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Changes of Electrokinetic Index of the Buccal Epithelium Correlated with the Changes of Some Parameters of EEG, HRV, Hemodynamics and Metabolism

I.G. KYRYLENKO

Ukrainian Scientific Research Institute of Transport Medicine, Odesa, Ukraine

Danylo Halytsky National Medical University, Lviv, Ukraine

O.O. Bohomolets' Institute of Physiology NAS, Kyiv, Ukraine

E-mail: Iryna2023@gmail.com

Introduction. It has been established that the level of somatic health is related to the bioelectric properties of cell nuclei. As an indicator of bioenergetics, the result of the micro electrophoretic investigating of buccal epithelium cells that has helped to discover the electrokinetic potential of cell nuclei (zeta potential), is a marker of the electrokinetic index (EKI), the percentage of electronegative nuclei, that has undergone the oscillatory movements during electrophoresis. It has been found that EKI of cell nuclei of animals naturally varies under different external influences, including decreasing when the temperature is high, UV exposure and inhibitors of protein and nucleic acids synthesis, when stimulants of biosynthesis increase. EKI almost linearly decreases with the aging. Also it is reduced under the condition of fatigue and different diseases, at the same time measure of reduction is associated with severity of disease, while successful treatment increases EKI to a level typical for this age group [8, 9, 14, 15, 20-24]. We were very impressed that when the device "Biotest" patenting his main purpose was stated rapid testing efficiency rehabilitation of human health, particularly in resort [15]. This inspired us to study the relationships of EKI with parameters of the neuroendocrine-immune complex, metabolism and hemodynamics, as well as the influence on them of balneotherapy on Truskavets' Spa.

Previously we have examined relations between EKI and some functional and metabolic parameters of 23 males suffering from chronic pyelonephritis in the phase of remission. We have shown that Baevsky's Adaptation Potential and Stange's Test determines EKI of 28 %. Vagal markers RMSSD and VLF as well as Baevskiy's Stress Index determines EKI of 31 %. Plasma Cholesterol and Klimov's Atherogenicity Coefficient determines EKI of 56 %. A model of multiple regression and stepwise excluding are currently two last parameters as well as Plasma Testosterone and relative Spectral Power VLF band HRV, that determine EKI of 73 % [5, 12, 13]. This article is a continuation of the implementation of the declared project.

Materials and methods. 32 males and 10 females 24-76 years old suffering from chronic pyelonephritis in the phase of remission have been examined. First, we have determined the rate of electronegative nuclei of buccal epithelium by intracellular microelectrophoresis using the device "Biotest" (Kharkiv State University), according to the described method[20]. Then the state of the autonomous (vegetative) regulation has been estimated by the method of

heart rate variability (HRV) [1, 2, 7], using a hardware-programmatic complex 'CardioLab+HRV' (KhAI Medica, Kharkiv, Ukraine) as well as EEG has been recorded by a hardware-software complex 'NeuroCom Standard' (KhAI Medica, Kharkiv, Ukraine) [17, 18].

Among hemodynamic parameters, systolic (Ps) and diastolic (Pd) blood pressure have been measured (by tonometer "Omron M4-I", Netherlands) as well as a heart rate (HR), ejection time (ET), end-diastolic (EDV) and end-systolic (ESV) volumes of left ventricle (by echo camera "Toshiba-140", Japan) with the following General Peripheral Resistance of Vessels calculation by classic equation:

$$\text{GPRV} = 80 \cdot (0,67 \cdot \text{Pd} + 0,33 \cdot \text{Ps}) / \text{HR} \cdot (\text{EDV} - \text{ESV})$$

as well as Contractility Index of left ventricle (RPCI) by Ruzylko-Popovych's [19] equation:

$$\text{RPCI} = 0,1332 \cdot (0,67 \cdot \text{Pd} + 0,33 \cdot \text{Ps}) \cdot (\text{EDV} - \text{ESV}) / \text{EDV} \cdot \text{ET}.$$

Stange's and Ghench's breath-holding duration tests have been also applied during the research. Venous blood samples have been taken for biochemical tests. Such plasma hormones have been found: Cortisol, Testosterone and Triiodothyronine (by the ELISA method with the use of analyzer "Tecan", Austria and corresponding sets of reagents from "Alkor Bio", RF); electrolytes: calcium (by reaction with arsenic III), magnesium (by reaction with colgamite), phosphates (phosphate-molybdate method), chloride (mercury-rhodanine method), sodium and potassium by flame photometry; nitric metabolites: creatinine (by Jaffe's color reaction by Popper's method), urea (urease method by reaction with phenol hypochlorite) and uric acid (uricase method) as well as cholesterol (by a direct method after the classic reaction by Zlatkis-Zack), according to the instructions [6] and using the analyzers "Reflotron" (BRD) and "Pointe-180" (USA) and corresponding sets of reagents. Most of the listed parameters of metabolism have been also detected in the daily urine. After 9-11 days of balneotherapy (drinking of bioactive water "Naftussia", applications of ozokerite, mineral pools) all tests have been repeated.

