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Comparative study of the effects on the EEG of drinking monotherapy with Naftussya water and therapy supplemented with "Myroslava" and "Khrystyna" mineral waters

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Abstract

Background. Earlier we showed that the newly created sulfate-chloride sodium-magnesium drinking mineral waters of Truskavets' spa have favorable effects on metabolism and neuroendocrine-immune complex of patients with their dysfunction. This report analyzes the effect of balneotherapy on the parameters of the electroencephalogram of the same contingent of patients. **Materials and Methods**. The object of clinical-physiological observation were 34 men aged 23-70 years, who underwent rehabilitation treatment of chronic cholecystitis and pyelonephritis in remission in the Truskavets' spa. The examination was performed twice, before and after a 7-10-day course of balneotherapy. All patients received bioactive water Naftussya, however, 11 men additionally drank water "Khrystyna", and the other 11 men - water "Myroslava". The subject of the study were the parameters of the electroencephalogram. **Results**. The complex balneotherapy by interval use of sulfate-chloride sodium-magnesium mineral waters with Naftussya water causes significant changes in the constellation of EEG parameters, which are different from the effects of Naftussya water monotherapy. Own effects of mineral waters are estimated by modeling. Two patterns of neurotropic effects have been identified - activating and inhibitory. In general, the neuromodulating effects are physiologically favorable. **Conclusion**. The newly created sulfate-chloride sodium-magnesium drinking mineral waters of Truskavets' spa have favorable neuromodulating effects on patients with chronic cholecystitis and pyelonephritis.

Keywords: sulfate-chloride sodium-magnesium drinking mineral waters, Truskavets' spa, EEG parameters.

INRODUCTION

Earlier we showed that the newly created sulfate-chloride sodium-magnesium drinking mineral waters of Truskavets' spa have favorable effects on metabolism and neuroendocrine-immune complex of patients with their dysfunction [2]. Given the close relationship between EEG parameters and endocrine and immune systems parameters [1,4-6], as well as between their changes under the influence of balneotherapy [1,7-11], the aim of this study was to analyze the effects of mineral water on EEG parameters of the same patients.

MATERIALS AND METHODS

The object of clinical-physiological observation were 34 men aged 23-70 years, who underwent rehabilitation treatment in the Truskavets' spa of chronic cholecystitis and pyelonephritis in remission with of neuroendocrine-immune complex dysfunction. The examination was performed twice, before and after a 7-10-day course of balneotherapy. All patients received bioactive water Naftussya (3 ml/kg one hour before meals three times a day), however, 11 men in half an hour additionally drank water "Khrystyna", and the other 11 men - water "Myroslava" in the same dose.

We recorded simultaneosly with HRV EEG a hardware-software complex "NeuroCom Standard" (KhAI MEDICA, Kharkiv) monopolar in 16 loci (Fp1, Fp2, F3, F4, F7, F8, C3, C4, T3, T4, P3, P4, T5, T6, O1, O2) by 10-20 international system, with the reference electrodes A and Ref tassels on the ears. The duration of the epoch was 25 sec. Among the options considered the average EEG amplitude (μV), average frequency (Hz), frequency deviation (Hz) as well as absolute (μV^2/Hz) and relative (%) power spectrum density (PSD) of basic rhythms: β (35÷13 Hz), α (13÷8 Hz), θ (8÷4 Hz) and δ (4÷0,5 Hz) in all loci, according to the instructions of the device. In addition, calculated Laterality Index (LI) for PSD each Rhythm using formula:

LI, % = Σ [200•(Right – Left)/(Right + Left)]/8.

We calculated also for each locus EEG Shannon's CE entropy (h) of normalized PSD using Popovych's IL formula [1]:

$$hEEG = - [PSD\alpha \bullet \log_2 PSD\alpha + PSD\beta \bullet \log_2 PSD\beta + PSD\theta \bullet \log_2 PSD\theta + PSD\delta \bullet \log_2 PSD\delta]/\log_2 4$$

Normal (reference) values of variables are taken from the database of the Truskavetsian School of Balneology.

RESULTS AND DISCUSSION

Following the accepted algorithm [2], the method of discriminant analysis [3] revealed 30 EEG parameters, according to which the conditions of patients before and after the two balneotherapy regimens differ significantly. Characteristic were 4 parameters of **beta**-rhythm, 6 parameters of **alpha**- and **theta**-rhythm and 8 parameters of **delta**-rhythm, as well as the **entropy** of PSD in 6 loci (Tables 1 and 3).

