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Relationships between caused by Kozyavkin© method changes in parameters of manual function and electroencephalogram, heart rate variability as well as gas discharge visualization in children with spastic form of cerebral palsy

Relacje między spowodowanymi przez Kozyavkin © Metodą zmianami parametrów manualnej funkcji i elektroencefalogramy, zmiennością rytmu serca, jak również zmian wizualizacji u dzieci z postacią spastyczną porażenia mózgowego

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Abstract

Background. Earlier we reported that in children with spastic forms of cerebral palsy (SFCP) after two-week course of rehabilitation by Kozyavkin© method reducing neural component of muscle tone (NCMT) stated in 79,3% cases while in 13,8% cases changes were not detected and in 2 children it increased. We hypothesized that such a variety of changes in NCMT is due to ambiguous changes in the background activity of the nerve centers. **Aim:** analysis of relationships between changes (Ch) in NCMT as well as manual functional tests, on the one hand, and parameters of EEG, HRV as well as Gas Discharge Visualization (GDV), on the other hand. **Material and research methods.** The object of observations were 14 children (6 girls and 8 boys) aged 8÷15 years with SFCP. State motor development at GMFCS was on II÷IV level. Functional status of the hand with MACS was at II÷III level. The estimation of hand function carried out by Dynamometry (D), Box and Block Test (B&B) and Nine Hole Peg Test (NHP).

We registered also NCMT by device “NeuroFlexor” (Aggero MedTech AB, Sweden), HRV and EEG simultaneosly by hardware-software complex “Cardiolab+VSR” and “NeuroCom Standard” respectively (KhAI Medica, Kharkiv, Ukraine) as well as GDV by “GDV Chamber” (“Biotechprogress”, St-Pb, RF). **Results.** After two-week course of rehabilitation at 9 children NCMT reduced from 19,8±3,4 to 12,3±2,8 Newtons (Ch: -7,5±2,0 N), at 3 children NCMT taked 8,2±3,3 before and 7,9±3,5 after rehabilitation (Ch: -0,3±0,3 N) while at one girl NCMT increased from 15,1 to 17,9 N and at one boy from 6,1 to 19,4 N. Manual functional tests also changed ambiguously. The Ch in NCMT are correlated with Ch in parameters HRV&EEG (R^2=0,786). The Ch in functional tests of Left hand are correlated with Ch in parameters HRV&EEG to the same extent: the level of R^2 is for D 0,799, for NHP 0,773 and for B&B 0,708. Instead, for the Right hand, the correlation is stronger: R^2 is 0,973, 0,792 and 0,978 respectively. As regards GDV parameters, connections are weaker, but they are also stronger for the Right hand: R^2 is 0,706 vs 0,462 for B&B and 0,679 vs 0,405 for NHP but not for D (0,719 and 0,709). The Ch in NCMT are correlated with Ch in parameters GDV also weaker (R^2=0,556). In its turn, changes in GDV parameters are very closely related to changes in parameters of both HRV (R^2=0,999) and EEG (R^2=0,998).
Conclusion. In children with spastic forms of cerebral palsy caused by Kozyavkin© method changes in manual functional tests and neural component of muscle tone are determined by changes in parameters of EEG and HRV as well as GDV.

Streszczenie

Tło. Wcześniej donieśliśmy, że u dzieci ze spastycznymi postaciami porażenia mózgowego (SFCP) po dwutygodniowym okresie rehabilitacji metodą Kozyavkin © zmniejszenie komponentu nerwowego napięcia mięśniowego (NCMT) stwierdzono w 79,3% przypadkach, podczas gdy w 13,8% przypadków zmiany nie zostały wykryte i u 2 dzieci się zwiększyło. Postawiliśmy hipotezę, że taka różnorodność zmian w NCMT wynika z niejednoznacznych zmian aktywności tła ośrodków nerwowych. Cel: analiza zależności pomiędzy zmianami (Ch) w NCMT oraz ręcznymi testami funkcjonalnymi, z jednej strony, a parametrami EEG, HRV, a także wizualizacją zdyspergowania gazów (GDV) z drugiej strony. Metody materialne i badawcze. Przedmiotem obserwacji było 14 dzieci (6 dziewcząt i 8 chłopców) w wieku 8 ÷ 15 lat z SFCP. Rozwój motoryczny stanu w GMFCS był na poziomie II ÷ IV. Funkcjonalny status ręki z MACS był na poziomie II ÷ III. Oszacowanie funkcji ręki przeprowadzonej przez Dynamometry (D), Box i Block Test (B & B) i Nine Hole Peg Test (NHP). Zarejestrowaliśmy również NCMT za pomocą urządzenia "NeuroFlexor" (Aggero MedTech AB, Szwecja), HRV i EEG jednocześnie przez kompleks sprzętowo-programowy "Cardiolab + VSR" i "NeuroCom Standard" odpowiednio (KhAI Medica, Charków, Ukraina) oraz GDV przez "Komora GDV" ("Biotechprogress", St-Pb, RF). Wyniki. Po dwutygodniowym kursie rehabilitacji u 9 dzieci NCMT zmniejszyło się z 19,8 ± 3,4 do 12,3 ± 2,8 Newtona (Ch: -7,5 ± 2,0 N), u 3 dzieci NCMT zajął 8, 2 ± 3,3 przed i 7,9 ± 3,5 po rehabilitacji (Ch: -0,3 ± 0,3 N), podczas gdy u jednej dziewczynki NCMT wzrósł z 15,1 do 17,9 N iu jednego chłopca z 6 , 1 do 19,4 N. Ręczne testy funkcjonalne również zmieniły się niejednoznacznie. Ch w NCMT są skorelowane z Ch w parametrach HRV i EEG (R2 = 0,786). Ch w testach funkcjonalnych lewej ręki są skorelowane z Ch w parametrach HRV i EEG w tym samym stopniu: poziom R2 jest dla D 0,799, dla NHP 0,773 i dla B & B 0,708. Zamiast tego dla prawej ręki korelacja jest silniejsza: R2 wynosi odpowiednio 0,973, 0,792 i 0,978. Jeśli chodzi o parametry GDV, połączenia są słabsze, ale są również mocniejsze dla prawej ręki: R2 wynosi 0,706 vs 0,462 dla B & B i 0,679 vs. 0,405 dla NHP, ale nie dla D (0,719 i 0,709). Ch w NCMT są skorelowane z Ch w parametrach GDV również słabsze (R2 = 0,556). Z kolei zmiany parametrów GDV są bardzo ściśle związane ze zmianami parametrów zarówno HRV (R2 = 0,999), jak i EEG (R2 = 0,998).
Wniosek. U dzieci ze spastycznymi postaciami porażenia mózgowego spowodowanymi przez metodę Kozyavkin © zmiany ręcznych testów czynnościowych i składowej nerwowej napięcia mięśniowego są determinowane przez zmiany parametrów EEG i HRV oraz GDV.

Key words: Cerebral palsy, Dynamometry, Box and Block Test, Nine Hole Peg Test, Neural component of Muscle Tone, EEG, HRV, GDV, Intensive Neurophysiological Rehabilitation System by Kozyavkin© method.

Słowa kluczowe: mózgowe porażenie dziecięce, Dynamometria, pole i bloku Test, dziewięć otworów Peg Test, neuronowe składnik napięcia mięśniowego, EEG, HRV, GRW, intensywny System rehabilitacji neurofizjologicznej przez Kozyavkin © Metoda.