The software package "Statistica 5.5" has been used to make a statistical analysis.

Results and discussion. Preliminary analysis has revealed ambiguous and varying degrees of marked changes of EKI, thus patients have been divided into four clusters, that are homogeneous if to talk about the changes of EKI.

The largest cluster has consisted of 26 people, EKI of whom has increased on average by $2,36 \pm 0,22$ % (from $41,2 \pm 2,1$ % to $43,5 \pm 2,2$ %), indicating a decrease in the biological age by $1,8 \pm 0,2$ years. EKI of other 5 people has increased slightly, but statistically significant, by $0,90 \pm 0,17$ % (from $49,7 \pm 4,1$ % to $50,6 \pm 4,1$ %), that means decreasing of the biological age by $0,7 \pm 0,1$ year. At the same time, EKI of other 7 patients has remained the same ($42,6 \pm 4,7$ %), and EKI of only 4 patients has decreased by $1,38 \pm 0,65$ % (from $37,7 \pm 8,3$ % to $36,3 \pm 7,9$ %), which indicates the increase of the biological age by $1,1 \pm 0,5$ year. Thus, in 74 % of the subjects balneotherapy has caused the so-called "youthful" effect, while in 17 % it has been ineffective, and in 9 % the effect has been unfavorable.

The obtained results perfectly fit the concept of the Truskavets Scientific School of Balneology on the multivariate effects of balneotherapy on the human and animals body, due to individual reactivity [3, 4, 10, 16, 19].

At the next stage, using the method of discriminant analysis [11], we have set the goal to identify the parameter, the totality of the changes under which four qualitative and quantitative variations of EKI changes differ. A discriminant model of 27 parameters (Tables 1 and 2), including 12 EEGs, 2 HRVs, 2 endocrine, 6 metabolic, 4 hemodynamic as well as Ghench test has been selected. The other 7 parameters have not been included in the model despite the characteristic changes.

Table 1

Discriminant Function Analysis Summary and Changes of Electrokinetic Index

Step 27, N of variables in model: 27; Grouping: 4 groups; Wilks' Lambda: 0,0005; approx. $F_{(81)} = 5,38$; $p < 10^{-6}$

Variables whose changes are currently in the model	Parameters of Wilks' Statistics					Changes in Electrokinetic Index (n)			
	Wilks' Λ	Par-tial Λ	F-remove	p-level	Tolerancy	- (4)	0 (7)	+ (5)	++ (26)
						Changes in Variables (Mean)			
α -rhythm Amplitude, μV	,0019	,251	11,9	,001	,085	-3	-2	0	+1
α -rhythm Frequency, Hz	,0011	,428	5,4	,014	,156	+0,25	+0,21	-0,67	+0,23
α -rhythm Deviation, Hz	,0016	,310	8,9	,002	,075	-0,63	+0,14	-0,17	+0,20
α -rhythm Asymmetry, %	,0006	,756	1,3	,323	,161	-4	+1	+7	+1
δ -rhythm Amplitude, μV	,0008	,585	2,8	,083	,168	-5	-9	+22	0
δ -rhythm Frequency, Hz	,0009	,536	3,5	,051	,126	0,0	+0,1	0,0	0,0
δ -rhythm Index, %	,0008	,640	2,2	,135	,140	-13	-3	-12	+11
δ -rhythm Laterality Index, %	,0006	,843	0,7	,546	,066	-9	-38	-3	+14
β -rhythm Index, %	,0010	,466	4,6	,023	,082	+2	+1	-3	-5
β -rhythm Asymmetry, %	,0008	,601	2,7	,096	,210	+7	-6	-2	+2
θ -rhythm Asymmetry, %	,0016	,294	9,6	,002	,096	+6	-7	-2	-5
θ -rhythm Laterality Index, %	,0015	,331	8,1	,003	,024	+8	-48	+9	-9
VLF band HRV, msec2	,0014	,339	7,8	,004	,038	-747	+251	-1254	-267
SDNN HRV, msec	,0010	,468	4,5	,024	,048	-12	+10	-11	-2
Testosterone, normalized by sex (Z)	,0010	,496	4,1	,033	,324	+0,22	-0,21	-1,06	-0,41
(Pu/Cau)0,5 as Parathyrin Activity	,0007	,738	1,4	,285	,172	+0,36	-0,25	+0,40	-0,09
Potassium Plasma, mM/L	,0014	,347	7,5	,004	,135	-0,56	+1,15	+0,45	-0,04
Cholesterol Plasma, mM/L	,0010	,494	4,1	,032	,204	-0,57	+0,60	-0,47	-0,36
Creatinine Plasma, $\mu M/L$	,0006	,743	1,4	,296	,320	-3	-11	-14	-4
Urea Urine, mM/L	,0006	,782	1,1	,382	,280	-58	-27	+29	0
Urates Excretion, mM/day	,0008	,624	2,4	,117	,245	+0,28	+0,82	+1,08	-0,25
Phosphates Excretion, mM/day	,0009	,512	3,8	,039	,125	+9	+22	+11	+7
Enddiastolic Vol. of Left Ventric., mL	,0006	,812	0,9	,457	,059	+8	-2	+9	-1
Endsystolic Volume of Left Vent., mL	,0007	,704	1,7	,223	,154	+8	+1	-2	0
Gener Periph Resist Vessels, $kPa \cdot s/m^3$	,0011	,453	4,8	,020	,055	-1,4	+0,5	-6,0	+0,4
Ruzhylo-Popovych's Contr Ind, kPa/s	,0009	,564	3,1	,067	,084	-0,5	-1,4	+2,2	-1,9
Ghench's Expiratory Test, s	,0007	,665	2,0	,166	,256	-2	-2	+6	+4