Table 1. Summary of the analysis of discriminant functions in relation to the parameters of EEG

Step 30, N of vars in model: 30; Grouping: 3 grps; Wilks' Λ: 0,057; approx. $F_{(61)}$=3,8; $p<10^{-6}$

Variables currently in the model	Groups (n) and Means±SE			Parameters of Wilks' Statistics					
	After Naftus-sya (12)	After Salt Waters and N (22)	Before thera-py (34)	Wilks' Λ	Par-tial Λ	F-re-move (2,36)	p-level	Tole-rancy	Norm Cv/σ (122)
Laterality β, %	-33 10	-4 4	-3 5	0,086	0,666	9,03	0,001	0,179	-6 ***28***
F4-β PSD, μV²/Hz	68 11	92 12	86 9	0,061	0,938	1,19	0,317	0,101	73 0,612
T4-β PSD, %	33,6 4,7	37,3 4,6	29,0 2,4	0,071	0,798	4,56	0,017	0,111	27,9 0,591
Fp2-β PSD, μV²/Hz	50 7	74 10	74 8	0,061	0,936	1,23	0,305	0,232	61 0,629
Laterality α, %	-23 9	-18 5	-1 6	0,066	0,858	2,97	0,064	0,096	-4 ***27***
T4-α PSD, %	23,0 3,2	32,6 3,9	28,0 2,9	0,058	0,987	0,23	0,794	0,069	29,2 0,628
F8-α PSD, μV²/Hz	37 13	23 2	37 4	0,063	0,909	1,80	0,179	0,267	40 0,957
F4-α PSD, %	22,0 3,8	31,5 3,1	31,4 3,4	0,120	0,475	19,9	10^{-6}	0,031	32,7 0,564
P3-α PSD, %	37,7 5,5	49,5 3,8	42,1 3,6	0,077	0,737	6,44	0,004	0,032	40,8 0,480
C3-α PSD, %	30,1 4,8	38,9 3,4	35,5 3,2	0,071	0,803	4,43	0,019	0,057	35,3 0,510
Laterality θ, %	-24 10	-35 10	-4 7	0,119	0,478	19,7	10^{-5}	0,036	-3 ***32***
T4-θ PSD, μV²/Hz	22 4	19 3	34 7	0,079	0,724	6,85	0,003	0,032	32 2,582
F7-θ PSD, %	9,8 1,0	8,8 1,3	7,1 0,7	0,127	0,450	22,0	10^{-6}	0,055	7,9 0,568
T4-θ PSD, %	9,1 0,8	6,4 0,7	9,5 1,2	0,101	0,565	13,86	10^{-4}	0,016	8,7 0,539
Fp2-θ PSD, %	8,9 0,8	6,7 1,3	9,7 1,5	0,095	0,600	12,0	10^{-4}	0,028	8,3 0,588
Fp2-θ PSD, μV²/Hz	18 3	20 4	29 7	0,083	0,690	8,08	0,001	0,033	25 1,186
Deviation δ, Hz	0,71 0,10	0,57 0,04	0,73 0,05	0,067	0,846	3,27	0,050	0,490	0,66 0,405
T6-δ PSD, μV²/Hz	53 11	279 136	174 73	0,124	0,458	21,3	10^{-6}	0,006	276 4,53
T5-δ PSD, μV²/Hz	85 21	234 111	395 200	0,078	0,735	6,49	0,004	0,084	174 3,737
F7-δ PSD, μV²/Hz	84 26	870 621	342 169	0,095	0,602	11,9	10^{-4}	0,016	319 4,542
F8-δ PSD, %	50,2 8,8	28,3 7,3	38,8 4,7	0,074	0,770	5,37	0,009	0,183	38,3 0,700
C4-δ PSD, %	34,8 6,5	22,9 4,0	28,6 3,5	0,066	0,865	2,81	0,073	0,107	29,9 0,617
O2-δ PSD, μV²/Hz	104 19	624 338	272 117	0,062	0,913	1,72	0,193	0,086	181 2,438

