should be considered, as it is safe for patients with heart failure and reduced left ventricular ejection fraction [26]. However, recent observational data suggest that antidepressant use increases the risk of sudden cardiac death (SCD) by 56% when used for 1 to 5 years [26]. Psychotherapy or short-term use of sertraline may be considered until the patient's condition improves.

Medications interaction screening of the prescribed pharmacotherapy, taking into account CYP isoenzyme metabolism, showed the following results (Table 2) [27-29].

Thus, optimization of pharmacotherapy is aimed at correcting decompensation of heart failure and will look as follows:

1. Sacubitril/valsartan dose titration over 3-4 weeks from 24/26 mg 2 times a day to optimally tolerated (under control of BP and K+ levels) or to the target level of 97/103 mg 2 times a day;
2. Carvedilol 6.25 mg 2 times a day, torasemide 20 mg until the disappearance of signs of leg edema with subsequent transition to a maintenance dose of 5 mg per day;
3. Atorvastatin 80 mg per day in combination with ezetimibe 10 mg per day with a control of lipid profile after 3 months;
4. Acetylsalicylic acid 100 mg per day;
5. Eplerenone 25 mg per day with titration to the target dose of 50 mg once a day;
6. Dapagliflozin 10 mg once a day;
7. Consultations with a psychiatrist and a pulmonologist are suggested for further correction of pharmacotherapy.
8. Training provided by a clinical pharmacist on lifestyle modification, dietary nutrition features (use of the DASH diet [7] and reducing salt intake, consumption of fresh vegetables instead of canned).
9. Recommendations were given for monitoring of blood pressure and heart rate, weight and recording daily results in the patient's diary.
10. Patient training was provided on the method of using and storing medications, and the features of using pillboxes.

The clinical pharmacist dedicated a total of 50 minutes to the patient's clinical assessment, including 20 minutes for the patient interview and 30 minutes for evaluating drug compatibility and justifying the optimized pharmacotherapy plan. The subsequent integration of pharmacists' defined functions into routine daily clinical practice, along with the implementation of multidisciplinary approaches involving pharmacists and clinical teams in a larger patient

**Table 2.** Drug interaction screening based on CYP isoenzyme metabolism [27-29]

| Medicines Combination | CYP Isoenzymes | Interaction |
|---|---|---|
| Losartan + Sertraline<br>Indapamide + Sertraline<br>Eplerenone + Sertraline<br>Bisoprolol + Sertraline<br>Carvedilol + Sertraline | 3A4 | Inhibition of action |
| Losartan + Sertraline<br>Carvedilol + Sertraline<br>Valsartan + Sertraline<br>Torasemide + Sertraline | 2C9 | Inhibition of action |
| Metoprolol succinate + Sertraline<br>Metoprolol tartrate + Sertraline<br>Nebivolol + Sertraline<br>Bisoprolol + Sertraline<br>Carvedilol + Sertraline | 2D6 | Inhibition of action |
| Atorvastatin + Sacubitril/Valsartan | | Increase in peak concentration of sacubitril by 74% and valsartan by 34% |

cohort, may contribute to advancing pharmacists' practical competencies toward a level of unconscious competence, thereby significantly reducing the time required for similar interventions.

The proposed model of clinical pharmacist interventions, integrated within multidisciplinary teams throughout various stages of medical care in the cardiac rehabilitation of patients following cardiovascular events (Fig. 2), demonstrates the potential to enhance adherence to prescribed pharmacotherapy, ensure the safe and rational use of medications, and reduce the risk of recurrent cardiovascular complications. Collectively, these outcomes probably may contribute to a measurable improvement in patients' quality of life.

## DISCUSSION

According to the results of the study, potential pharmacist interventions in the clinical practice of patient rehabilitation after acute coronary syndrome were identified and substantiated, enabling their practical implementation as part of a multidisciplinary team. The effectiveness of a multidisciplinary approach involving pharmacists in the rehabilitation of such patients was demonstrated in a systematic review [11], the results of which showed the following: improvement in both clinical and non-clinical treatment outcomes; reduction of low-density lipoprotein cholesterol levels to optimal target values; enhancement of adherence to pharmacotherapy and health-related quality of life [11].

In a prospective, randomized, controlled trial of patients with acute coronary syndrome, the results of a pharmacist intervention after three months of follow-up showed a decrease in the number of adverse reactions and drug interactions, improved adherence to pharmacotherapy and better achievement of blood pressure and heart rate targets among the patients participating in cardiac rehabilitation programs [9].

A prospective quasi-experimental study demonstrated the effectiveness of pharmacist interventions, including monitoring and adjustment of pharmacotherapy; structured education on lifestyle modification and appropriate medication use; development of a medication monitoring plan after discharge from the inpatient department; creation of a personalized medication schedule with the simultaneous use of a pillbox; provision of the informational materials on diet and an active lifestyle for patients with chronic coronary syndrome after hospitalization [30].

According to the results of a randomized clinical trial, pharmacists have shown effectiveness in optimizing pharmacotherapy and improving the results of adherence to guidelines in secondary prevention of chronic coronary syndrome [23].

Taking into account the above-mentioned data, the functional fulfillment of the roles of pharmacists of good pharmacy practice in the rehabilitation of patients after acute coronary syndrome as part of multidisciplinary teams has been identified and scientifically substantiated. These measures can further improve the quality of life of patients, save healthcare costs for the treatment of adverse reactions, drug interactions and reduce the burden on healthcare systems by reducing the number of premature hospitalizations. However, as we noted earlier, the separate functions of pharmacists, in accordance with the current Ukrainian legislation, are of a recommended nature [19], and the position of clinical pharmacist in healthcare institutions [17] is limited in terms of the participation of clinical pharmacists in multidisciplinary teams, which also contradicts the norms of the Law of Ukraine "On Medicinal Products" [18]. The outlined contradictions require further harmonization of the current Ukrainian legislation in accordance with the European one. In addition, to ensure the continuous process of providing pharmaceutical care in the health care structure, attention