Variables whose changes currently not in the model	Parameters of Wilks' Statistics					Changes in Electrokinetic Index (n)			
	Wilks' Λ	Par-tial Λ	F-remove	p-level	Tolerancy	- (4)	0 (7)	+ (5)	++ (26)
						Changes in Variables (Mean)			
θ -rhythm Amplitude, μV	,0005	,937	,25	,862	,371	-1,7	-2,2	+0,5	+0,2
Baevskiy's Stress Index HRV, units	,0005	,956	,17	,914	,225	+11	-34	+73	-62
Cortisol Plasma, nM/L	,0004	,817	,82	,509	,366	-71	-90	-174	+36
Calcium Plasma, mM/L	,0004	,844	,68	,582	,230	0,00	-0,11	-0,02	+0,02
Chloride Excretion, mM/day	,0004	,841	,69	,574	,402	+27	-7	+83	+35
Magnesium Excretion, mM/day	,0004	,839	,70	,569	,209	-0,06	+1,73	+0,07	+0,37
Ejection Time, msec	,0004	,910	,36	,782	,099	-23	+13	+5	0

Table 2

Summary of Stepwise Analysis

Variables whose changes are currently in the model	F to enter	p-level	Δ	F-value	p-level
Potassium Plasma, mM/L	5,8	,002	,687	5,8	,002
VLF band HRV, msec ²	4,4	,009	,506	5,0	10 ⁻³
θ-rhythm Laterality Index, %	2,8	,051	,409	4,3	10 ⁻⁴
θ-rhythm Asymmetry, %	2,8	,052	,329	4,0	10 ⁻⁴
Urea Urine, mM/L	3,0	,042	,259	4,0	10 ⁻⁵
β-rhythm Asymmetry, %	2,7	,065	,209	3,9	10 ⁻⁵
δ-rhythm Index, %	3,1	,040	,162	3,9	10 ⁻⁵
δ-rhythm Laterality Index, %	2,2	,105	,133	3,8	10 ⁻⁵
α-rhythm Frequency, Hz	2,9	,052	,103	3,8	10 ⁻⁶
Ghench's Expiratory Test, s	2,5	,080	,082	3,8	10 ⁻⁶
α-rhythm Asymmetry, %	2,5	,083	,065	3,9	10 ⁻⁶
Enddiastolic Volume of Left Ventricle, mL	2,5	,082	,051	3,9	10 ⁻⁶
General Peripheral Resistance of Vessels, kPa • s/m ³	3,5	,028	,036	4,1	10 ⁻⁶
α-rhythm Deviation, Hz	4,0	,018	,024	4,5	10 ⁻⁶
α-rhythm Amplitude, μV	3,5	,031	,017	4,7	10 ⁻⁶
β-rhythm Index, %	3,6	,030	,012	5,0	10 ⁻⁶
SDNN HRV, msec	3,1	,048	,008	5,2	10 ⁻⁶
δ-rhythm Frequency, Hz	2,2	,118	,006	5,3	10 ⁻⁶
Cholesterol Plasma, mM/L	2,2	,121	,005	5,4	10 ⁻⁶
Phosphates Excretion, mM/day	2,1	,135	,004	5,4	10 ⁻⁶
Ruzhylo-Popovych's Contractility Index, kPa/s	1,8	,187	,003	5,4	10 ⁻⁶
Creatinine Plasma, μM/L	2,1	,133	,002	5,5	10 ⁻⁶
Testosterone Plasma, normalized by sex (Z)	1,5	,265	,002	5,5	10 ⁻⁶
Urates Excretion, mM/day	2,3	,120	,001	5,7	10 ⁻⁶
δ-rhythm Amplitude, μV	1,2	,350	,001	5,5	10 ⁻⁶
Endsystolic Volume of Left Ventricle, mL	1,3	,331	,001	5,4	10 ⁻⁶
(Pu/Cau)0,5 as Parathyrin Activity	1,4	,285	,000	5,4	10 ⁻⁶