INTRODUCTION

Earlier we reported that after two-week course of Intensive Neurophysiological Rehabilitation System (INRS) officially recognized as Kozyavkin© method [1-3] the parameters of the functional tests of hands in 108 children with spastic forms of cerebral palsy (SFCP) are significantly improved. It is detected increase in Box and Block Test by 22,9±2,2% right and by 19,1±1,3% left, in Nine Hole Peg Test by 16,7±1,9% right and by 18,8±1,8% left, in Dynamometry by 30,6±5,0% right and by 31,6±6,1% left. In total the effectiveness of the restoration of functional parameters of hands by Kozyavkin© method makes average 23,3±1,6% versus 3,5±1,4% in control. However, the average values obscure significant differences between individual children. In particular, in 58% of patients, changes are very tangible, in 22% moderate, while in 20% are minor [4].

In another contingent of 29 children, we found that reducing neural component of muscle tone (NCMT) stated in 79,3% cases from 7,6±1,0 N to 1,6±0,5 N (direct difference: -6,0±0,8 N), while in 13,8% cases changes were not detected and in 2 children only NCMT increased from 1,6 to 3,4 and from 4,6 to 6,1 N respectively [5,6].

It is known about abnormalities in autonomous nervous system (ANS) in patients with CP [7-9]. Obviously, these abnormalities are associated with CNS damage. We have recently discovered relationships between the parameters heart rate variability (HRV) as markers of ANS activity and background EEG activity [10,11]. Proceeding from this we hypothesized that such a variety of changes in NCMT is due to ambiguous changes in the background activity of the nerve centers. For their evaluation are available HRV and Electroencephalography (EEG) methods (about of Neuroimaging in the conditions of Ukraine can only dream). Since such children are not always able to register EEG and HRV due to uncontrolled movements, the search for other methods for evaluating neural activity remains relevant.

Back in 1880 Nikola Tesla demonstrated that when placing the man in the high-frequency field around the body there is a bright glow. In 1892 YO Nardkevych-Yodko recorded glow human hands on photographic plate. However, a well-known method of "high-frequency photography" was due to spouses SD and VH Kirlian who in 1939 independently discovered this phenomenon, later called "Kirlian effect" [cit. by: 12]. In 1996 KG Korotkov created a new scientific approach, based on the digital videotechnics, modern electronics and computer processing quantitative data, called as method gas discharge visualization (GDV bioelectrography). Parallel uses the terms Kirlianography and Electrophotonics. Method of GDV, essence of which consists in registration of photoelectronic emission of skin, induced by high-frequency electromagnetic impulses, allows to estimate integrated psycho-somatic state of organism. The first base parameter of GDV is area of Gas Discharge Image (GDI) in Right, Frontal and Left projections registered both with and without polyethylene filter. The second base parameter is a coefficient of Shape (ratio of square of length of external contour of GDI toward his area), which characterizes the measure of serration/fractality of external contour. The third base parameter of GDI is Entropy, id est measure of chaos. It is considered that GDI, taken off without filter, characterizes the functional changes of organism, and with a filter characterizes organic changes [12,13].

Since ambiguous attitude to the method, previously we conducted the study on its verification and have shown that GDV parameters are correlated with HRV [14-16] and EEG [17] parameters. In another study, we have shown that GDV parameters can change with changes in other functional parameters of the body [18,19].

The purpose of this study is to analyze of relationships between caused by Kozyavkin© method changes in NCMT as well as manual functional tests, on the one hand, and parameters of EEG, HRV as well as GDV, on the other hand.

MATERIAL AND RESEARCH METHODS

The object of observations were 14 children (6 girls and 8 boys) aged 8÷15 years with Spastic Forms of Cerebral Palsy. Diagnose, Stage. Phase as well as Gross Motor Function Classification System [20] and Manual Ability Classification System [21] levels is given in the Table 1.

Table 1. Clinical characteristics of the observed children

Child	Gender	Age	Diagnose	Stage	Phase	GMFCS	MACS
Hou L	Girl	14	**G80.0 CCP: spastic tetraplegia**	movement by turning	lying to the control head	4	3
Myk	Boy	10	**G80.1 CCP: spastic diplegia**	crawling on their bellies	independent seat	4	3
Pet	Girl	10	**G80.1 CCP: spastic diplegia**	walking on the knees	getting up at the support	4	3
Hou D	Girl	14	**G80.1 CCP: spastic diplegia**	walk with aids	independent seat	3	3
Hav	Boy	10	**G80.1 CCP: spastic diplegia**	walk with aids	rising support near	3	3
Pav	Boy	9	**G80.1 CCP: spastic diplegia**	walk with aids	rising support near	3	2
Boj A	Boy	15	**G80.1 CCP: spastic diplegia**	walk with aids	self-rising	2	2
Boj D	Boy	15	**G80.1 CCP: spastic diplegia**	independent moves	self-rising	2	2
Vor	Boy	9	**G80.1 CCP: spastic diplegia**	independent moves	self-rising	2	2
Kry	Boy	8	**G80.2 CCP: spastic hemiplegia Left**	independent moves	self-rising	2	2
Lan	Girl	12	**G80.2 CCP: spastic hemiplegia Left**	independent moves	rising support near	2	2
Kul	Girl	12	**G80.1 CCP: spastic diplegia**	altenative crawling	independent seat	4	3
Kuch	Girl	13	**G80.1 CCP: spastic diplegia**	walk with aids	rising support near	3	3
Str	Boy	12	**G80.2 CCP: spastic hemiplegia Left**	independent moves	self-rising	1	1

The estimation of hand function carried out by Dynamometry, Box and Block Test and Nine Hole Peg Test.

To measure the strength of the hand we used dynamometer of “Jamar” company [22]. In the study the patient is sitting on chair, or with good fixation on the mother's knees. The hand, which perform measurements, reduced to the torso, arms along the body, elbow bent at right angles, is on the anvil. The instructor explains and demonstrates correct assignment. Conducted 2-3 attempts to adapt and understanding of the task on each hand.

Box and Block Test is a simple, reliable and valid test of hand function. This test was developed in 1985 V Mathiowetz et al [23] to assess hand function in adults with cerebral palsy. It is widely used by specialists in physical rehabilitation and ergotherapy. The essence of the test is to determine the number of wooden cubes that patient can shift from one box to the second in a minute. For the test requires a wooden box divided into two parts by a partition height of 15 cm. One half of the box is 150 wooden blocks measuring 1 inch (2,5 cm). Patient explain and show how to rearrange blocks. At the command as soon as the patient begins to shift blocks from one box to the other half. Instructor captures a patient and stops after one minute. First, examine the dominant hand, then rearrange blocks in place and inspect second hand. Registers the number of translated blocks each hand. Time test three to five minutes.

The essence of Nine Hole Peg Test [24,25] is to determine how long the patient can turn each hand insert and then remove wooden 9 pegs in 9 holes in the wooden bar. Before the test ergotherapist shows the patient how to do it. At the command as soon as the patient begins to insert wooden plugs into the holes in the wooden bar. Instructor intersect time. At first examined the dominant hand, then the other.

For each test we calculated Laterality Index (LI) using the equation [26]:

LI=100%•(Right - Left)/0,5•(Right + Left)

We registered also Neural, elastic and viscous Components of Muscle Tone by device "NeuroFlexor" (Aggero MedTech AB, Sweden). Recent studies have indicated that device is suitable for measurement changes in spasticity during CP treatment [6,27-30].

The next morning in a sitting position we recorded during 7 min electrocardiogram in II lead by hardware-software complex "CardioLab+HRV" ("KhAI-Medica", Kharkiv, Ukraine) to assess the parameters of HRV as markers of vagal and sympathetic outflows. For further analysis the following parameters HRV were selected. Temporal parameters (Time Domain Methods): the standart deviation of all NN intervals (SDNN), coefficient of variation (C_V), the square root of the mean of the sum of the squares of differences between adjacent NN intervals (RMSSD), the percent of interval differences of successive NN intervals greater then 50 ms (pNN_{50}), triangulary index (TINN); heart rate (HR), moda (Mo), the amplitude of moda (AMo), variational sweep (MxDMn or ΔX). Spectral parameters (Frequency Domain Methods): spectral power (SP) bands of HRV: high-frequency (HF, range 0,4÷0,15 Hz), low-frequency (LF, range 0,15÷0,04 Hz), very low-frequency (VLF, range 0,04÷0,015 Hz) and ultra low-frequency (ULF, range 0,015÷0,003 Hz). We calculated also relative SP all bands as well as classical indexes: LF/HF, LFnu=100%•LF/(LF+HF), Centralization Index=(VLF+LF)/HF, Baevskiy's Stress Index (BSI=AMo/2•Mo•MxDMn) and Baevskiy's Activity Regulatory Systems Index [31-33].