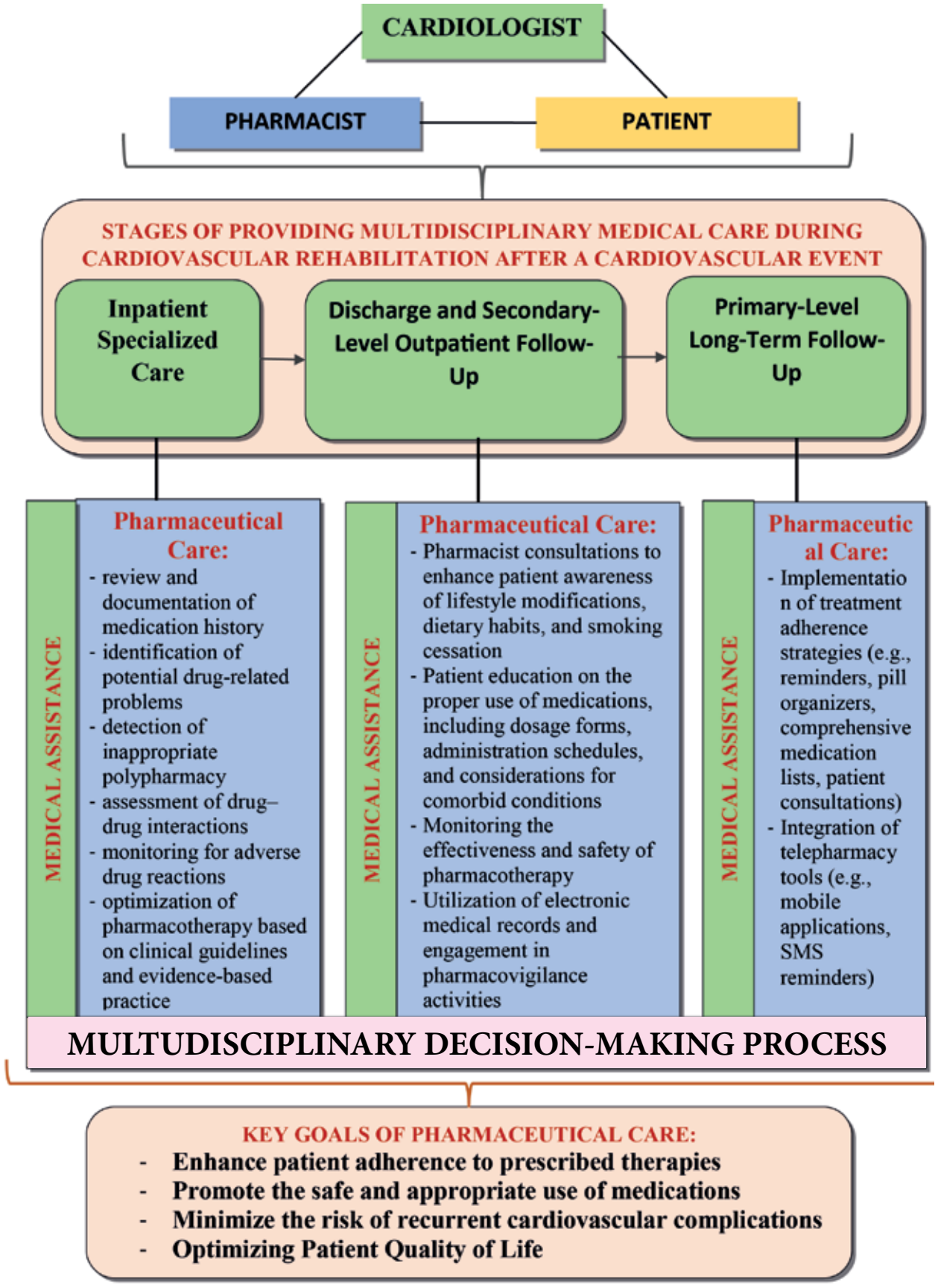


**Fig. 3.** Model of clinical pharmacist/pharmacist interventions as part of multidisciplinary teams at various stages of medical care in the cardiac rehabilitation of patients after cardiovascular events

*Source: compiled by the authors of this study*

should be paid to postgraduate training of pharmacists as part of multidisciplinary teams in specialized areas (cardiology) in the process of continuous professional development in accordance with the update of ESC/AHA clinical recommendations, as well as the development of recommendations on clinical pharmacology in cardiology for individual nosologies (arterial hypertension, chronic coronary syndrome, chronic heart failure, type 2 diabetes mellitus, atrial fibrillation, etc.).

## CONCLUSIONS

1. Based on the results of the analysis of international and Ukrainian regulatory framework, the need to harmonize the current Ukrainian legislation in accordance with the European one for the further inclusion of pharmacists in multidisciplinary teams has been identified.
2. The functional fulfillment of the roles of pharmacists in multidisciplinary teams in the process of cardiac rehabilitation of patients after acute coronary syndrome has been identified, ~~and~~ scientifically substantiated, and applied in clinical practice.
3. The need to develop and implement recommendations on clinical pharmacology in cardiology for individual nosologies for community pharmacists and clinical pharmacists has been identified.
4. It is recommended to update the curricula in postgraduate training of community pharmacists and clinical pharmacists in accordance with ESC/AHA/ACC standards.

We see the development and implementation of recommendations on clinical pharmacology for individual nosologies for community pharmacists and clinical pharmacists as a prospect for further research.

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## CONFLICT OF INTEREST

The Authors declare no conflict of interest

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A – Work concept and design, B – Data collection and analysis, C – Responsibility for statistical analysis, D – Writing the article, E – Critical review, F – Final approval of the article

**RECEIVED:** 11.05.2025
**ACCEPTED:** 26.08.2025

CLINICAL CASE

# Efficacy of the cognifit app in improving cognitive function and balance in post-stroke patient

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**ABSTRACT**

The aim of this study was to determine how well the cognifit mobile application may help a stroke patient's balance and cognitive function. Both balance and cognition significantly improved. This study's novelty is its integrative methodology, which targets cognitive and balance deficiencies in a post-stroke patient by integrating structured physical therapy exercises with the scientifically verified digital cognitive training tool. In contrast to traditional rehabilitation techniques, this case study addresses motor recovery through progressive physical therapies and emphasizes the customized, adaptable nature of the mobile application in real-time cognitive enhancement. The dual-modality intervention highlights how technology-assisted neurorehabilitation can result in quantifiable gains in balance and cognition. The MoCA and MMSE were used to assess cognitive level, and the BBS and TUG test were used to assess balance.

This study illustrates that integrating digital cognitive training with physical therapy can significantly enhance recovery outcomes in post-stroke patients. CogniFit proved to be a practical and effective tool in this context, supporting both cognitive rehabilitation and motor function restoration through an engaging and patient-centered approach.

**KEYWORDS:** Stroke, cognition, balance, Cognifit application, balance and strength training

Acta Balneol. 2025;67(5):397-403. doi: 10.36740/ABAL202505113

## INTRODUCTION

A cerebrovascular accident, often known as a stroke, is an occurrence in which focal neurological abnormalities occur suddenly as a result of altered vascularity, leading to ischemia or bleeding and the eventual loss of all or part of brain function [1]. Around 85% of strokes are ischemic, with the other strokes being hemorrhagic. Stroke mortality and incidence have been increasing during the last few decades. Therefore, early stroke detection and prompt treatment are essential for preventing or reducing morbidity and mortality. Strokes can have a variety of reasons. The most common cause of ischemic stroke is hypertension. Numerous factors, such as coagulation abnormalities, carotid dissection, and illicit drug misuse, can cause stroke in younger people [2, 3]. The main cause of stroke is embolism, which can be cardiac or result from atherosclerotic plaques in the aortic arch or epiaorstic arteries. Atrial fibrillation-related strokes, in particular, are on the rise and have been found to be larger and more incapacitating than other types of strokes. Small vascular disease and intracranial atherosclerosis with in situ thrombosis are additional significant stroke mechanisms, in addition cervical artery dissection is one of the most common causes of stroke in younger individuals [4].