Identification information is condensed in three canonical roots. The first root contains 57,7 % of discriminant capacity, it **directly** reflects the changes in plasma levels of potassium and cholesterol, phosphate excretion, vagus tone markers and delta-rhythm frequency, while in **turn** it also reflects the changes in the lateralization of theta- and delta-rhythms, asymmetry of beta- and theta-rhythms, parathyrin activity (estimated for excretion of phosphates and calcium), as well as end-diastolic volume of the left ventricle. The second root contains 26,8 % of discriminant capacity, it **directly** reflects the changes in deviation and amplitude of alpha-rhythm and index of delta-rhythm as well as urine level of urea, while in **turn** it also reflects the changes of index of beta-rhythm and end-systolic volume of the left ventricle. The third root contains 15,5 % of discriminant capacity, it **inversely** reflects the changes in General Peripheral Resistance of Vessels, plasma levels of creatinine and testosterone (normalized by sex) as well as the frequency of alpha-rhythm, while it **directly** reflects the changes in excretion of urates, amplitude of delta-rhythm and asymmetry of alpha-rhythm as well as in Ruzhylo-Popovych's Contractility Index of the left ventricle and duration of respiratory detention on exhalation (Table 3).

Table 3

Means of Roots, Changes of the Variables and Factor Structure Matrix
(Pooled-within-groups correlations)

Means of Roots (as χ^2) and Changes in Variables (as Z-score)	dEKI -1,4 %	dEKI 0 %	dEKI +0,9 %	dEKI +2,4 %	Root 1	Root 2	Root 3
Root 1 (57,7 %)	-6,8	+9,1	-4,6	-0,5	Correlations Variables- Roots		
Potassium Plasma	-1,18	+2,43	+0,95	-0,07	,115	-,036	,146
VLF band HRV	-1,14	+0,65	-1,53	-0,31	,107	-,013	-,072
SDNN HRV	-1,24	+0,86	-0,97	-0,16	,072	-,001	-,016
Phosphates Excretion	+1,21	+2,92	+1,43	+0,93	,055	-,058	,042
Cholesterol Plasma	-0,57	+0,57	-0,48	-0,34	,038	,013	-,120
δ -rhythm Frequency	0,00	+0,39	0,00	-0,27	,034	-,053	,028
β -rhythm Asymmetry	+0,49	-0,42	-0,14	+0,12	-,056	,000	-,064
(Pu/Cau) ^{0,5} as Parathyrin Activity	+0,51	-0,35	+0,57	-0,13	-,050	-,038	,048
Enddiastolic Volume of Left Ventricle	+0,28	-0,06	+0,60	-0,11	-,021	-,019	,027
θ -rhythm Asymmetry	+0,43	-0,52	-0,12	-0,38	-,019	-,024	-,010
θ -rhythm Laterality Index	+8 %	-48 %	+9 %	-9 %	-,074	,011	-,008
δ -rhythm Laterality Index	-9 %	-38 %	-3 %	+14 %	-,045	,071	-,030
Root 2 (26,8 %)	-7,5	-3,0	-0,7	+2,1	Correlations Variables- Roots		
α -rhythm Deviation	-1,59	+0,36	-0,42	+0,51	,057	,120	,014
α -rhythm Amplitude	-0,21	-0,15	+0,02	+0,09	-,019	,116	,006
Urea Urine	-1,00	-0,47	+0,49	0,00	-,014	,084	,089
δ -rhythm Index	-0,23	-0,07	-0,27	+0,26	,002	,051	-,028
Endsystolic Volume of Left Ventricle	+0,83	+0,12	-0,26	-0,04	-,008	-,053	-,071
β -rhythm Index	-0,01	+0,08	-0,17	-0,27	,016	-,038	,006
Root 3 (15,5 %)	-2,9	+0,7	+6,0	-0,9	Correlations Variables- Roots		
General Peripheral Resistance of Vess	-0,30	+0,09	-1,18	+0,12	,049	,033	-,143
Creatinine Plasma	-0,23	-0,83	-1,06	-0,30	-,020	,032	-,138
Testosterone, normalized by sex	+0,22	-0,21	-1,06	-0,41	,011	-,048	-,103
α -rhythm Frequency	+0,35	+0,30	-0,93	+0,31	,019	,002	-,099
Urates Excretion	+0,38	+1,09	+1,44	-0,33	,015	-,062	,096
δ -rhythm Amplitude	-0,82	-1,53	+3,74	+0,04	-,046	,039	,091
Ruzhylo-Popovych Contractility Index	-0,44	-0,71	+0,52	-1,04	-,016	-,021	,062
Ghench's Expiratory Test	-0,20	-0,16	+0,54	+0,36	-,011	,085	,051
α -rhythm Asymmetry	-0,42	+0,11	+0,73	+0,06	,005	,018	,044