P3-δ PSD, %	27,5 4,9	19,8 3,4	27,3 3,3	0,082	0,695	7,89	0,001	0,036	26,5 0,672
Entropy F7	0,851 0,024	0,724 0,054	0,704 0,039	0,060	0,956	0,83	0,446	0,122	0,751 0,282
Entropy Fp2	0,797 0,036	0,705 0,048	0,817 0,024	0,202	0,282	45,9	10^{-6}	0,021	0,799 0,180
Entropy T4	0,843 0,029	0,736 0,030	0,819 0,022	0,131	0,434	23,5	10^{-6}	0,029	0,790 0,215
Entropy O2	0,798 0,027	0,669 0,037	0,769 0,028	0,082	0,698	7,77	0,002	0,106	0,727 0,242
Entropy T6	0,834 0,026	0,710 0,046	0,790 0,031	0,069	0,826	3,79	0,032	0,108	0,761 0,249
Entropy P3	0,851 0,032	0,771 0,025	0,797 0,024	0,068	0,834	3,57	0,038	0,098	0,804 0,155

Note. In each column, the first line is the average, the second – SE for variables and Cv or ***SD*** for Norm.

A number of variables despite their recognizable properties, were outside the discriminant model, apparently due to duplication and/or redundancy of information (Table 2).

Table 2. EEGs parameters not included in the model

Variables currently in the model	**Groups (n) and Means±SE**			**Parameters of Wilks' Statistics**					
	After Naftus-sya (12)	**After Salt Waters and N (22)**	**Before thera-py (34)**	Wil ks' Λ	Par-tial Λ	F to en-ter	p-level	Tole-rancy	Norm Cv/**σ** (122)
F8-β PSD, %	23,9 4,9	39,0 5,1	29,9 3,5	0,057	0,995	0,09	0,912	0,067	28,7 0,702
F8-θ PSD, μV²/Hz	23 5	11 2	22 5	0,056	0,985	0,26	0,772	0,252	19 1,791
O2-θ PSD, %	7,2 0,8	5,1 0,6	6,1 0,7	0,057	0,996	0,07	0,928	0,255	6,0 0,603
Entropy T5	0,835 0,028	0,770 0,041	0,744 0,033	0,057	0,998	0,03	0,969	0,170	0,778 0,211

The identifying information contained in the 30 discriminant variables is condensed into two roots. The major root contains 90% of discriminatory opportunities (r*=0,944; Wilks' Λ=0,057; $\chi^2_{(60)}$=145; $p<10^{-6}$), while minor root 10% only (r*=0,689; Wilks' Λ=0,526; $\chi^2_{(29)}$=32; p=0,299).

Table 3. Summary of stepwize analysis of discriminant variables ranked by criterion Λ

Variables currently in the model	F to enter	p-level	**Λ**	F-va-lue	p-level
Laterality β, %	6,28	0,003	0,84	6,28	0,003
Laterality θ, %	4,02	0,023	0,74	5,09	0,001
Entropy F7	2,83	0,067	0,68	4,41	10^{-3}
Entropy Fp2	3,31	0,043	0,62	4,23	10^{-3}
T4-α PSD, %	2,00	0,144	0,58	3,83	10^{-3}
Entropy T4	2,37	0,102	0,54	3,65	10^{-3}
T6-δ PSD, μV²/Hz	2,87	0,065	0,49	3,62	10^{-4}
T4-θ PSD, μV²/Hz	1,96	0,150	0,46	3,46	10^{-4}
F8-α PSD, μV²/Hz	2,25	0,115	0,42	3,38	10^{-4}
F4-α PSD, %	1,72	0,188	0,40	3,25	10^{-4}
P3-α PSD, %	3,02	0,057	0,36	3,32	10^{-4}
T5-δ PSD, μV²/Hz	3,22	0,048	0,32	3,43	10^{-5}

F7-θ PSD, %	2,08	0,135	0,30	3,38	10^{-5}
Entropy O2	2,78	0,071	0,27	3,43	10^{-5}
T4-θ PSD, %	2,26	0,115	0,25	3,43	10^{-5}
F7-δ PSD, μV²/Hz	5,41	0,007	0,20	3,80	10^{-6}
F4-β PSD, μV²/Hz	3,21	0,049	0,18	3,91	10^{-6}
Fp2-θ PSD, %	1,63	0,207	0,17	3,82	10^{-6}
Laterality α, %	2,22	0,120	0,15	3,83	10^{-6}
Fp2-θ PSD, μV²/Hz	2,13	0,131	0,14	3,82	10^{-6}
Deviation δ, Hz	2,06	0,139	0,13	3,82	10^{-6}
F8-δ PSD, %	1,97	0,152	0,12	3,80	10^{-6}
C4-δ PSD, %	1,77	0,183	0,11	3,77	10^{-6}
O2-δ PSD, μV²/Hz	2,61	0,085	0,10	3,85	10^{-6}
P3-δ PSD, %	1,34	0,272	0,09	3,78	10^{-6}
Entropy T6	2,29	0,114	0,08	3,83	10^{-6}
Entropy P3	1,13	0,334	0,08	3,74	10^{-6}
T4-β PSD, %	1,05	0,359	0,07	3,65	10^{-6}
C3-α PSD, %	3,86	0,030	0,06	3,89	10^{-6}
Fp2-β PSD, μV²/Hz	1,23	0,305	0,06	3,83	10^{-6}

Calculating the values of discriminant roots for each patient by the raw coefficients and the constant (Table 4) allows visualization of each patient in the information space of roots.