In India, stroke is becoming more common; it is currently the fifth most common cause of disability and the fourth most common cause of death. According to earlier studies, India's annual stroke incidence is between 105 and 152/100 000 persons [5].

Despite the fact that stroke mortality has decreased due to better medication management and medical advancements, long-term survivors frequently experience poor outcomes along with secondary consequences such as dementia and cognitive impairment, pain, anxiety, despair, exhaustion, and epilepsy. These issues significantly raise the chance of a later death and recurrence [6].

Acute impairments in cognitive domains like memory, attention, perception, executive functioning, and social communication can be caused by stroke. Patients who have had a stroke may eventually develop chronic cognitive impairment [7]. Poststroke cognitive impairment and dementia, is still quite common and incapacitating. Depending on the type, criteria, and time point of testing, about 70% of stroke survivors have cognitive abnormalities. Cognitive abnormalities that appear three to six months following an episode stroke are referred to as poststroke cognitive impairment (PSCI). It comprises impairments that may have existed before to the stroke as well as those that are particular to the stroke lesion site, such as aphasia or memory problems, as well as those brought on by strategic infarcts in the thalami, hippocampi, and important cortical regions. Cognitive screening after a stroke often identifies higher-order executive, attentional, and visuospatial deficits, which is more closely linked to conventional vascular cognitive impairment (VCI). As a result, VCI and PSCI are frequently confused [8].

Studies indicates that stroke impairs synaptic plasticity, which could be a possible cause of PSCI. Activity-dependent

variations in the strength of synaptic connections and the effectiveness of synaptic transmission at pre-existing synapses are referred to as synaptic plasticity. There are two types of synaptic plasticity: structural and functional. Adaptive modifications to the synaptic ultrastructure, including the number, density, and distribution of synapses, that emphasize the strength of synaptic connections are referred to as structural synaptic plasticity. The effectiveness of synaptic transmission, encompassing long-term depression (LTD) and long-term potentiation (LTP), is referred to as functional synaptic plasticity. The recovery and improvement of cognitive impairment are tightly linked to synaptic plasticity; stronger synaptic connections and more effective synaptic transmission directly enhance information processing and storage within the central nervous system, thus improving the cognition function [9-12].

A stroke can cause a number of physical and psychological conditions, including irregular muscular movement, aberrant balance, and trouble carrying out activities of daily living (ADL) on one's own. Approximately 83% of stroke survivors experience impairments in their balance, either static or dynamic. Furthermore, imbalance has been shown to impair ADL performance and raise the risk of falls following a stroke [13]. Compared to individuals without cognitive impairment (CI), patients with CI had substantially diminished balance function. This could be linked to a decline in executive function, the most prevalent kind of cognitive function deficit that is absorbed by frontal areas [14].

Global cognitive function is measured by the Montreal Cognitive Assessment (MoCA). Initially, it was created to identify moderate cognitive impairment (MCI). The Montreal Cognition Assessment tool (MoCA) receives a score of 30. The MoCA is a quick cognitive function test that takes ten minutes to complete. It evaluates language, orientation, working memory, attention, concentration, executive function, short-term memory, and visuospatial function [15]. The Mini Mental State Examination (MMSE) is a 30-point test that is widely used in clinical and research settings to assess cognitive impairment. It includes basic tasks focused on language use and comprehension, basic motor skills, arithmetic, including serial subtractions of seven, repeating lists of words, and time and place [16].

To evaluate muscle power, the MRC grading scale was used. The MRC is a valid, consistent, and reliable test; its total scores, which indicate minimal and maximal performance, respectively, range from 0 to 5. The Berg Balance Scale and the Timed Up and Go test were used to evaluate the balance component. From baseline to four weeks, all of these measurements were taken.

Research indicates that cognitive training applications can enhance older persons' cognitive function that helps in the diagnosis, prevention, and treatment of dementia and cognitive impairment. Though more research is required to determine their efficacy, digital therapeutics – such as gaming, virtual reality, AI, and smartphone apps – are becoming more and more popular. Although there are many apps for cognitive training, there isn't a thorough evaluation of their effectiveness and content [17].

CogniFit is a digital health platform that provides practitioners, academics, and users with computerized cognitive tests and therapies. Desktop and laptop computers, as well as mobile devices like tablets and smartphones, can all benefit from assessments and interventions. The general cognitive assessment (CAB) from CogniFit is an online neurocognitive test designed to examine cognitive abilities in the following areas: executive functions, coordination, attention, perception, memory, and physical, psychological, and social health. This tool has been used extensively for cognitive evaluation [18].

## AIM

This case study aims to evaluate the efficacy of the CogniFit app in improving cognition and balance among post-stroke patients.

## CASE STUDY

A 53-year-old woman presented to the rehabilitation clinic four months after an ischemic stroke affecting the right middle cerebral artery. Four months after suffering an ischemic stroke that affected her right middle cerebral artery, a 53-year-old woman arrived at the rehabilitation center. She currently experiences balance issues, walking difficulty, and left side hemiparesis.She also suffered from cognitive impairment, which includes memory, attention, and executive function. Her medical history indicates that on September 15, 2023, at 10:00 AM, the patient experienced facial droop, slurred speech, dizziness, and extreme left-sided weakness while preparing breakfast. Following her hospitalization, an NIHSS assessment indicated moderate severity, and MRI and CT scans confirmed that she had experienced an acute ischemic stroke in the right MCA zone. She was under close observation while undergoing thrombolytic treatment (rtPA). Although she demonstrated partial speech recovery after her two-week hospital stay, she continued to experience cognitive impairment, balance problems, and left hemiparesis. She has a medical history of type 2 diabetes mellitus and hypertension, and she is now taking the right medications. She had no prior surgical history that was relevant. She follows a balanced diet, no addictive habits, and a regular sleep cycle.

Her initial score of 18/30 on the Montreal Cognitive Assessment (MoCA) indicated mild cognitive impairment. Her score of 22 out of 30 on the Mini Mental State Examination also suggests mild cognitive impairment. Muscle strength was assessed using the Medical Research Council (MRC) scale, and she showed mild left-sided hemiparesis. Grades for shoulder abduction, elbow flexion, and wrist extension in the left upper extremity (LUE) are 3/5, 4/5, and 3/5, respectively. Grades for hip flexion, knee extension, and ankle dorsiflexion in the left lower extremity (LLE) are 4/5, 3/5, and 3/5, respectively. These results indicate severe weakness, especially in the left upper and lower extremity's distal muscles.