Notes. Z=(Actual variable/Norm Mean – 1)/Coefficient of variation.
Changes in Laterality Index expressed as %.

After calculating the individual values of roots using coefficients for variables and constants given in Table 4, the position of each patient have been visualized in two-dimensional information space of the roots (Fig. 1).

Table 4

Standardized and Raw Coefficients and Constants for Canonical Variables

	Standardized Coefficients			Raw Coefficients		
	Root 1	Root 2	Root 3	Root 1	Root 2	Root 3
Variables whose changes are currently in the model						
Potassium Plasma, mM/L	1,902	-,122	1,252	2,4588	-,1576	1,6182
VLF band HRV, msec ²	1,877	-3,767	-1,191	,0021	-,0043	-,0014
θ-rhythm Laterality Index, %	-5,290	-,651	-,367	-,1104	-,0136	-,0077
θ-rhythm Asymmetry, %	-2,109	,782	-1,702	-,0749	,0278	-,0604
Urea Urine, mM/L	-,820	-,369	,103	-,0126	-,0057	,0016
β-rhythm Asymmetry, %	-1,343	,425	-,102	-,1163	,0368	-,0089
δ-rhythm Index, %	-1,572	-,266	,403	-,0361	-,0061	,0092
δ-rhythm Laterality Index, %	1,546	-,055	,335	,0270	-,0010	,0059
α-rhythm Frequency, Hz	1,954	,027	,051	2,7347	,0376	,0719
Ghench's Expiratory Test, s	1,078	-,161	-,441	,0823	-,0123	-,0337
α-rhythm Asymmetry, %	,912	,436	-,792	,0537	,0256	-,0466
Enddiastolic Volume of Left Ventricle, mL	-1,245	,753	-1,163	-,0517	,0312	-,0483
General Peripheral Resistance of Vessels, kPa·s/m ³	,229	1,370	-3,071	,0575	,3448	-,7728
α-rhythm Deviation, Hz	,957	2,894	-,834	1,8603	5,6238	-1,6213
α-rhythm Amplitude, μV	,227	3,089	,149	,0558	,7581	,0366
β-rhythm Index, %	1,011	-2,374	-,645	,0631	-,1483	-,0403
SDNN HRV, msec	-,916	1,792	2,938	-,0520	,1018	,1669
δ-rhythm Frequency, Hz	1,543	-1,039	-,687	8,7945	-5,9206	-3,9169
Cholesterol Plasma, mM/L	-,600	1,414	-,598	-,7511	1,7717	-,7486
Phosphates Excretion, mM/day	,553	1,749	-,972	,0334	,1059	-,0588
Ruzhylo-Popovych's Contractility Index, kPa/s	-,588	-2,214	,657	-,1009	-,3802	,1128
Creatinine Plasma, μM/L	,095	,468	-,829	,0098	,0486	-,0861
Testosterone Plasma, normalized by sex (Z)	,624	-,881	-,739	,5885	-,8313	-,6967
Urates Excretion, mM/day	-,855	,415	,889	-,4975	,2417	,5172
δ-rhythm Amplitude, μV	-,367	1,149	1,147	-,0199	,0623	,0622
Endsystolic Volume of Left Ventricle, mL	,062	-1,341	-,559	,0082	-,1758	-,0733
(Pu/Cau) ^{0.5} as Parathyrin Activity	,183	-1,021	-,792	,2409	-1,3409	-1,0409
	Constants			-2,2574	-2,6897	-1,3808
	Cumulative Properties			,577	,845	1,000