Simultaneosly with HRV we recorded EEG for 25 sec using hardware-software complex "NeuroCom Standard" (KhAI Medica, Kharkiv, Ukraine) 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. Among the options considered the average EEG amplitude (μV), average frequency (Hz), frequency deviation (Hz), index (%), coefficient of asymmetry (%) as well as absolute (μV^2/Hz) and relative (%) spectral power density (SPD) in the standard frequency bands: 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 for the device.

In addition, calculated Laterality Index (LI) for SPD each Rhythm using formula [26]:

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

We calculated also for each locus the Entropy (h) of normalized SPD using classical CE Shannon's formula [34]:

$$h = -[SPD\alpha \bullet \log_2 SPD\alpha + SPD\beta \bullet \log_2 SPD\beta + SPD\theta \bullet \log_2 SPD\theta + SPD\delta \bullet \log_2 SPD\delta]/\log_2 4$$

The Kirlianogram have been registered by the method of GDV with the use the device "GDV Chamber" ("Biotechprogress", SPb, RF) [13].

After testing children within two weekes received a classic course rehabilitation (a detailed description is provided in the manual [3]), then repeated the tests listed.

Digital material is treated by methods factor, cross-correlation and canonical analyses with the use of package of softwares "Statistica-5.5" and algorithm of Truskavets' scientific school of balneology [19,35].

RESULTS AND DISCUSSION

Individual fragments were published in abstract format [36,37].

It is stated that at 9 children Neural Components of Muscle Tone (NCMT) reduced from 19,8±3,4 to 12,3±2,8 Newtons (change: -7,5±2,0 N; $p<0,01$), at 3 children NCMT taked 8,2±3,3 before and 7,9±3,5 after rehabilitation (change: -0,3±0,3 N) while at one girl NCMT increased from 15,1 to 17,9 N as well as at one boy from 6,1 to 19,4 N. Thus, the previously obtained data on the diversity of rehabilitation effects were confirmed.

In the first stage of data processing, we used a factor analysis to reduce the number of variables (data reduction) and to determine the structure of interconnections between variables, ie, their classification. A number of factor analysis methods involve the analysis of the Principal Components (PC). It is believed that in order to study the factor structure of the field under investigation, we can limit ourselves to considering such an amount of PC, the total contribution of which in the total variance of the output data exceeds 2/3. Another approach to determining the number of PC is to apply the Kaiser ($\lambda>1$) and Cattell (with the maximum deceleration of the eigenvalue λ, graphically visualized) criteria [38]. It was found that the variance of the information field of the changes of the registered parameters is absorbed by 15 factors (Fig. 1). Applying Cattel's method, the number of factors we are limited to six, the total contribution of which in the total dispersion of data is 76%, that is significantly exceeds the required critical level (2/3).

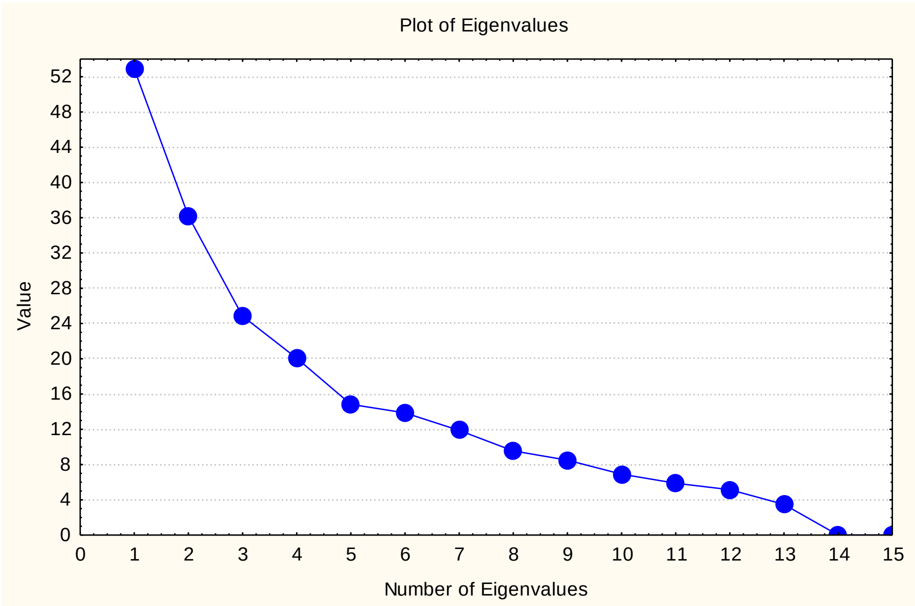


Fig. 1. Plot of Eigenvalues for changes in parameters of Manual tests, EEG, HRV and GDV

It was revealed (Table 2) that the first PC explains 24,2% of the Dispersion and includes changes in **relative** SPD of δ- α- and β-rhythms as well as in Amplitude and Laterality of δ-rhythm. When comparing factor loads from left (odd) and right (pair) loci, it can be seen that in relation to δ-rhythm in Frontalis Anterior, Occipitalis and Frontalis Medialis loci take place Left side Lateralization while in Parietalis, Frontalis Lateralis, Temporalis Anterior and Posterior as well as Centralis loci Lateralization is Right side. Regarding α-rhythm factor loads from Parietalis, Temporalis Anterior and Posterior as well as Frontalis Lateralis loci are also bigger to the right, and from Frontalis Medialis is also bigger to the left. Instead, for Occipitalis and Frontalis Anterior loci take place Right side Lateralization, while for Centralis loci Left side. Regarding β-rhythm Right side Lateralization take place in Temporalis Posterior, Parietalis, Frontalis Lateralis and Anterior as well as Centralis loci while Left side Lateralization in Temporalis Anterior, Occipitalis and Frontalis Medialis loci. It should be noted that the factor loads from δ-rhythm are negative, but positive from α- and β-rhythms.

Table 2. Factor Loadings (Equamax normalized). Extraction: Principal Components
(Marked loadings are >**0,700**)

Variables	F1	F2	F3	F4	F5	F6
Fp1-δ SPDR	**-0,981**					
Fp2-δ SPDR	**-0,938**					
O1-δ SPDR	**-0,968**					
O2-δ SPDR	**-0,946**					
F3-δ SPDR	**-0,952**					
F4-δ SPDR	**-0,899**					
P4-δ SPDR	**-0,960**					
P4-δ SPDA	**-0,852**					
F7-δ SPDR	**-0,874**					
F8-δ SPDR	**-0,919**					
T3-δ SPDR	**-0,944**					
T4-δ SPDR	**-0,962**					
T5-δ SPDR	**-0,908**					
T6-δ SPDR	**-0,934**					
C3-δ SPDR	**-0,767**			-0,483		
C4-δ SPDR	**-0,908**					
Amplitude of δ	**-0,830**			0,437		
Laterality of δ	**-0,738**					
P4-α SPDR	**0,948**					
P3-α SPDR	**0,743**					
T4-α SPDR	**0,931**					
T3-α SPDR	**0,753**					
O2-α SPDR	**0,917**					
O1-α SPDR	**0,876**					
T6-α SPDR	**0,905**					
T5-α SPDR	**0,836**					
Fp2-α SPDR	**0,770**					
Fp1-α SPDR	**0,764**					
F8-α SPDR	**0,769**					
C4-α SPDR	**0,880**					
C3-α SPDR	**0,903**					
F4-α SPDR	**0,789**					
F3-α SPDR	**0,841**					
T6-β SPDR	**0,904**					
T5-β SPDR	**0,856**					
P4-β SPDR	**0,901**					
P3-β SPDR	**0,780**			0,429		
F8-β SPDR	**0,869**					
F7-β SPDR	**0,763**					
Fp2-β SPDR	**0,859**					
Fp1-β SPDR	**0,791**					
C4-β SPDR	**0,758**					
T4-β SPDR	**0,845**					
T3-β SPDR	**0,856**					
O2-β SPDR	**0,838**					
O1-β SPDR	**0,856**					
F4-β SPDR	**0,762**					
F3-β SPDR	**0,850**					
Frequency of θ	0,672					
C4-θ SPDA		**0,941**				
C3-θ SPDA		**0,784**				
C3-θ SPDR		**0,696**				0,500
P4-θ SPDA		**0,881**				
P3-θ SPDA		**0,741**				
Fp2-θ SPDA		**0,812**				
Fp1-θ SPDA		**0,720**				
O2-θ SPDA		**0,829**				
O1-θ SPDA		**0,894**				