Additionally, she exhibits mild spasticity in the right upper and lower limbs, with a Modified Ashworth Scale score of 1+ in the LUE and 1 in the LLE. Her Berg Balance Scale

(BBS) score was 38/56 indicating moderate risk fall. She had difficulty in tandem walking and single leg standing. Her Timed Up and Go (TUG) test took 18 seconds, indicating reduced mobility.

## METHODOLOGY

### *INTERVENTION*

After collecting the baseline assessment and informed consent from the patient, the patient underwent 45 minutes of treatment session that included 30 minutes of CogniFit application usage (Fig.1) and 15 minutes of exercises. The treatment was given four days a week for four consecutive weeks.

## COGNIFIT MOBILE APPLICATION

CogniFit is a digital tool with scientific validation that uses customized brain training programs to enhance cognitive abilities like memory, balance, attention, and executive function. Adaptive algorithms are used by the app to evaluate users' cognitive capacities and customize interventions according to their individual requirements. In order to improve balance, Cognifit incorporates workouts

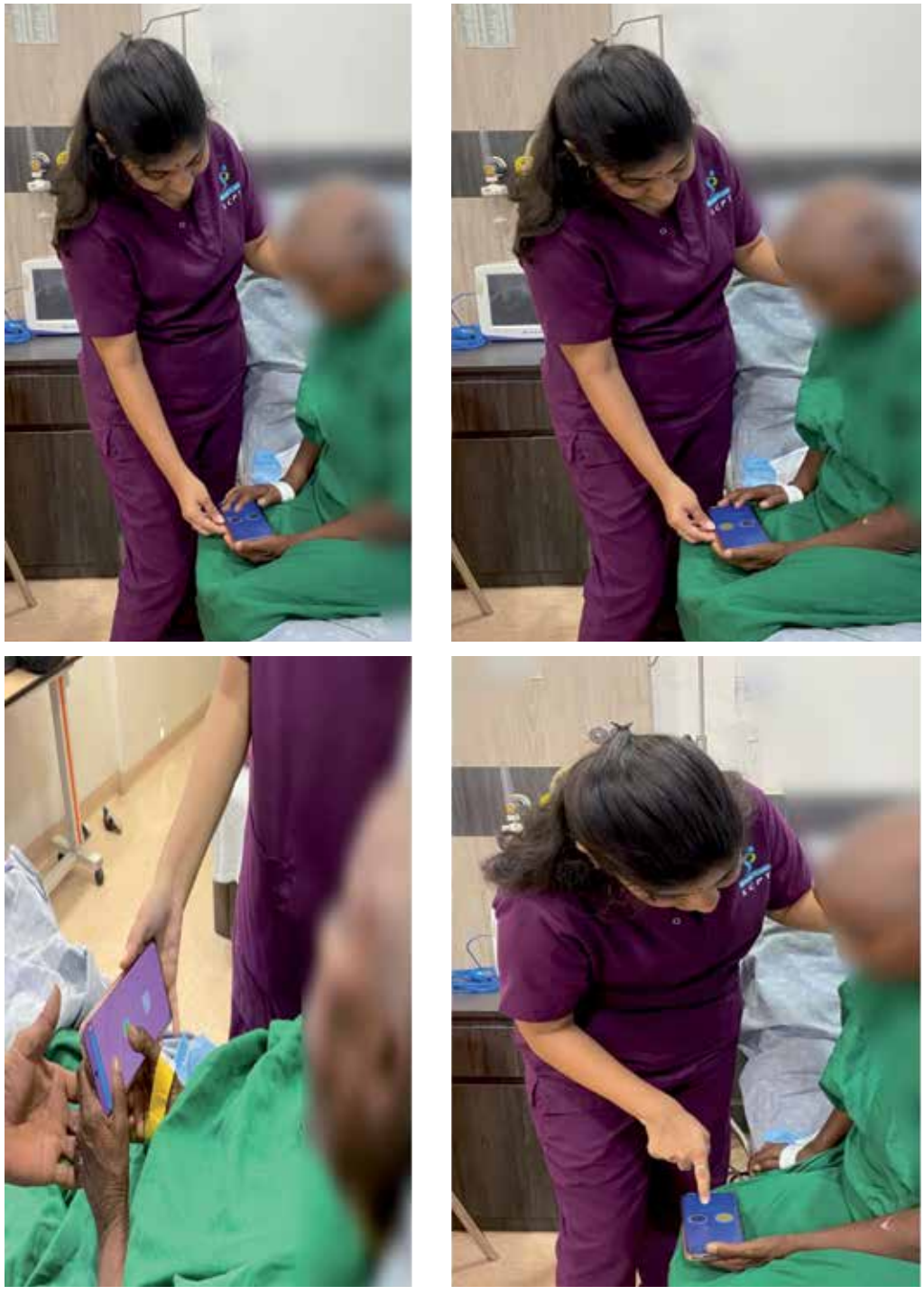

**Fig. 1.** Patient performing cognitive rehabilitation CogniFit exercises using mobile app

*Picture taken by the authors*

that activate the parts of the brain that control coordination and spatial awareness, both of which are essential for preserving physical stability. To enhance attention, the app offers tasks that require sustained focus, selective attention, and divided attention, helping users improve their ability to concentrate and filter out distractions. In order to improve decision-making and goal-directed behavior, executive function is addressed through exercises that test planning, problem-solving, cognitive flexibility, and inhibitory control. Exercises that focus on memory improvement use repetition and more difficult activities to increase working memory, short-term memory, and long-term memory. Because of the intervention's foundation in neuroplasticity, regular usage of the app can result in quantifiable cognitive gains. Because of its systematic and data-driven methodology, CogniFit is a useful tool for clinical and research applications that aim to improve cognitive and physical performance.

**1st week**

During the first week, the Cognifit app was used for 20-minute sessions, three times a week to enhance cognitive performance by concentrating on attention and memory exercises. In addition to using the mobile application, the patient was instructed to perform static balance exercises, such standing on one leg for 10 seconds, and light resistance workouts, like squats and step-ups, to improve strength and stability (Table 1).

**2nd week**

Four times a week, CogniFit sessions last up to 25 to 30 minutes and incorporate executive function activities like problem-solving and planning to enhance cognitive abilities. Resistance bands are used to progress strength training activities like squats and step-ups, and dynamic balancing exercises like tandem walking and heel-to-toe stance are incorporated to improve coordination and stability. To assess the progress, the MoCA and Berg Balance Scale were utilized to check the level of cognition and balance respectively (Table 1).