Extremely right localization along the axis of the first root of the cluster (centroid: +9,1) shows that the values of EKI have not change, and reflects as the maximum positive values of the changes of 6 parameters, correlated with this root positively, and the maximum negative values of the changes of the other 6 parameters, correlated with it negatively. Instead, the cluster EKI values of which have diminished, occupies the extreme left zone (centroid: -6,8) along the axis of the first root and the extreme lower zone (centroid: -7,5) along the axis of the second root. Such a localization in the information field of the two roots reflects the most pronounced changes of the parameters associated with them. Finally, a cluster localized along the third root axis, (centroid: +6,0) is the highest and its EKI values increases moderately, that reflects both the

maximum reduction of the 4 parameters and the maximum increase of the other 5 parameters.

Fig. 1. Individual values of discriminant roots of the changes of the parameters characterise different variants of the changes of the electrokinetic index.

The visual impression of the clear separation between clusters of changes is documented by calculating Squared Mahalanobis Distances (Table 5).

Table 5

Squared Mahalanobis Distances (over diagonal), F-values (under diagonal) and p-levels

Changes in EKI	+	0	-	++
+	#	245	144	80
0	6,9 10 ⁻³	#	318	135
-	2,9 0,029	7,4 10 ⁻³	#	151
++	3,2 0,018	7,6 10 ⁻³	4,7 0,004	#

The application of the classifying functions (Table 6) makes the retrospective identification of four clusters very precise (Table 7).

Table 6

Coefficients and Constants of Classification Functions

Variables whose changes are currently in the model	++	+	0	-
	p=,619	p=,119	p=,167	p=,095
Potassium Plasma, mM/L	2,868	4,366	30,034	-14,372
VLF band HRV, msec ²	-,019	-,025	,022	,012
θ-rhythm Laterality Index, %	-,319	,120	-1,325	,526
θ-rhythm Asymmetry, %	-,049	-,236	-1,013	,277
Urea Urine, mM/L	-,066	,013	-,156	,065
β-rhythm Asymmetry, %	-,055	,258	-1,380	,344
δ-rhythm Index, %	-,098	,131	-,399	,171
δ-rhythm Laterality Index, %	,082	,014	,357	-,091
α-rhythm Frequency, Hz	6,512	-4,339	32,776	-11,306
Ghench's Expiratory Test, s	,136	-,400	,937	-,200
α-rhythm Asymmetry, %	,270	-,344	,578	-,225
Enddiastolic Volume of Left Ventricle, mL	,079	-,129	-,659	,200
General Peripheral Resistance of Vessels, kPa•s/m ³	1,644	-4,893	-,856	-,520
α-rhythm Deviation, Hz	30,577	-4,092	16,823	-32,226
α-rhythm Amplitude, μV	3,864	1,752	,554	-3,871
β-rhythm Index, %	-,615	-,735	,691	,495
SDNN HRV, msec	,440	1,518	-,310	-,541
δ-rhythm Frequency, Hz	-9,167	-55,649	99,592	-,024
Cholesterol Plasma, mM/L	6,289	-,777	-11,315	-4,562
Phosphates Excretion, mM/day	,615	-,226	,294	-,501
Ruzhylo-Popovych's Contractility Index, kPa/s	-1,857	,407	-,683	2,225
Creatinine Plasma, μM/L	,096	-,674	-,202	-,265
Testosterone Plasma, normalized by sex (Z)	-3,993	-8,875	4,811	1,672
Urates Excretion, mM/day	,717	5,648	-4,466	,516
δ-rhythm Amplitude, μV	,267	,602	-,143	-,330
Endsystolic Volume of Left Ventricle, mL	-,640	-,683	,225	1,149
(Pu/Cau)0,5 as Parathyrin Activity	-5,663	-10,055	1,852	7,795
Constants	-15,328	-35,732	-70,495	-27,389

Table 7

Classification Matrix. Rows: Observed classifications; Columns:
Predicted classifications

Change in EKI	Percent correct	++	+	0	-
		p = ,619	p = ,119	p = ,167	p = ,095
++	100	26	0	0	0
+	100	0	5	0	0
0	100	0	0	7	0
-	100	0	0	0	4
Total	100	26	5	7	4

In conclusion, causal relations between the changes of EKI, on the one hand, and discriminant parameters, on the other hand, have been analysed. The changes of EKI (zeta-potential of the cell nucleus) are caused by the changes of the regulatory nervous, hormonal and metabolic factors, this shows that the dependence is almost linear with respect to the parameters condensed in the second root (Fig. 2).