F4-θ SPDA		**0,831**				
F3-θ SPDA		**0,844**				
T3-θ SPDA		**0,825**				
T5-θ SPDA		**0,819**				
Amplitude of θ		**0,791**				
C4-α SPDA		**0,909**				
C3-α SPDA		**0,837**				
Fp2-α SPDA		**0,850**				
P4-α SPDA		**0,846**				
P3-α SPDA		**0,831**				
T3-α SPDA		**0,873**				
F4-α SPDA		**0,839**				
F3-α SPDA		**0,862**			0,418	
O1-α SPDA		**0,751**				
Amplitude of α		**0,734**				
C4-δ SPDA	-0,418	**0,784**				
Box&Block LI	-0,468	0,554				
VLF/TP		-0,515				-0,438
Entropy L GDI f		-0,435				
Baevskiy Stress Ind			**0,953**			
AMo/ΔX			**0,865**			
AMo			**0,843**			
Heart Rate			**0,833**			
Baevskiy ARS Ind			**0,777**			
ΔX			**-0,952**			
SDNN			**-0,934**			
Cv			**-0,920**			
TINN			**-0,906**			
Total Power HRV			**-0,819**			
SP LF HRV			**-0,772**			
SP VLF HRV			**-0,756**			
Moda HRV			**-0,745**			
RMSSD			**-0,651**			0,417
Entropy F GDI f			**0,710**			
Shape C L GDI f			**0,684**			
Shape C R GDI			**0,626**		0,492	
Shape C F GDI f				**0,869**		
Area F GDI				**-0,623**	-0,426	
F8-β SPDA				**0,855**		
O1-β SPDA		0,438		**0,697**		
F7-δ SPDA	-0,659			**0,659**		
Frequency of δ	0,507			**-0,679**		
Viscous CMT				**0,810**		
Elastic CMT				**0,528**		
Neural CMT				**-0,332**		-0,299
Entropy R GDI					**0,833**	
Symmetry GDI					**-0,702**	
Area L GDI					**-0,595**	
O2-β SPDA					**0,799**	
Fp1-β SPDA					**0,723**	
T4-β SPDA			0,429		**0,689**	
Amplitude of β				0,412	**0,687**	
LF/TP					**-0,737**	
Dynamometry LI					**0,421**	
9-Hole Peg LI					**0,244**	
Deviation of θ						**-0,836**
Index of θ						**-0,743**
T3-θ SPDR		0,439				**0,628**
F7-θ SPDR				-0,462		**0,585**
F3-θ SPDR		0,445				**0,585**
HF/TP		0,593				**0,718**
(VLF+LF)/HF	-0,400					**-0,691**
LFnu HRV		-0,519			-0,413	**-0,676**

LF/HF HRV	-0,466					**-0,658**
ULF/TP						**-0,613**
Dynamometry L						**0,725**
Box&Block L					0,349	**0,720**
Box&Block R					0,351	**0,655**
9-Hole Peg R			-0,492			**-0,602**
9-Hole Peg L					-0,336	**-0,591**
Dynamometry R					0,296	**0,592**
Symmetry GDI f	-0,482					**-0,688**
Area R GDI	-0,533					**-0,617**
Entropy R GDI f						**-0,536**
Area F GDI f	-0,463					**-0,509**
Area L GDI f			0,416		0,360	**-0,505**
Area R GDI f			0,402			**-0,491**
Shape C R GDI f	0,426					**0,558**
Shape C F GDI			0,445		0,356	**0,466**
Shape C L GDI					0,312	**0,430**
Explained Variance	**51,8**	**32,3**	**24,6**	**19,9**	**16,2**	**17,7**
Proportion of Total	**0,242**	**0,151**	**0,115**	**0,093**	**0,076**	**0,083**

The second PC absorbs 15,1% of the Variance and includes changes in **absolute** (A) SPD of θ- and α-rhythms as well as their Amplitudes. If desired, it is easy to detect lateralization of loads from individual loci. Attention is drawn to the lack of loads from θ-rhythm in Frontalis Lateralis loci as well as from α-rhythm in Frontalis Lateralis and Temporalis Posterior loci. At the same time, there is a factor load, albeit insignificant, from the changes in Lateralisation of Box&Block test as well as **relative** SP VLF band HRV (it is speculated that this band associated with oscillation blood levels of renin and epinephrine, reflects thermoregulatory cycles [cit by: 32], cerebral ergotropic and metabolotropic outflows [cit by: 33], activation of cerebral sympatho-adrenal system [39]) and Entropy of GDI in Left projection, which gives an idea of the relationships between the changes in these parameters.

The third PC explains 11,5% of the Dispersion, getting the maximum load exactly from the changes in Baevskiy's Stress Index as integral characteristics of sympathetic, vagal and humoral outflows on heart rate. Slightly less positively load gives AMo/ΔX ratio as marker of Sympatho/Vagal balance and Baevskiy's Activity of Regulatory Systems Index as integral characteristics of their strain [33] as well as Amplitude of Moda and Heart Rate as markers of Sympathetic outflows while negatively load gives nine HRV markers of Parasympathetic outflows. Interestingly, the changes in parameters of the GDV are also loaded on the same PC, which again suggests their connection with changes in parameters of the HRV.

The changes in components of muscle tone give a loads on the fourth PC only, which explains only 9,3% of the Variance. Contrary to expectations, the significant load is given by the Viscous component, while by the Neural component it is minimal. The changes in components of muscle tone associated with changes in some parameters of GDV and EEG.

The fifth PC explains 7,6% of the Dispersion, getting the significant loads from changes in parameters of both GDV and EEG&HRV, but insignificant loads from changes in Laterality of Dynamometry and 9-Hole Peg test.

Instead, the sixth PC receives significant factor loads from changes in the functional tests of hands. It is important to note that these changes are accompanied by concordant changes in SPD of θ-rhythm in Left Temporalis Anterior, Frontalis Lateralis and Medialis loci as well as in Vagal tone while discordant changes in markers of Sympathetic tone as well as Deviation and Index of θ-rhythm. Regarding parameters of GDV found concordant changes in Coefficients of Shape of GDI while discordant changes in Symmetry, Area and Entropy of GDI.

At the second stage of factor analysis, a correlation matrix for oblique factors was obtained, which was subjected to further analysis in order to distinguish the set of orthogonal factors that divide the variability in the variables into that relating to the general dispersion (Secondary factors) and to the individual dispersions belonging to the clusters or similar variables (Primary factors) (Table 3).