Table 4. Standardized and raw coefficients and constants for discriminant EEG variables

Coefficients	**Standardized**		**Raw**	
Variables	Root 1	Root 2	Root 1	Root 2
Laterality β, %	1,374	-0,613	0,0550	-0,0245
Laterality θ, %	-3,999	0,492	-0,1119	0,0138
Entropy F7	-0,591	-0,314	-3,1466	-1,6701
Entropy Fp2	6,220	-0,378	42,538	-2,5875
T4-α PSD, %	-0,174	-0,578	-0,0122	-0,0404
Entropy T4	-4,676	0,530	-40,737	4,6211
T6-δ PSD, μV²/Hz	10,024	0,449	0,0252	0,0011
T4-θ PSD, μV²/Hz	-3,112	0,440	-0,1137	0,0161
F8-α PSD, μV²/Hz	0,083	0,840	0,0034	0,0350
F4-α PSD, %	4,266	1,032	0,2782	0,0673
P3-α PSD, %	-3,000	-0,717	-0,1691	-0,0404
T5-δ PSD, μV²/Hz	-1,756	0,903	-0,0022	0,0011
F7-θ PSD, %	-3,351	-0,172	-0,8149	-0,0419
Entropy O2	1,788	0,087	13,073	0,6355
T4-θ PSD, %	5,478	-1,528	1,1257	-0,3139
F7-δ PSD, μV²/Hz	-5,196	-1,160	-0,0036	-0,0008
F4-β PSD, μV²/Hz	-0,261	-1,081	-0,0057	-0,0237
Fp2-θ PSD, %	-4,001	0,581	-0,6332	0,0920
Laterality α, %	1,280	-0,107	0,0480	-0,0040
Fp2-θ PSD, μV²/Hz	3,187	0,695	0,1170	0,0255
Deviation δ, Hz	-0,575	0,198	-2,3259	0,8004
F8-δ PSD, %	-1,147	0,423	-0,0429	0,0159
C4-δ PSD, %	1,024	-0,824	0,0565	-0,0454
O2-δ PSD, μV²/Hz	0,121	-1,455	0,0001	-0,0017
P3-δ PSD, %	-3,103	0,037	-0,1946	0,0023
Entropy T6	1,313	-0,371	8,3683	-2,3617
Entropy P3	-1,378	0,050	-12,129	0,4444

T4-β PSD, %	-1,370	-0,549	-0,0913	-0,0366
C3-α PSD, %	-1,903	-0,704	-0,1222	-0,0452
Fp2-β PSD, μV²/Hz	0,487	0,366	0,0126	0,0095
	Constants		7,567	5,967
	Eigenvalues		8,22	0,90
Cumulative Proportion			0,901	1

The localization of the cluster of patients who received only **Naftussya** water in the extreme left zone of the first root axis (Fig. 1) reflects the maximum decrease in the initial parameters that are **positively** related to the root, as well as the maximum increase **inversely** correlated parameters (Table 5). Recall that a negative value of the Laterality Index indicates a left shift of symmetry. In contrast, in patients receiving **complex balneotherapy**, these EEG parameters deviated from the initial to a much lesser extent or remained unchanged.

On the other hand, these patients are characterized by reduced or minimal for sample EEG parameters that correlate **positively** with the second root, and correspondingly increased or maximum for sample EEG parameters that correlate **negatively** with it, which is visualized by localization of the cluster in the lower root axis.