Fig. 2. Three variants of the relations between the changes of the discriminant parameters and electrokinetic index.

In contrast with almost the same value of the coefficient of determination of the EKI from the side of the parameters condensed in the first root, the dependence is approximated by the second order curve in the form of an inverted letter V; after reaching the maximum increase of the EKI due to certain regulatory influences, further amplification of them has caused a negative effect. However, the causal relations between the changes of EKI and parameters have condensed in the third root.

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Accordance to ethical standards. All tests in which the patients have been engaged are conducted in accordance with the regulations of Helsinki Declaration 1975, revised and complemented in 2002, and directive of National Committee on ethics of scientific researches. During the research all participants have been properly informed and have given a consent, all participants still are anonymous.

REFERENCES

1. Baevskiy RM, Ivanov GG. Heart Rate Variability: theoretical aspects and possibilities of clinical application. *Ultrazvukovaya i Funktsionalnaya Diagnostika*. 2001;3:106-27.
2. Berntson GG, Bigger JT jr, Eckberg DL, Grossman P, Kaufman PG, Malik M, Nagaraja HN, Porges SW, Saul JP, Stone PH, Van der Molen MW. Heart Rate Variability: Origines, methods, and interpretive caveats. *Psychophysiology*. 1997;34:623-48.
3. Chebanenko OI, Chebanenko LO, Popovych IL. Variety Balneoeffects of Factors Spa Truskavets' and their Forecast. K.: UNESCO-SOCIO; 2012. 496 p.
4. Chebanenko OI, Flyunt IS, Popovych IL, Balanov'skyi VP, Lakhin PV. Water Naftussya and hydro-mineral exchange. K.: Naukova Dumka; 1997. 141 p.
5. Fil' VM, Kyrylenko IG, Popovych IL, Matroshylin AG. Electrokinetic index of buccal epithelium correlated with some functional and metabolic parameters. In: *Valeology: the current state, trends and prospects of development*. Abstract supplementary XIV International science-practice conf. (Kharkiv-Drogobych, April 14–16, 2016). Kharkiv: VN Karazin NU; 2016. 350-54.
6. Goryachkovskiy AM. Clinical Biochemistry [in Russian]. Odesa: Astroprint; 1998. 608 p.
7. Heart Rate Variability. Standards of Measurement, Physiological Interpretation, and Clinical Use. Task Force of ESC and NASPE. *Circulation*. 1996;93(5):1043-65.
8. Honcharenko MS (editor). *Valeological toolkit hardware-software diagnostics and monitoring of health*. Kharkiv: VN Karazin NU; 2011. 135 p.
9. Honcharenko MS, Yereshchenko YA. Test system for assessing the physiological state of the body by electrophoretic properties of buccal epithelium cells: Methodical Development. Kharkiv; 1992.
10. Ivassivka SV, Popovych IL, Aksentiychuk BI, Flyunt IS. Physiological activity of uric acid and its role in the mechanism of action of water Naftussya. Kyiv: Computerpress; 2004. 163 p.
11. Klecka WR. Discriminant Analysis [trans. from English in Russian] (Seventh Printing, 1986). In: *Factor, Discriminant and Cluster Analysis*. Moskwa: Finansy i Statistika; 1989.78-138.
12. Kyrylenko IG, Fajda OI, Drach OV, Popel SL, Popel RL, Zukow W. Relationships between electrokinetic index of buccal epithelium and some functional and metabolic parameters at men with