Table 3. Secondary & Primary (Unique) Factor Loadings
Marked loadings are >**,700**

Variables	S1	S2	P1	P2	P3	P4	P5	P6
LFnu	**-,668**							,512
HF/TP	**,610**							-,568
LF/HF	**-,468**							,539
(VLF+LF)/HF	**-,459**							,576
F3-α SPDA	**,524**			**,720**				
Amplitude of α	**,516**			,598				
T4-α SPDA	**,507**			,582				
F4-α SPDA	**,481**			**,699**				
Fp1-α SPDA	**,480**			,563				
C4-β SPDA	**,524**						,510	
F3-β SPDA	**,481**						,569	
C4-θ SPDR	**,459**			,472				
T4-θ SPDR	**,438**		,452					
Box&Block R	**,515**							-,529
Box&Block L	**,405**							-,615
9-Holy Peg R	**-,368**				-,489			,510
9-Holy Peg L	**-,344**							,503
Entropy GDI R	**,495**						**,715**	
Symmetry GDI f	**-,433**							,577
Area GDI R	**-,413**		-,468					,510
Fp1-δ SPDA		**,570**	-,478			-,459		
Amplitude of δ		**,561**	**-,710**					
T6-δ SPDA		**,549**						
F7-δ SPDA		**,526**	-,544			-,556		
O2-δ SPDA		**,522**						
T6-θ SPDA		**,530**						
F8-θ SPDA		**,514**	-,498	,537				
F7-α SPDR		**-,562**	,523					
F8-α SPDR		**-,511**	,643					
AMo HRV		**-,422**			**,781**			

It seems that the **favorable** changes in B&B and 9-HP tests (increasing the number of transmitted blocks for a fixed time and accelerating the performance of the second test) are due to a **decrease** in the sympathetic tone and **increased** tone of the vagus as well as the Amplitude and SPD of the α-rhythm in the Left&Right Frontalis Medialis, Right Temporalis Anterior and Left Frontalis Anterior loci, β-rhythm in Right Centralis and Left Frontalis Medialis loci as well as θ-rhythm in Right Centralis and Temporalis

Anterior loci. This is accompanied by an **increase** in Entropy and a **decrease** in the Area of GDI in Right projection as well as its Symmetry. In addition, judging by the signs of the loads on the second Secondary factor, a favorable **decrease** in sympathetic tone is accompanied by an **increase** in Amplitude and SPD of the δ-rhythm in Left Frontalis Anterior and Medialis and Right Temporalis Anterior and Occipitalis loci as well as θ-rhythm in Right Temporalis Posterior and Frontalis Lateralis loci while an **decrease** in SPD of the α-rhythm in the Left&Right Frontalis Lateralis loci.

Now let's see if the results of **factor** analysis are confirmed by the results of **correlation** analysis. According to the formula:

$$|r|\geq\{exp[2t/(n-1,5)^{0,5}] - 1\}/\{exp[2t/(n-1,5)^{0,5}] + 1\},$$

for a sample of 14 observations critical value of correlation coefficient module |r| at $p<0,05$ ($t>2,14$) is **0,54**, at $p<0,01$ ($t>2,98$) is 0,70, at $p<0,001$ ($t>4,14$) is **0,84**. Nevertheless, in regressive models with step-by-step exclusion, there were separate variables with the values |r| less than critical level whereas some variables with meaningful modules were not included in the models.

But first, rather than switching to regressive models, we note that the parameters of Box & Block and 9-Hole Peg Test as well as Dynamometry change in a consistent way, which can not be said about changes in the muscle tone component (Table 4).

Table 4. Correlation matrix for changes in parameters of Manual Function

n=14	B&B R	B&B L	9-HP R	9-HP L	D R	D L	Neural CMT L	Elastic CMT L	Viscous CMT L
B&B R	1,00	**,82**	**-,87**	**-,83**	**,58**	**,64**	-,43	*-,38*	*,29*
B&B L		1,00	**-,82**	**-,83**	*,40*	**,67**	-,33	*-,22*	*,35*
9-HP R			1,00	**,77**	*-,37*	**-,71**	**,63**	*,21*	*-,33*
9-HP L				1,00	**-,61**	**-,75**	*,35*	*,35*	*-,27*
D R					1,00	**,74**	*-,26*	**-,56**	*-,18*
D L						1,00	-,48	*-,35*	*,08*
NC MT L							1,00	*,20*	*-,30*
Elast CMT								1,00	0,51

The screening of pairwise correlations found (Table 5) that the **favorable** changes in manual tests (increasing the number of transferred blocks and the strength of the brush, in conjunction with the reduction of the time of the 9-Hole Peg test and the decrease of the neural component of the muscle tone) are accompanied by an **increase** in the quantities of HRV-markers of **vagal** tone in combined with a **decrease** in **sympathetic** tone markers as well as probably in level of circulating cathecholamines marker of which are possible ULF and VLF bands of HRV.

Judging by the means of the modulus of the correlation coefficients, the most informative are the normalized HRV parameters that reflect the Vagal (HF/TP) and Sympathetic (LFnu) tone.

Judging by the values of the modulus of the correlation coefficients, changes in the tests of the right hand are usually more sensitive to changes in the vago-sympathetic balance than the left one.

Table 5. Correlation matrix for changes in parameters of Manual Function and HRV

n=14	B&B R	B&B L	D R	D L	9-HP R	9-HP L	NCMTL	Mean |r|
HF/TP	**,86**	**,57**	**,61**	**,54**	**-,68**	**-,60**	*-,31*	**0,596**
HF	,52	*,27*	**,54**	*,28*	*-,16*	*-,28*	*,07*	**0,303**
LFnu	**-,78**	**-,63**	-,45	-,45	**,62**	,53	*,25*	**0,530**
VLF	-,48	*-,35*	*-,25*	*-,40*	**,68**	*,43*	**,60**	**0,456**
ULF	*-,43*	*-,31*	**-,64**	-,49	*,26*	**,64**	*-,11*	**0,411**
VLF/TP	**-,57**	*-,20*	-,44	*-,40*	,46	*,42*	*,23*	**0,389**
LF	*-,38*	-,44	*-,02*	*-,26*	**,67**	*,31*	**,54**	**0,374**
ULF/TP	*-,31*	*-,30*	**-,60**	**-,55**	*,18*	*,47*	*-,10*	**0,359**

Regarding the EEG parameters, it seems that an increase of six of them is accompanied by adverse changes in manual tests, while favorable changes are accompanied by an increase in the ten EEG parameters regardless of frequency bands as well as of locus side (Table 6).

Table 6. Correlation matrix for changes in parameters of Manual Function and EEG

Variables	B&B R	B&B L	D R	D L	9-HP R	9-HP L	NC MTL	Mean |r|
Index θ	-,52	-,53	**-,73**	**-,75**	,48	**,63**	,43	**0,581**
Deviation θ	**-,59**	**-,66**	*-,35*	-,46	,50	**,61**	*,25*	**0,489**
P3-θ SPDA	*,23*	*,01*	*-,06*	*-,14*	*-,10*	*-,03*	,52	**0,156**
T3-β SPDR	-,50	-,40	-,34	-,33	*,42*	,50	*,06*	**0,364**
Frequency α	*-,42*	*-,34*	*-,42*	*-,28*	*,40*	**,58**	*,19*	**0,376**
C3-α SPDA	*,12*	*-,14*	*-,05*	*-,26*	*,03*	*,10*	**,55**	**0,179**
F3-θ SPDR	,46	*,31*	*,27*	*,38*	-,52	*-,16*	*-,39*	**0,356**
F3-θ SPDA	**,55**	*,13*	*,13*	*,06*	-,44	*-,13*	*-,14*	**0,226**
O2-θ SPDR	*,39*	*,40*	*,19*	*,23*	-,50	*-,28*	*-,06*	**0,293**
Asymmetry θ	*,27*	,53	*-,04*	*,10*	-,43	*-,30*	*-,35*	**0,289**
Amplitude θ	**,63**	*,30*	*,02*	*,03*	-,51	*-,21*	*-,13*	**0,261**
T4-β SPDA	*,39*	,52	*,18*	*,09*	*-,36*	*-,41*	*-,11*	**0,294**
T4-α SPDA	,52	*,33*	*,17*	*-,02*	-,43	*-,28*	*-,14*	**0,270**
Laterality α	*,01*	*,08*	*,14*	,48	*-,34*	*-,06*	**-,76**	**0,267**
Fp1-α SPDA	,49	*,14*	*,15*	*-,15*	*-,30*	*-,26*	*-,22*	**0,244**
F8-α SPDA	**,55**	*,27*	*,02*	*,07*	-,43	*-,27*	*,03*	**0,234**

Let's proceed to the next stage of the analysis, namely, the construction of the regressive models for the changes of individual manual tests. Regarding the changes in Box&Block test for Right hand found (Fig. 2) that the favorable changes in 8 children are accompanied by an increase in the vagus tone of 7, while its reduction is established only in one child. Instead, the lack of changes in two children and adverse changes in the test in four children are accompanied by a reduction in vagus tone.