Table 5. Correlations between EEGs variables and roots, centroids of clusters and Z-scores of variables

Variables	**Correlations Variables-Roots**		**After Naftussya (12)**	**After Salt Waters and N (22)**	**Before therapy (34)**
Root 1 (90%)	**Root 1**	**Root 2**	**-5,77**	+0,06	+2,00
Laterality β	**0,149**	-0,112	**-0,95**	+0,08	+0,10
Laterality α	**0,098**	0,144	**-0,71**	-0,52	+0,12
F4-α PSDr	**0,076**	-0,065	**-0,58**	-0,06	-0,07
Fp2-β PSDa	**0,075**	-0,061	**-0,26**	+0,35	+0,35
Fp2-θ PSDa	**0,048**	0,079	**-0,23**	-0,17	+0,14
T5-δ PSDa	**0,047**	0,032	**-0,14**	+0,09	+0,34
Entropy F7	**-0,096**	0,039	**+0,47**	-0,13	-0,22
Entropy T5			**+0,35**	-0,05	-0,20
F7-θ PSDr	**-0,077**	-0,082	**+0,51**	+0,29	-0,11
Root 2 (10%)	**Root 1**	**Root 2**	+0,61	**-1,34**	+0,65
Laterality θ	0,063	**0,240**	-0,66	**-0,98**	-0,04
Entropy Fp2	0,012	**0,256**	-0,02	**-0,66**	+0,13
T4-θ PSDr	0,006	**0,215**	+0,08	**-0,49**	+0,17
F8-α PSDa	-0,007	**0,201**	-0,07	**-0,44**	-0,08
Entropy O2	-0,031	**0,277**	+0,40	**-0,32**	+0,24
Entropy T4	-0,032	**0,272**	+0,31	**-0,32**	+0,17
Deviation δ	0,007	**0,218**	+0,17	**-0,34**	+0,26
Entropy T6	-0,039	**0,206**	+0,39	**-0,27**	+0,15
F8-δ PSDr	-0,056	**0,180**	+0,45	**-0,37**	+0,02
P3-δ PSDr	-0,005	**0,166**	+0,06	**-0,38**	+0,04
Fp2-θ PSDr	0,012	**0,157**	+0,13	**-0,34**	+0,29
T4-θ PSDa	0,049	**0,155**	-0,12	**-0,16**	+0,03
C4-δ PSDr	-0,045	**0,145**	+0,27	**-0,38**	-0,07
O2-θ PSDr			+0,32	**-0,25**	+0,03
F8-θ PSDa			+0,11	**-0,24**	+0,08
Entropy P3	-0,061	**0,127**	+0,38	**-0,27**	-0,06
O2-δ PSDa	0,028	**-0,167**	-0,18	**+1,00**	+0,21
T4-β PSDr	-0,034	**-0,164**	+0,35	**+0,58**	+0,07
F8-β PSDr			-0,24	**+0,51**	+0,06

P3-α PSDr	0,034	**-0,171**	-0,15	**+0,45**	+0,07
F4-β PSDa	0,050	**-0,085**	-0,11	**+0,43**	+0,30
F7-δ PSDa	0,025	**-0,145**	-0,16	**+0,38**	+0,02
T4-α PSDr	0,046	**-0,147**	-0,34	**+0,19**	-0,07
C3-α PSDr	0,045	**-0,111**	-0,29	**+0,20**	+0,01
T6-δ PSDa	0,040	**-0,123**	-0,18	**0,00**	-0,08

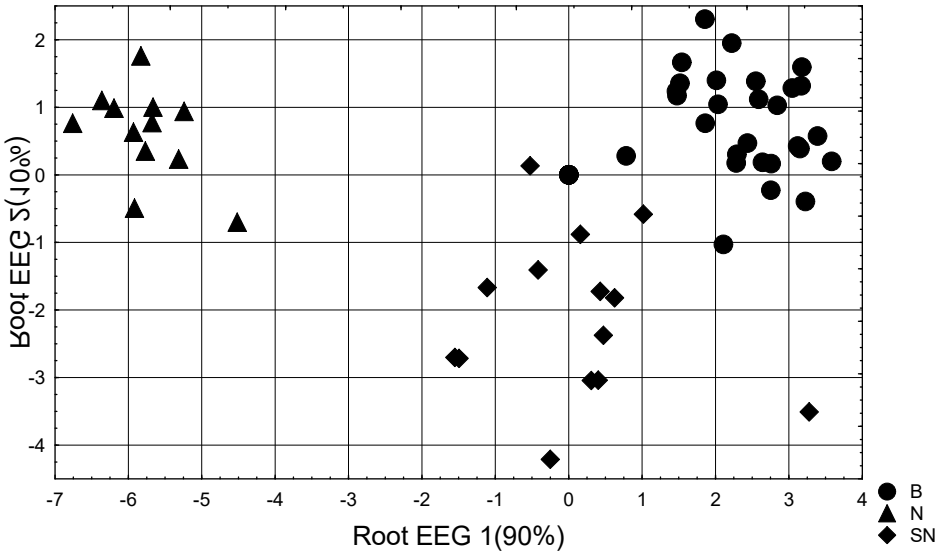

Fig. 1. Scattering of individual values of the first and second EEG discriminant roots of patients before (circles) and after the course of drinking only water Naftussya (triangles) and in combination with water "Myroslava" or "Khrystyna" (rhombuses)