**3rd week**

During the third week, the use of the cognifit app was extended to four times a week for 30 minutes, and more complex memory and executive function activities were added. Along with the mobile intervention, the exercise resistance was increased to enhance strength and balance training (such as weighted squats and lunges) (Table 1).

**4th week**

During the last week, there was a 30-minute mobile application session with a range of difficult tasks that addressed every aspect of cognition. High intensity resistance training was implemented to enhance balance and muscle strength.

The baseline assessments were repeated once again to find out the improvement in balance, strength, and cognition (Table 1).

## RESULTS

This study revealed that there is significant improvement in the level of cognition as well as improvement in balance by using Cognifit mobile application along with physical therapy. Table 2 shows cognitive scores from MoCA and MMSE tools before and after the intervention. MoCA scores improved from 18 to 23, and MMSE from 22 to 27. Both tools show a mean score of 24.5 and a 5-point improvement, indicating enhanced cognitive function. Table 3 highlights change in balance assessment scores. The BBS score increased

**Table 1.** List of Interventions provided using Cognifit and physical activity

| Week | Duration per Session | Frequency | Cognitive Intervention | Physical Intervention |
|---|---|---|---|---|
| Week 1 | 45-60 minutes | 3 times/week | 20 mins of CogniFitapp focusing on attention and memory | Light resistance: Squats & step-ups (2 sets × 10 reps). Static balance: Single leg stand (10 sec). |
| Week 2 | 50-60 minutes | 4 times/week | 25–30 mins of CogniFit app with executive function tasks (planning, problem-solving) | Moderateresistance: Squats & step-ups with resistance bands (2 sets × 15 reps). Dynamic balance: Heel-to-toe stance, Tandem walking. |
| Week 3 | 60 minutes | 4 times/week | 30 mins of CogniFit app with complex memory & executive function tasks | Advanced resistance: Weighted squats & lunges (3 sets × 15 reps). |
| Week 4 | 60 minutes | 4 times/week | 30 mins of CogniFit app with challenging tasks across all cognitive domains | High-intensity resistance training to improve muscle power and balance. |

*Source: compiled by the authors of this study*

**Table 2.** Tabular column representing cognitive level

| Tool | Pre Test Score | Post Test Score | Mean Score | Range Between Pre And Post Test Score |
|---|---|---|---|---|
| MoCA | 18 | 23 | 24.5 | 5 |
| MMSE | 22 | 27 | 24.5 | 5 |

*Source: compiled by the authors of this study*

**Table 3.** Tabular column representing the balance scores

| Tool | Pre Test Score | Post Test Score | Mean Score | Range Between Pre And Post Test Score |
|---|---|---|---|---|
| BBS | 38 | 45 | 41.5 | 7 |
| TUG | 18 seconds | 15 seconds | 16.5 seconds | 3 seconds |

*Source: compiled by the authors of this study*

from 38 to 45, showing a 7-point improvement with a mean of 41.5. The TUG test time decreased from 18 to 15 seconds, reflecting a 3-second improvement and a mean time of 16.5 seconds – both indicating enhanced balance and mobility.

## DISCUSSION

The aim of this study was to determine how well the cognifit mobile application may help a stroke patient's balance and cognitive function. Both balance and cognition significantly improved. This study's novelty is its integrative methodology, which targets cognitive and balance deficiencies in a post-stroke patient by integrating structured physical therapy exercises with the scientifically verified digital cognitive training tool. In contrast to traditional rehabilitation techniques, this case study addresses motor recovery through progressive physical therapies and emphasizes the customized, adaptable nature of the mobile application in real-time cognitive enhancement. The dual-modality intervention highlights how technology-assisted neurorehabilitation can result in quantifiable gains in balance and cognition. The MoCA and MMSE were used to assess cognitive level, and the BBS and TUG test were used to assess balance.

Computerized cognitive training has been shown in a study by Cramer et al. to enhance executive functioning, memory, and attention in stroke survivors. By customizing exercises to the user's cognitive level, CogniFit's adaptive algorithms guarantee steady advancement [19].

In a randomized controlled experiment, Corbett et al. also showed that online cognitive training programs improved older persons' cognitive function in quantifiable ways. This result can be applied to groups affected by stroke. With its adaptive algorithms, CogniFit closely resembles these results. Because neuroplasticity and long-term cognitive improvement depend on workouts that are neither too easy nor too difficult, the app adjusts the exercises to the user's cognitive ability [20].

Saposnik et al. showed that stroke patients' cognitive and motor results were enhanced by cognitive training based on virtual reality. Despite not being a virtual reality platform, CogniFit's interactive and feedback-driven design is similar to VR-based therapies, which may provide advantages for improving balance [21].

Kim et al. revealed that stroke patients' cognitive and motor outcomes, particularly balance, significantly improved as a result of virtual reality-based cognitive training. By requiring users to process information and make judgments quickly, CogniFit's multitasking workouts may improve cognitive-motor integration, which in turn may lead to improved balance and coordination. CogniFit's cognitive training exercises can enhance conventional balance training regimens, even if it is not made expressly for physical rehabilitation. CogniFit's combined emphasis on motor and cognitive recovery makes it a potentially useful supplement to traditional stroke rehabilitation treatments [22].

According to Bauer & Andringa, stroke patients who utilized gamified cognitive training tools expressed more satisfaction and were more likely to finish their rehabilitation programs than those who used conventional techniques. Users are kept interested and dedicated to their training routine by CogniFit's engaging interface and variety of training sessions [23].

## CONCLUSIONS

This study concluded that there was a significant improvement in both the cognition and balance by using Cognifit mobile application and physical therapy exercises for a post stroke patient.

LIMITATIONS

- As a case study, this research usually focuses on one patient or a relatively limited number of patients. This restricts the applicability of results to a larger group of stroke survivors.
- The short study period makes it difficult to determine the app's long-term impact on balance and cognitive function.
- The balance function needs to be more focused and can be addressed using modern interventions because Cognifit primarily aims in enhancing cognition.

RECOMMENDATIONS

- The study's reliability would be increased by include a larger and more varied sample of post-stroke patients. Including individuals with different levels of stroke severity can aid in assessing the Cognifit app's overall efficacy.
- Future studies should look at how Cognifit works in conjunction with conventional rehabilitation procedures rather than testing it alone. Examining hybrid approaches that incorporate physical treatment and digital cognitive training could improve overall healing results.
- Upcoming research should investigate adaptive learning strategies in the app to customize activities to meet the unique requirements of every patient.