chronic pyelonephrite. Journal of Education, Health and Sport. 2016;6(1):302-14. **13.** Kyrylenko IG, Korolyshyn TA, Zukow W, Barylyak LG, Popovych IL. Electrokinetic index of buccal epithelium correlated with some functional and metabolic parameters. In: IX International Symposium "Actual Problems of Biophysical Medicine" (Kyiv, May 12-15, 2016). K.: Bohomolets' Institute of Physiology; 2016. 50-1. **14.** Pat. 20071113, RF. 1994. Device for evaluating the electrokinetic properties of buccal epithelium cells. **15.** Pat. 28113, Ukraine, NSI A61V10/00. Method of rapid testing efficiency rehabilitation of health. Shakhbazov VG, Kolupaeva TV, Shuvalov IM et al. 2000; Bul N 5. **16.** Popovych IL. Stresslimiting Adaptogene Mechanism of Biological and Curative Activity of Water Naftussya. K.: Computerpress; 2011. 300 p. **17.** Popovych IL, Kozyavkina OV, Kozyavkina NV, Korolyshyn TA, Lukovych YuS, Barylyak LG. Correlation between Indices of the Heart Rate Variability and Parameters of Ongoing EEG in Patients Suffering from Chronic Renal Pathology. Neurophysiology. 2014;46(2):139-48. **18.** Popovych IL, Lukovych YuS, Korolyshyn TA, Barylyak LG, Kovalska LB, Zukow W. Relationship between the parameters heart rate variability and background EEG activity in healthy men. Journal of Health Sciences. 2013; 3(4): 217-40. **19.** Popovych IL, Ruzhylo SV, Ivassivka SV, Aksentiychuk BI (editors). Balneocardioangiology. K.: Computerpress; 2005. 229 p. **20.** Shakhbazov VG, Kolupaeva TV, Nabokov AL. New method for determining biological age of man. Laboratornoye Delo. 1986;7:404-7. **21.** Shkorbatov YG, Kolupaeva TV, Shakhbazov VG, Pustovoyt PA. About relationship electrokinetic properties of nuclei cells of human with physiological parameters [in Russian]. Fiziologiya Cheloveka. 1995;21(2):25-7. **22.** Tsodikova OA, Kolupaeva TV, Garbar KB, Krylova OB. The application of the information and entropy method for complex assessment of the state of health of adolescents. Journal of VN Kazarin Kharkiv NU. Series: Biology. 2013;17(1056):184-8. **23.** Ushakov IB, Kukushkin YA, Bogomolov AV. Physiology of labor and reliability activity of human. M.: Nauka; 2008. 317 p.

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RESEARCH ARTICLE

Changes in Electrokinetic Index of the Buccal Epithelium Correlated with Changes in Some Parameters of EEG, HRV, Hemodynamics and Metabolism

I.G. KYRYLENKO

Ukrainian Scientific Research Institute of Transport Medicine, Odesa, Ukraine

Danylo Halytsky National Medical University, L'viv, Ukraine

OO Bohomolets' Institute of Physiology NAS, Kyiv, Ukraine

E-mail: Iryna2023@gmail.com

Background. It is known that buccal epithelium cell nuclei in human electrokinetic mobility, named Electrokinetic Index (EKI), almost linearly decreases during aging. Also it is reduced under the condition of fatigue and different diseases, at the same time measure of reduction is associated with severity of disease, while successful treatment increases EKI to a level that is typical for this age group. The relationships caused by balneotherapy changes in EKI and some functional and metabolic parameters of body have been examined

Methods. 32 males and 10 females of the age of 24-76 years with chronic pyelonephritis in the phase of remission, who have been treated at the Truskavets' spa, have been observed. We have estimated the EKI, state of EEG, autonomous and hormonal regulation, metabolism as well as hemodynamics.

Results. All patients have been divided into four clusters, homogeneous in the changes of EKI. The largest cluster has consisted of 26 people, in which the EKI has increased by $2,36 \pm 0,22$ %, indicating the decrease of the biological age (BA) by $1,8 \pm 0,2$ years. In another 5 people, EKI has increased by $0,90 \pm 0,17$ %, the BA has decreased by $0,7 \pm 0,1$ year. At the same time, in 7 patients, EKI has remained the same, and only in 4 patients it has decreased by $1,38 \pm 0,65$ %, that indicates the increase of the BA by $1,1 \pm 0,5$ year. Thus, in 74 % of the subjects balneotherapy has caused the so-called "youthful" effect, while in 17 % it has been ineffective, and in 9 % the effect should be assessed as unfavorable. The method of discriminant analysis has revealed 27 parameters (12 parameters of EEG. 2 HRV markers of vagal tone, plasma levels testosterone normalized by sex, cholesterol, creatinine, potassium, excretion of urea, urates and phosphates, parathyrin activity as well as 4 parameters of hemodynamics and Hench's expiratory test), the changes in which are characteristic of four qualitative-quantitative variations of the changes of EKI

Conclusion. Changes of Electrokinetic Index of the buccal epithelium really reflect the changes of neuro-endocrine regulation, metabolism and hemodynamics.

Keywords: Electrokinetic Index, EEG, HRV, Metabolism, Relationships.