Fig. 2 illustrates that the integrated initial state of all three groups of patients was almost the same as the effect on the discriminant EEG variables of both sulfate-chloride sodium-magnesium mineral waters.

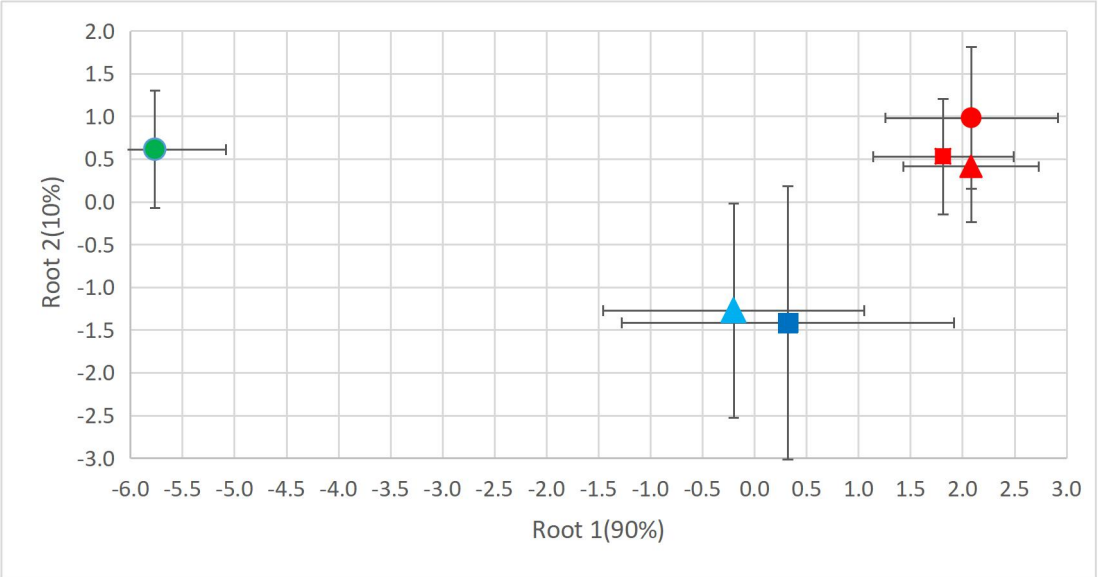

Fig. 2. Mean values (M±SD) of the first and second discriminant EEG roots of patients before (red fill) and after the course of drinking only water "Naftussya" (circle) and in combination with water "Myroslava" (triangle) or "Khrystyna" (square)

The visual impression of a clear demarcation of the three clusters in the information field of the two roots is documented by calculating the distances of Mahalanobis (Table 6).

Table 6. Squares of Mahalanobis distances between clusters (above the diagonal) and F-criteria (df=30,3) and p-levels (below the diagonal)

Clusters	Before therapy	After Naftussya	After SW&N
Before therapy	0	60	7,7
After Naftussya	**9,9** 10^{-6}	0	38
After SW&N	**1,91** 0,033	**5,4** 10^{-5}	0

Selected discriminant variables were used to identify the affiliation of a patient to a particular cluster. This goal of discriminant analysis is realized with the help of classification functions (Table 7).