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**CONFLICT OF INTEREST**
The Authors declare no conflict of interest

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**RECEIVED:** 01.05.2025
**ACCEPTED:** 30.08.2025

 

CLINICAL CASE

# Spinal epidural hematoma in the spinal canal in a patient treated with low-molecular-weighted-heparin

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**ABSTRACT**

Epidural hematomas in the spinal canal (SEH) are a rare cause of spinal canal compression syndromes with symptoms of neurological deficits, usually requiring fast surgical decompression. We present a case report of a patient treated with low-molecular-weighted-heparin (LMWH) for suspected inferior vena cava and right cardiac atrium thrombosis. In the course of the LMWH treatment in therapeutic doses, the patient developed an epidural hematoma on the Th3-Th12 level with symptoms of paraplegia, sensory impairments and sphincter disorders. Immediate neurosurgical intervention resulted in the withdrawal of neurological symptoms. The case shows that LMWHs are drugs which should be administered with utmost caution as they are, unfortunately, likely to produce serious side effects. The case seems to deserve attention due to the difficult differential diagnosis of SEH which may simulate acute coronary syndrome, ischemic cardiac or spinal cord stroke or aortic dissection. The case is also of particular educational value to physiatrists who often include LMWH in the treatment of immobile patients commencing physical rehabilitation.

**KEYWORDS:** Spinal Epidural Hematoma (SEH), Low-molecular-weighted-heparin [LMWH], Spontaneous Spinal Epidural Hematoma (SSEH)

Acta Balneol. 2025;67(5):404-408. doi: 10.36740/ABAL202505114

## INTRODUCTION

Spinal hematomas are divided into: spinal epidural hematoma (SEH), subdural hematoma (SDH), subarachnoid hematoma (SAH) and intramedullary hematoma (IMH). The most common of them – SEH – can be subdivided depending on their etiology into: post-traumatic and iatrogenic (spontaneous) [1-3]. Some authors divide SEH into secondary and spontaneous (idiopathic), i.e. SSEH (spontaneous spinal epidural hematoma). SEH will then apply to hematomas diagnosed in patients with lack of identified factors predisposing to the development of a hematoma [4]. Secondary SEH will be hematomas caused by indirect or direct interference with vessels or hemostasis – either through trauma or due to iatrogenic factors such as surgeries of the spinal cord, lumbar punctures or application of anticoagulants [4-6].

SEH is a rare, but important, cause of acute spinal compression syndrome. Failed to be diagnosed in time, it can result in a patient's permanent disability. SEH is most commonly localized in the thoracic or thoracolumbar segment of the spine [7]. There are controversies as regards the origin of the blood to be found in the epidural space, whether it is venous or arterial [8, 9]. In the highly mobile cervical segment of the spine, the bleeding seems to proceed from the free anastomotic arteries. Another hypothesis is possible bleeding from the vertebral venous plexus or epidural vein due to disc herniation or presence of malformations [10-12]. Typical first symptoms of SEH include severe localized spinal pain in the cervical, thoracic or lumbar segment, with gradually developing neurological symptoms resulting from the stenosis of the nervous system structures – direct compression of the spinal cord and spinal nerve roots as well as oedema of the adjacent tissues leading to deficits dependent on the location of the hematoma. MRI is the gold standard in diagnosing SEH. The examination shows the exact location and size of the hematoma. It also allows to estimate the time of its development, in the hyperacute or acute period (up to 72 h). The hematoma is isointense in T1W (weighted time) while in T2W it is initially hyperintense gradually becoming hypointense. Due to meningeal hyperemia, SEH can develop edge reinforcement following the administration of gadolinium contrast [13-15]. Conservative treatment is applied only in case of small SEH's causing discrete deficits in patients with specific dysfunctions. All other SEH's are treated surgically. The

best results are observed in patients operated on within the first 12-24 hours. Factors such as sex, age, size and location of the hematoma seem to be of no prognostic value [4].

## CASE STUDY

The patient aged 75 was sent to the Hospital from a cardiological consultancy for suspected inferior vena cava and right cardiac atrial thrombosis revealed on echocardiogram. Since childhood, the patient has been complaining of shortness of breath which was explained in terms of thoracic malformation (the shoemaker's chest). Subjective perception by the patient of increased shortness of breath made her report to the cardiological consultancy. The patient's comorbidities included: type 2 diabetes, treated with diet and Metformin, hypothyroidism (treated with Levothyroxine 75ug – thyroid hormones within the normal limits), arterial hypertension (monotherapy with Nebivolol 1,25mg per day), past history of oncological treatment – BCT (breast conserving therapy of the right breast 3 years ago, without chemo- and radio- therapy, long-term Tamoxifen therapy, past history of thrombosis of the right lower leg intramuscular veins 10 months earlier. The patient was admitted to the Cardiology Ward of a district hospital near Warsaw. On admission the patient was in a generally good condition, with good circulatory and respiratory efficiency, yet still complaining of increased shortness of breath, with no decreases in saturation values, blood pressure and pulse within normal limits, no ECG abnormalities. Laboratory examinations did not reveal any abnormalities, blood coagulation parameters, including d-dimers, normal, slightly increased Nt-pro-BNP (N-terminal natriuretic pro-peptide) – 192 pg/ml against the standard of below 125. Therapeutic doses of LMWH were initiated – enoxaparin sodium 60 mg 2x daily. The patient was independent within the hospital room. As the CT angiography of thoracic arteries could not be performed during the weekend, the examination was planned for Monday. In the evening on the second day of hospitalization, the patient reported sudden acute pain in the LS region of the spine. In the following hours, the patient developed muscle weakness of the lower limbs, sensory disturbances and sphincter disturbances. Neurological examination revealed flaccid paraplegia with areflexia, weakening of all types of sensation in the lower extremities, bilateral positive Babinski sign, urinary incontinence. The patient was urgently transferred to the Military Medical Institute in Warsaw (MMI). The MRI examination performed there revealed the presence of an epidural hematoma in the spinal canal from the Th3 to the Th12 level – Fig. 1a-d. Control imaging – CT angiograph of the lungs and echocardiography – excluded the presence of obstructing material. Supplementary examinations performed in the patient – blood platelet level as well as coagulation parameters – remained within the normal limits, both in the District Hospital and upon her transfer to the MMI.

The patient underwent an immediate surgery – the surgery commenced within less than 12 hours from the appearance of the first hematoma symptoms in the patient. Right-side hemilaminectomy – Th12, Th11, Th10, Th9 and partly Th8 – was performed, intracanal tightness was revealed caused by masses of mainly clotted and partly liquid hematoma and the hematoma mass was removed. On the days following the surgery, the neurological condition of the patient improved significantly and rehabilitation was begun. After 4-week rehabilitation, the patient was discharged from the Hospital without deficits on neurological examination.

## DISCUSSION

Found in literature are most commonly descriptions of SEH in patients being administered oral old-generation anticoagulants (Acenocoumarol, Warfarin), one description of EDH in the cervical segment of the spine in a patient treated with LMWH, in whom spontaneous resorption of the change had place [8] and three descriptions of spinal SDH in the course of LMWH treatment – all of which were surgically treated [9-11].