Almost the same situation occurs with respect to the accompanying changes in the θ-rhythm amplitude (Fig. 3).

In regressive model with step-by-step exclusion, six parameters have been included, the changes which together determine the changes in the Box&Block test for the Right hand, judging by the Adjusted R^2 level, by 95,6% (Table 7 and Fig. 4).

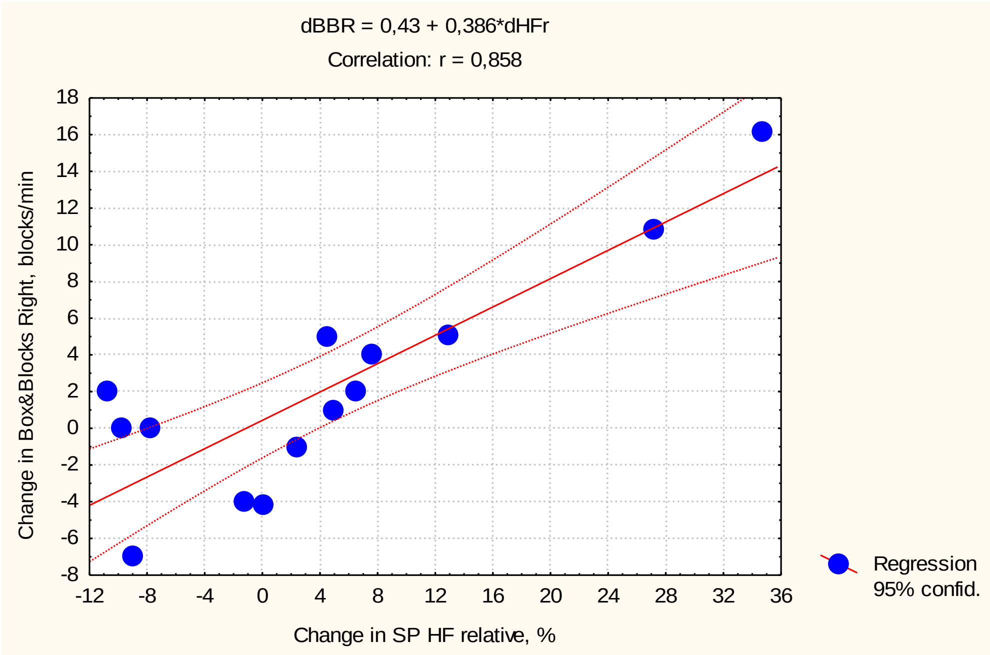


Fig. 2. Scatterplot of correlation between changes in relative Spectral Power of HF band HRV (line X) and Box&Block test for Right hand (line Y)

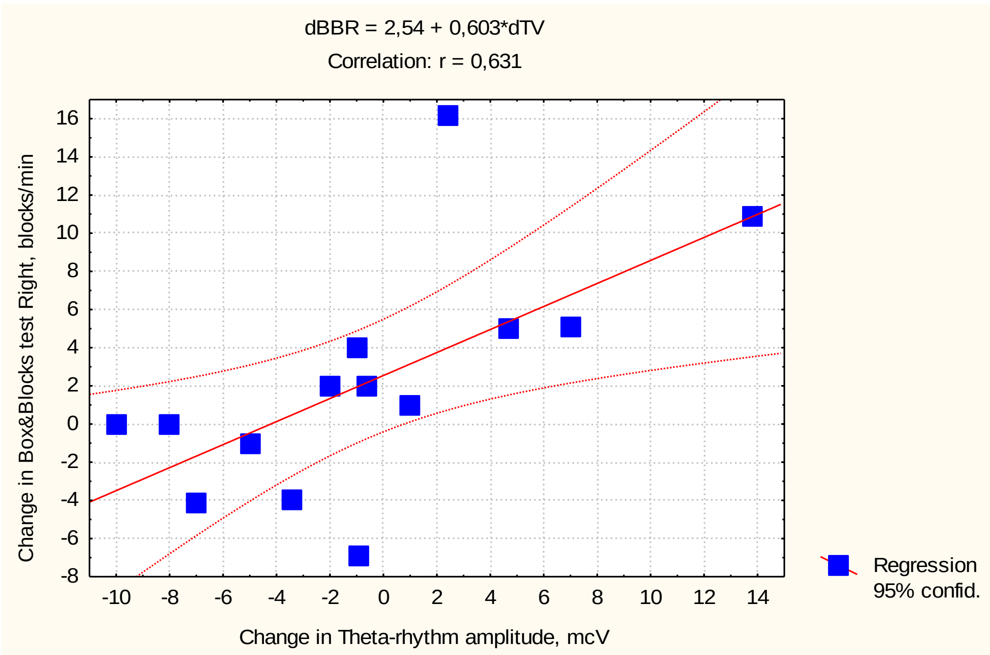
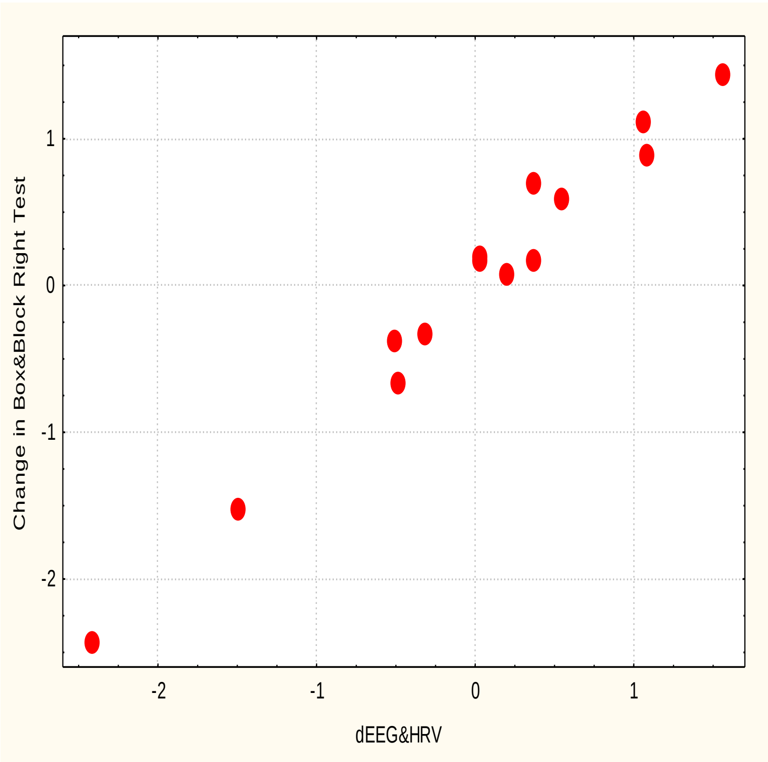