Table 7. Coefficients and constants of classification functions

Clusters	Before therapy	After Naftussya	After Salt W&N
Variables	p=,500	p=,176	p=,324
Laterality β, %	-0,914	-1,340	-0,972
Laterality θ, %	-0,046	0,822	0,143
Entropy F7	233,3	257,8	242,8
Entropy Fp2	-83,74	-413,79	-160,9
T4-α PSD, %	2,086	2,182	2,190
Entropy T4	-353,5	-37,51	-283,9
T6-δ PSD, $\mu V^2/Hz$	-0,226	-0,422	-0,277
T4-θ PSD, $\mu V^2/Hz$	-0,583	0,299	-0,395
F8-α PSD, $\mu V^2/Hz$	0,032	0,004	-0,045
F4-α PSD, %	-0,515	-2,678	-1,188
P3-α PSD, %	6,436	7,750	6,844
T5-δ PSD, $\mu V^2/Hz$	0,037	0,055	0,040
F7-θ PSD, %	-4,860	1,466	-3,200
Entropy O2	386,6	285,1	360,0
T4-θ PSD, %	15,31	6,583	13,76
F7-δ PSD, $\mu V^2/Hz$	0,054	0,081	0,062
F4-β PSD, $\mu V^2/Hz$	0,976	1,021	1,035
Fp2-θ PSD, %	2,844	7,755	3,886
Laterality α, %	1,108	0,735	1,023
Fp2-θ PSD, $\mu V^2/Hz$	-2,362	-3,270	-2,639
Deviation δ, Hz	11,68	29,70	14,59
F8-δ PSD, %	0,296	0,628	0,347
C4-δ PSD, %	2,239	1,802	2,220
O2-δ PSD, $\mu V^2/Hz$	0,069	0,068	0,072
P3-δ PSD, %	6,638	8,148	7,010
Entropy T6	-135,2	-200,0	-146,7
Entropy P3	757,5	851,7	780,1
T4-β PSD, %	5,517	6,227	5,766
C3-α PSD, %	5,831	6,781	6,158

Fp2-β PSD, μV²/Hz	-0,295	-0,392	-0,338
Constants	-838,8	-913,5	-864,5

The accuracy of the classification is 91,2% (Table 8).

Table 8. Classification matrix
Rows: observed classifications; columns: projected classifications

Groups	Percent Correct	**Before therapy** p=,500	**After Naftussya** p=,176	**After Salt W&N** p=,324
Before therapy	82,4	**28**	0	6
After Naftussya	100	0	**12**	0
After Salt W&N	100	0	0	**22**
Total	91,2	28	12	28

Thus, we have shown that complex balneotherapy by interval use of sulfate-chloride sodium-magnesium mineral water with Naftussya water causes significant changes in the constellation of EEG parameters, which are different from the effects of Naftussya water monotherapy.

Using the algebraic approach described in the previous article [2], we modeled the neurotropic effects of mineral waters **themselves**.

Three patterns of neurotropic effects of mineral waters emerge (Fig. 3). The first pattern (12 parameters) reflects a more or less pronounced activation of neurons that generate delta, alpha and beta rhythms, as well as a right-hand shift of symmetry of beta-rhythm. In contrast, the antipode pattern (17 parameters) reflects the inhibition of neurons that generate delta, alpha, and theta rhythms and the left-hand shift of theta-rhythm symmetry, as well as the decrease in EEG entropy. The intermediate position in the profiles is occupied by 5 parameters, the changes of which are insignificant.

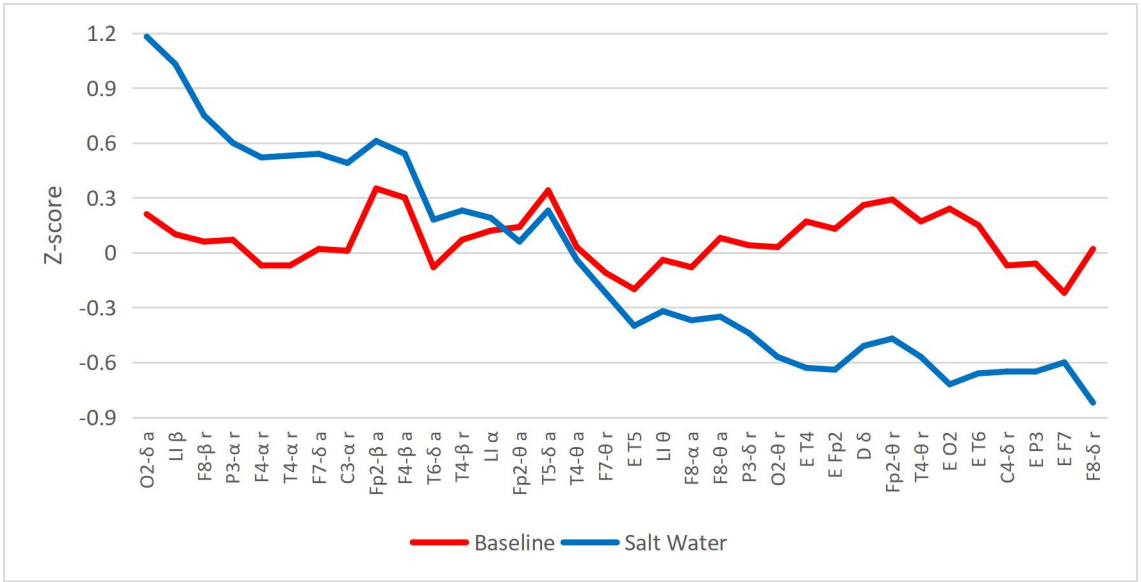

Fig. 3. Profiles of real Z-scores of initial discriminant EEGs variables and their simulated Z-scores after consumption of sulphate-chloride sodium-magnesium mineral waters