What we also find in literature are descriptions of SSEH in the thoracic segment of the spine. Patients with this SEH location usually complain of severe pain in the region of spinal nerve roots accompanied by weakening of the muscles of the lower limbs and sphincter disturbances. The isolated pain experienced in the presence of SSH in the thoracic segment can simulate coronary pain which can affect therapeutic decisions and thus delay causal treatment [2].

The result of the causal treatment depends on the pre-operative condition of the patient as well as on the time which expired from the operation. The majority of the authors point to the advantage of decompression performed within the first 12-48 hours from the appearance of the problem [4, 16, 17]. Some authors postulate the advantage of conservative treatment, particularly in patients with numerous comorbidities when only slight deficits are revealed on neurological examination and the patient's neurological condition shows early improvement followed by improvement of the radiological image [18, 19 ].

In the case presented here, the pain in the Th and L-S region was very severe and accompanied by paraplegia and sphincter functions disturbances. Literature gives us descriptions of two-phase course of SEH where the first episode of pain is followed by a transient pain-free period, with pain recurring accompanied by neurological symptoms [1]. In our patient, we observed a one-phase course. The patient was on long-term treatment for arterial hypertension and type 2 diabetes, both of which can contribute to the dysfunction of vascular endothelium increasing the risk of bleeding. What may arouse doubt in the analysis of our patient's case is the decision to include a therapeutic dose of LMWH on the basis of one echocardiography performed in the outpatient clinic – Cardiological Consultancy – without clear, objective clinical symptoms or deviations in the patient's laboratory results. There is no doubt that the past history of the right calf veins thrombosis was the factor which might have affected therapeutic decisions. Fortunately, the fast transfer of the patient to the Reference Unit – the MMI in Warsaw – immediate diagnostics and surgical treatment allowed to achieve full withdrawal of neurological deficits.

**Fig. 1a.** Sagittal sections of T2-dependent images of the MR examination of the TH spinal cord performed with DICOVERY MR 750 in 3T of GE MEDICAL SYSTEM firm (TE 120, 3, TR 3874, layer thickness 3 mm) (red arrows) show the presence of an extended epidural hematoma in the spinal canal at the level of Th3 to Th12, compressing and dislocating the spinal cord. The hematoma signal is not homogenous with levels of lower signal suggestive of sedimentation

*Picture taken by the authors*

**Fig. 1b.** Sagittal sections of STIR images of the MR examination of the TH spinal cord performed with DICOVERY MR 750 in 3T of GE MEDICAL SYSTEM firm (TE 120, 3, TR 3874, layer thickness 3 mm) show the presence of an extended epidural hematoma (red arrows) in the spinal canal at the level of Th3 to Th12, compressing and dislocating the spinal cord. The spinal cord with areas of elevated signal, slight oedema episodically

*Picture taken by the authors*

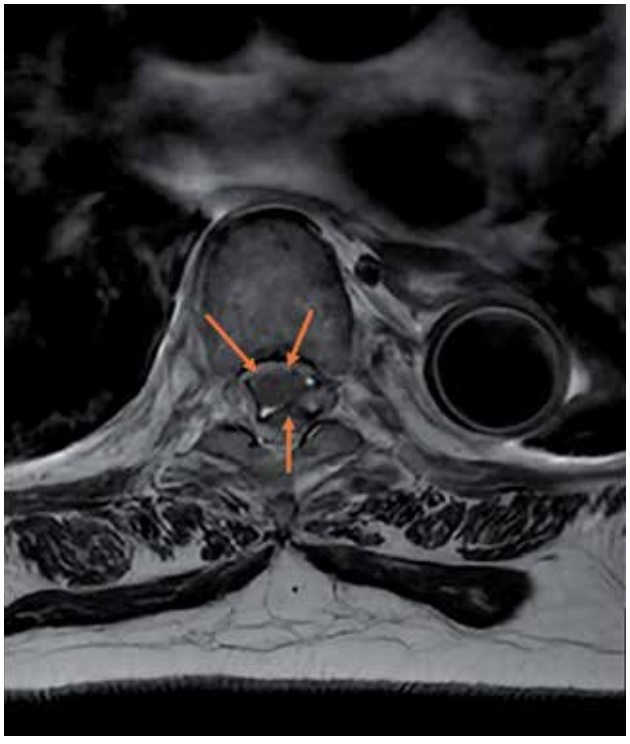

**Fig. 1c.** Cross sections of T2-dependent images (Th6 level) of the MR examination of the TH spinal cord performed with DICOVERY MR 750 IN 3T of GE MEDICAL SYSTEM firm (TE 124, 1, TR 4281, layer thickness 4 mm) show the presence of an extended epidural hematoma (red arrows) in the spinal canal situated anteriorly, laterally and posteriorly to the spinal cord, compressing and dislocating the spinal cords

*Picture taken by the authors*

**Fig. 1d.** Cross sections of T2-dependent images (level Th3) of the MR examination of the TH spinal cord performed with DICOVERY MR 750 in 3T of GE MEDICAL SYSTEM firm (TE 120, 1, TR 4281, layer thickness 4 mm) show the presence of an extended epidural hematoma (red arrows) in the spinal canal at the level of Th3 to Th12, situated anteriorly, laterally and posteriorly to the spinal cord, compressing and dislocating the spinal cords

*Picture taken by the authors*

## CONCLUSIONS

The case shows that LMWHs are drugs which should be administered with utmost caution as they are, unfortunately, likely to produce serious side effects. The case seems to deserve attention due to the difficult differential diagnosis of SEH which may simulate acute coronary syndrome, ischemic cardiac or spinal cord stroke or aortic dissection. The case is also of particular educational value to physiatrists who often include LMWH in the treatment of immobile patients commencing physical rehabilitation.

CLINICAL IMPLICATIONS/FUTURE DIRECTIONS

Spontaneous hematomas in the spinal canal (SEH) may not be a common, and yet important, complication of anticoagulant therapy. It is worthwhile to remember that the risk of this complication increases not only with the application of powerful anticoagulants, but also with LMWH treatment very frequently applied in Rehabilitation Wards.

Another trap may also arise in the differential diagnostics of the fast-increasing spastic paresis. In a SEH patient, the latter may be incorrectly attributed to, for instance, ischemic brain or spinal cord stroke. A CT scan of the head without fresh focal changes might then result in the initiation of thrombolytic treatment and cause disastrous consequences [1].

What is most commonly chosen in SEH treatment is an immediate surgical procedure, conservative treatment being a rational option in individually selected situations [3].

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**CONFLICT OF INTEREST**
The Authors declare no conflict of interest

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A – Work concept and design, B – Data collection and analysis, C – Responsibility for statistical analysis, D – Writing the article, E – Critical review, F – Final approval of the article

**RECEIVED:** 27.05.2025
**ACCEPTED:** 03.09.2025

VARIA

# Advanced balneology course for physicians – October 2025. Information about the completed course

From 29 September to 10 October 2025, we organised the 28th Advanced Balneology Course for Physicians. The course focused on: "Balneology and Physical Medicine – Therapeutic Methods and Selected Issues in Thermal Medicine".