Fig. 3. Scatterplot of correlation between changes in Amplitude of θ-rhythm EEG (line X) and Box&Block test for Right hand (line Y)

Table 7. Regression Summary for change in Dependent Variable: Box&Block test for Right hand
$R=0{,}989$; $R^2=0{,}978$; Adjusted $R^2=0{,}956$; $F_{(6,7)}=51$; $p<10^{-4}$; SE of estimate: 1,2 blocks/min

Change in Independent Variables	r	Beta	St. Err. of Beta	B	St. Err. of B	$t_{(7)}$	p-level
			Intercpt	-,8610	,5357	-1,61	,152
HF/TP, %	**0,86**	1,077	,116	,4843	,0522	9,28	10^{-4}
Amplitude θ, μV	**0,63**	1,019	,201	,9737	,1917	5,08	,001
F3-θ SPDR, %	0,46	-1,300	,220	-,0668	,0113	-5,90	10^{-3}
Deviation θ, Hz	**-0,59**	,260	,089	1,6486	,5628	2,93	,022
T3-β SPDR, %	-0,50	-,379	,063	-,1260	,0210	-6,00	10^{-3}
VLF SP, ms^2	-0,48	-,175	,061	-,0007	,0002	-2,85	,025



$R=0{,}989$; $R^2=0{,}978$; $\chi^2_{(6)}=34{,}2$; $p<10^{-5}$; Λ Prime=0,022

Fig. 4. Scatterplot of canonical correlation between changes in parameters of EEG&HRV (line X) and Box&Block test for Right hand (line Y)

The size of the article does not allow us to characterize in detail the other regressive models, therefore we confine ourselves to establishing their different structure and the measure of the determination of changes in manual functions by changing the parameters of EEG and HRV (Fig. 5-11, Tables 8-12).

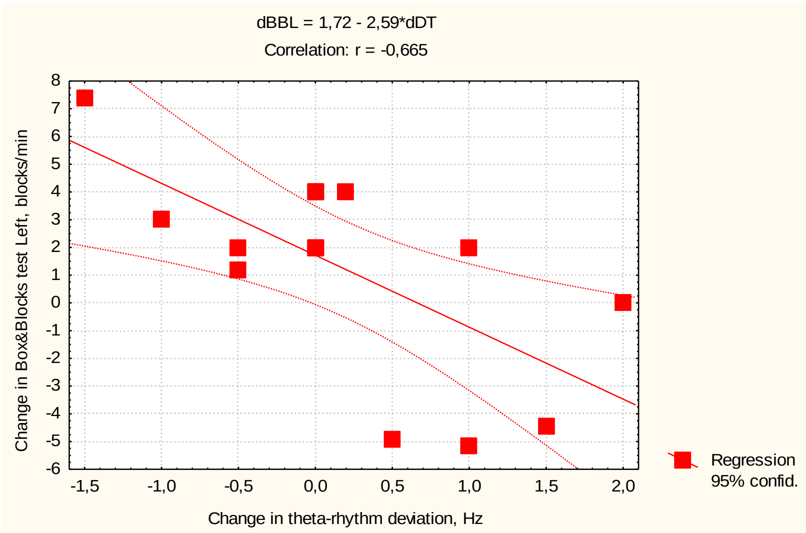
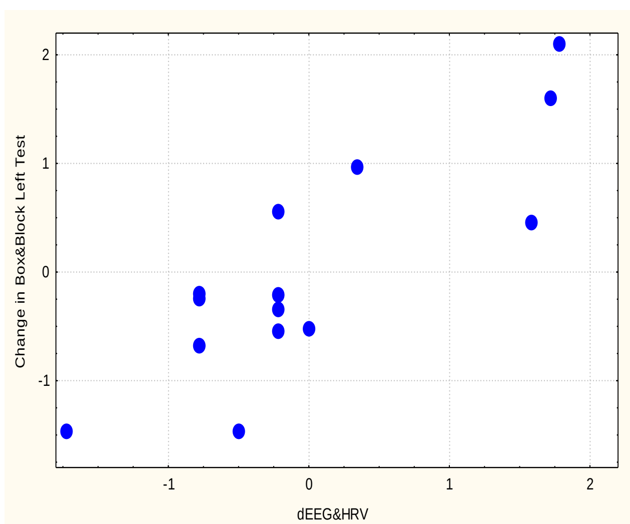


Fig. 5. Scatterplot of correlation between changes in Deviation of θ-rhythm EEG (line X) and Box&Block test for Left hand (line Y)

Table 8. Regression Summary for change in Dependent Variable: Box&Block test for Left hand
$R=0,842$; $R^2=0,708$; Adjusted $R^2=0,526$; $F_{(5,8)}=3,9$; $p=0,044$; SE of estimate: 2,6 blocks/min

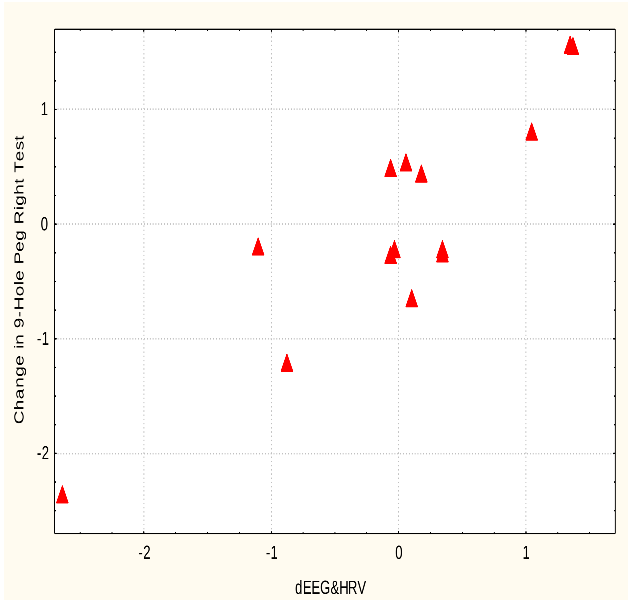
Change in Independent Variables	r	Beta	St. Err. of Beta	B	St. Err. of B	$t_{(8)}$	p-level
			Intercpt	,9891	,7843	1,26	,243
Deviation θ, Hz	**-0,66**	-,416	,273	-1,6222	1,0651	-1,52	,166
Index θ, %	-0,53	-,353	,297	-,0287	,0242	-1,19	,269
LF SP, ms^2	-0,44	-,735	,350	-,0032	,0015	-2,10	,069
T3-β SPDR, %	*-0,40*	-,309	,215	-,0632	,0440	-1,44	,189
VLF SP, ms^2	*-0,35*	,587	,386	,0014	,0009	1,52	,167



$R=0,842$; $R^2=0,708$; $\chi^2_{(5)}=11,7$; $p=0,039$; Λ Prime=0,291
Fig. 6. Scatterplot of canonical correlation between changes in parameters of EEG&HRV (line X) and Box&Block test for Right hand (line Y)

Table 9. Regression Summary for change in Dependent Variable: 9-Hole Peg test for Right hand
$R=0,890$; $R^2=0,792$; Adjusted $R^2=0,730$; $F_{(3,1)}=12,7$; $p<10^{-3}$; SE of estimate: 23 sec

Change in Independent Variables	r	Beta	St. Err. of Beta	B	St. Err. of B	$t_{(10)}$	p-level
			Intercpt	-,3162	6,9331	-0,05	,965
HF/TP, %	**-0,68**	-,585	,158	-1,9163	,5171	-3,71	,004
Asymmetry θ, %	*-0,43*	-,362	,157	-,7541	,3263	-2,31	,043
VLF PS, ms^2	**0,68**	,350	,167	,0096	,0046	2,10	,062