Since the described neuromodulation is accompanied by physiologically favorable changes in HRV, immune and metabolic parameters [2], a priori it is also favorable. In the next article, this assumption will be verified by correlation analysis.

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ACCORDANCE TO ETHICS STANDARDS

Tests in patients are carried out in accordance with positions of Helsinki Declaration 1975, revised and complemented in 2002, and directive of National Committee on ethics of scientific researches. During realization of tests from all participants the informed consent is got and used all measures for providing of anonymity of participants.

REFERENCES

1. Gozhenko AI, Korda MM, Popadynets' OO, Popovych IL. Entropy, Harmony, Synchronization, Harmony and Their Neuro-Endocrine-Immune Correlates [in Ukrainian]. Odesa. Feniks; 2021: 232.
2. Hrytsak MV, Popovych DV, Badiuk NS, Hrytsan II, Zukow X. Comparative study of the effect on the neuroendocrine-immune complex and metabolism of drinking monotherapy with Naftussya water and therapy supplemented with "Myroslava" and "Khrystyna" mineral waters. Journal of Education, Health and Sport. 2022; 12(1): 355-367.
3. Klecka WR. Discriminant Analysis [trans. from English in Russian] (Seventh Printing, 1986). In: Factor, Discriminant and Cluster Analysis. Moskva: Finansy i Statistika; 1989: 78-138.
4. Kul'chyns'kyi AB**,** Gozhenko AI, Zukow W, Popovych IL. Neuro-immune relationships at patients with chronic pyelonephrite and cholecystite**.** Communication 3. Correlations between parameters EEG, HRV and Immunogram. Journal of Education, Health and Sport. 2017; 7(3): 53-71.
5. Kul'chyns'kyi AB, Kovbasnyuk MM, Korolyshyn TA, Kyjenko VM, Zukow W, Popovych IL. Neuro-immune relationships at patients with chronic pyelonephrite and cholecystite. Communication 2. Correlations between parameters EEG, HRV and Phagocytosis. Journal of Education, Health and Sport. 2016; 6(10): 377-401.
6. Kul'chyns'kyi AB**,** Kyjenko VM, Zukow W, Popovych IL. Causal neuro-immune relationships at patients with chronic pyelonephritis and cholecystitis**.** Correlations between parameters EEG, HRV and white blood cell count. Open Medicine. 2017; 12(1): 201-213.
7. Kul'chyns'kyi AB**,** Zukow W, Korolyshyn TA, Popovych IL. Interrelations between changes in parameters of HRV, EEG and humoral immunity at patients with chronic pyelonephritis and cholecystitis. Journal of Education, Health and Sport. 2017; 7(9): 439-459.
8. Kul'chyns'kyi AB**,** Zukow W. Three variants of immune responses to balneotherapy at the spa Truskavets' in patients with chronic pyelonephritis and cholecystitis. Journal of Education, Health and Sport. 2018; 8(3): 476-489.
9. Popovych IL, Kul'chyns'kyi AB**,** Korolyshyn TA, Zukow W**.** Interrelations between changes in parameters of HRV, EEG and cellular immunity at patients with chronic pyelonephritis and cholecystitis. Journal of Education, Health and Sport. 2017; 7(10): 11-23.
10. Popovych IL, Kul'chyns'kyi AB**,** Gozhenko AI, Zukow W, Kovbasnyuk MM, Korolyshyn TA**.** Interrelations between changes in parameters of HRV, EEG and phagocytosis at patients with chronic pyelonephritis and cholecystitis. Journal of Education, Health and Sport. 2018; 8(2): 135-156.
11. Vis'tak HI, Popovych IL. Vegetotropic effects of bioactive water Naftussya and their endocrine and immune support in female rats [in Ukrainian]. Medical Hydrology and Rehabilitation. 2011; 9(2): 39-57.