The programme included 80 hours of instruction: 76 hours of lectures and 4 hours of practical training at a balneology facility. During the practical sessions, physicians both received balneological and physiotherapeutic treatments and observed the techniques used, allowing them to experience the effects first-hand.

The aim of the two-week training course was to familiarise physicians planning to work in thermal medicine facilities with the fundamental principles of balneology, physiotherapy, and health resort treatment. The lectures and practical sessions were designed to inspire physicians to pursue further learning in the field of thermal medicine. The course was attended by 53 physicians from over 50 towns and cities across Poland. The majority of attendees held clinical specialisations in various fields, including family medicine, emergency medicine, geriatrics, rheumatology, internal medicine, surgery, intensive care and anaesthesiology, diabetology, allergology, otolaryngology, neurology, pathology, psychiatry, and dermatology. Several participants were in the process of completing their clinical specialisations. For the first time, the course was also attended by four final-year medical students. The students reported that this subject had not been included in their curriculum and wished to expand their knowledge in a field that genuinely interested them.

The course covered fundamental topics in thermal geology, climatology, balneochemistry, indications and contraindications for thermal therapy, health resort infrastructure, as well as selected clinical disciplines from a thermal medicine perspective, including rheumatology, hypertension, cardiology, geriatrics and gerontology, hepatology, diabetology, endocrinology, and gynaecology. In addition, the course participants were introduced to the most important methods used in thermal therapy, including balneohydrotherapy, peloid therapy, balneogas therapy, hydrotherapy, kinesiotherapy, hyperthermia therapy, ultrasound therapy, magnetotherapy, laser therapy, and electrotherapy.

During the course, the participants had the opportunity to meet with the National Consultant in Balneology and Physical Medicine, Dr Aleksandra Sędziak, which allowed them to learn about organisational aspects and future development prospects of Polish thermal therapy centres. Among the lecturers was also Professor Joanna Głogowska-Szeląg, President of the Polish Association of Balneology and Physical Medicine. The course participants thus were able to meet some of the most prominent figures in the fields of balneology and physical medicine. At the end of the course (during a break while the test was being graded), the participants met with Mr Andrzej Kościałkowski – a Pole from Australia, who spoke about how the healthcare system functions in Australia, which he considers the best in the world. Lectures were delivered by outstanding specialists who have been collaborating with us for many years. Most are academic staff at universities, holding both clinical and balneology specialisations.

At the end of the course, the participants were required to take a test consisting of 42 multiple-choice question


photo: archive

*photo: archive*

sets covering the topics addressed throughout the programme. All of them passed the test with good or very good results. On the final day, the participants were formally presented with their certificates of completion, along with the accompanying qualifications, to the applause of the entire group.

All the lecturers noted that the group consisted of physicians highly interested in balneology and thermal therapy; they frequently contributed to discussions and actively participated in the sessions. The participants also had the opportunity to purchase from the publisher the two-volume textbook "The Great Book of Balneology, Physical and Thermal Medicine" as well as the recently published work by Professor Irena Ponikowska, "On Longevity and Good Quality of Life". These resources enabled them to consolidate and expand the knowledge acquired during the course. According to participant feedback, the lectures were of a high standard, highly engaging, and provided a broad understanding across various areas of medical knowledge.

A number of physicians attending the course expressed their interest in furthering their expertise through specialisation in balneology and physical medicine. Several individuals submitted declarations of intent to join the Polish Association of Balneology and Physical Medicine.

The course was held in excellent facilities at St. George Family & Senior Spa in Ciechocinek, located in the very heart of the health resort. I extend my sincere thanks to the facility management team for their dedication and for fostering a warm, supportive environment for all the participants. The course was conducted in a spirit of friendliness and teamwork. The non-academic aspects of the course were managed by the Social Coordinator, in close and effective collaboration with the organisers. The Coordinator also made efforts to make the participants' free time enjoyable through pleasant coffee gatherings and local sightseeing, which further strengthened group bonds. Before returning home, most participants exchanged contact details to maintain their new friendships and professional connections. The course concluded with a group photograph of all the participants.

We extend our heartfelt thanks to all lecturers, as well as to Ms Anita Gawrońska, Ms K. Golis (accountant), and Ms Diana Nowosad for their invaluable support in organising the course. We also thank the participants for their enthusiasm and for cultivating a collegial, friendly atmosphere – with special appreciation for the Social Coordinator, Dr Mariusz Pacholski.

*Scientific Director of the Course*
*Prof. Irena Ponikowska, MD, PhD*

# METRUM CRYOFLEX

## Discover the future of physiotherapy and rehabilitation!

Metrum Cryoflex presents a revolutionary local cryotherapy device that combines the latest technological advancements with practical clinical needs. The innovative blower nozzle is equipped with a FLIR Lepton 3.5 thermal imaging camera and a thermogram analysis algorithm, which allows for precise monitoring of skin temperature and maximizing the effectiveness of the treatment.

CRYO-T | Vital

**Industrial Research**

· A treatment methodology for cryotherapy with an IR camera (8–12 µm) was developed, taking into account environmental conditions and medical standards.
· The FLIR Lepton 3.5 sensor (160×120 px) was chosen as the optimal sensor for nozzle integration.
· Dedicated electronics have been designed to control the indicators, RGB diode and interface.
· Benchmarks with the FLIR T1020 camera and system calibration were performed.
· The influence of environmental conditions on the measurements was investigated – human skin is an ideal thermal imaging object.
· Methodology compliant with ISO/TR 80601-2-56:2013, ASTM, IACT and Glamorgan protocol.

**Development**

· An algorithm for the analysis of thermograms with a measuring grid and color signaling was developed:
Blue: continue cooling.
White: optimal temperature.
Red: Stop cooling.
Black: Critical Temperature.
· The algorithm was clinically validated by Prof. Agata Stanek, MD, PhD.
· Software was created that integrates the IR camera into the user interface.
· Ergonomic nozzles in Solid Edge have been designed, evaluated by physiotherapists.
· Prototypes were made using injection molding technology and functional tests were carried out.
· 100 test procedures were carried out – average ergonomics rating: 9.8/10, software: 4.9/5.
· Expert validation by Prof. Grzegorz Cieślar, MD, PhD, confirmed its effectiveness and safety.
· Patent application in Poland (P.451922) and Community design in the EU (MTC-3/2021).

POIR.01.01.01-00-1192/17
"Innovative nozzle for local cryotherapy with integrated infrared imaging system and support for the evaluation of the effectiveness of the treatment"

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