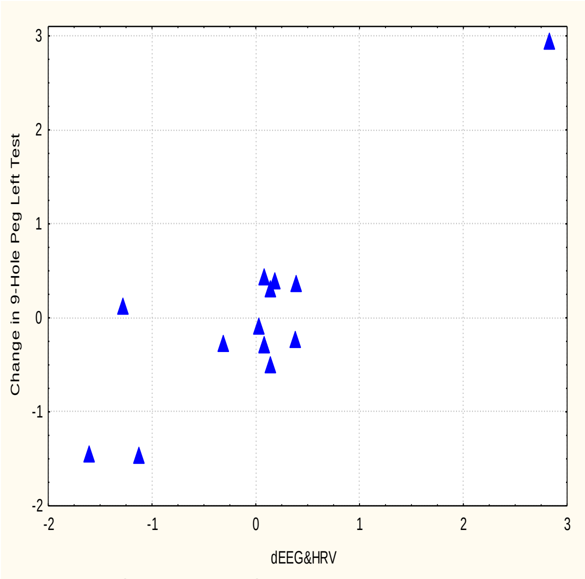


$R=0,890$; $R^2=0,792$; $\chi^2_{(3)}=16,5$; $p=0,039$; Λ Prime=0,208

Fig. 7. Scatterplot of canonical correlation between changes in parameters of EEG&HRV (line X) and 9-Hole Peg test for Right hand (line Y)

Table 10. Regression Summary for change in Dependent Variable: 9-Hole Peg test for Left hand
$R=0,879$; $R^2=0,773$; Adjusted R2=0,672; $F_{(4,9)}=7,7$; $p=0,006$; SE of estimate: 30 sec

Change in Independent Variables	r	Beta	St. Err. of Beta	B	St. Err. of B	$t_{(9)}$	p-level
			Intercpt	-10,6	9,4	-1,12	,291
ULF PS, ms^2	**0,64**	,254	,201	,1092	,0867	1,26	,239
Index θ, %	**0,63**	,500	,198	,5830	,2314	2,52	,033
T3-β SPDR, %	0,50	,401	,174	1,175	,509	2,31	,047
T3-β SPDA, $\mu V^2/Hz$	*-0,41*	-,236	,169	-,0465	,0333	-1,40	,196

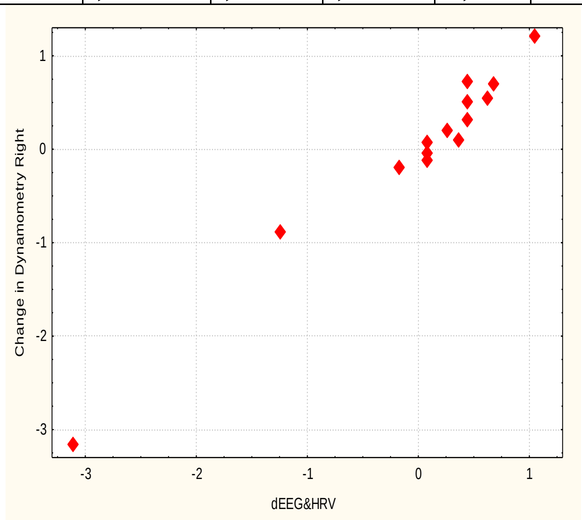


$R=0,879$; $R^2=0,773$; $\chi^2_{(4)}=14,8$; $p=0,005$; Λ Prime=0,227

Fig. 8. Scatterplot of canonical correlation between changes in parameters of EEG&HRV (line X) and 9-Hole Peg test for Left hand (line Y)

Table 11. Regression Summary for change in Dependent Variable: Dynamometry for Right hand
$R=0,986$; $R^2=0,973$; Adjusted $R^2=0,956$; $F_{(5,8)}=57$; $p<10^{-5}$; SE of estimate: 1,2 kG

Change in Independent Variables	r	Beta	St. Err. of Beta	B	St. Err. of B	$t_{(8)}$	p-level
			Intercpt	3,01	,42	7,09	10^{-3}
Index θ, %	**-0,73**	-1,105	,084	-,1397	,0106	-13,2	10^{-6}
LFnu, %	-0,45	,218	,087	,0783	,0313	2,51	,037
Deviation θ, Hz	*-0,35*	,509	,087	3,084	,527	5,85	10^{-3}
T3-β SPDR, %	*-0,34*	-,463	,065	-,1471	,0205	-7,17	10^{-4}
HF SP, ms^2	**0,54**	,528	,072	,0053	,0007	7,31	10^{-4}



$R=0,986$; $R^2=0,973$; $\chi^2_{(5)}=34,2$; $p=0,005$; Λ Prime=0,027

Fig. 9. Scatterplot of canonical correlation between changes in parameters of EEG&HRV (line X) and Dynamometry for Right hand (line Y)

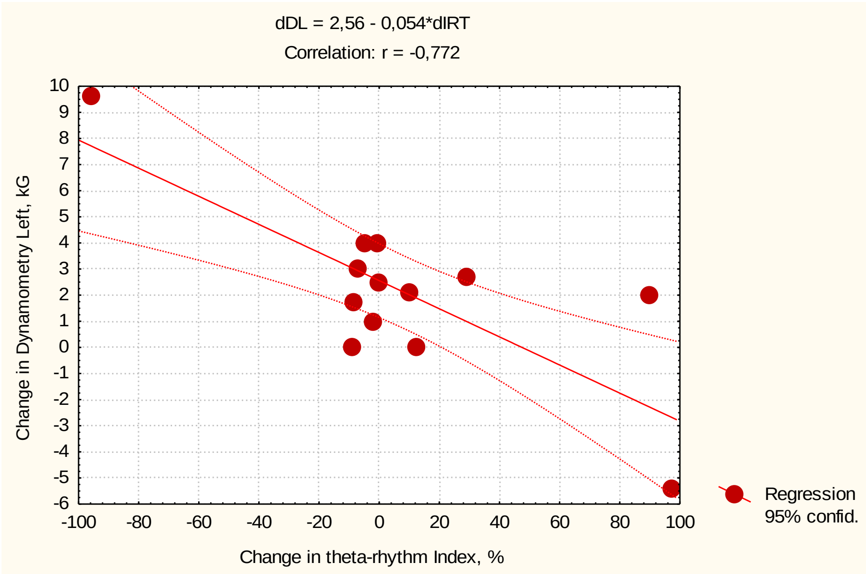
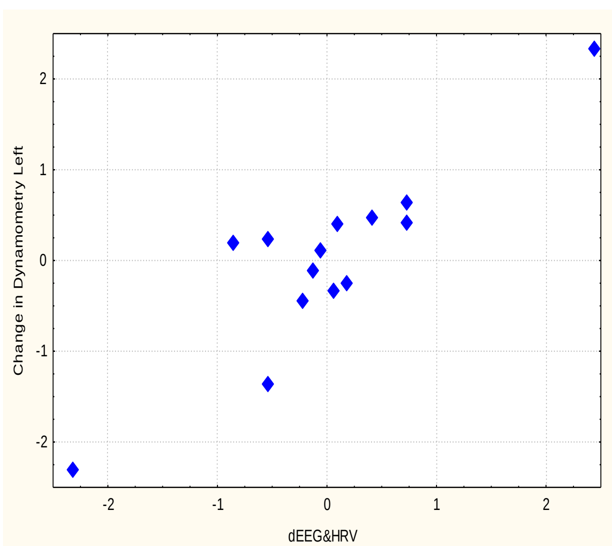


Fig. 10. Scatterplot of correlation between changes in Index of θ-rhythm EEG (line X) and Dynamometry for Left hand (line Y)

Table 12. Regression Summary for change in Dependent Variable: Dynamometry for Left hand
$R=0,894$; $R^2=0,799$; Adjusted $R^2=0,739$; $F_{(3,1)}=13$; $p<10^{-3}$; SE of estimate: 1,7 kH

Change in Independent Variables	r	Beta	St. Err. of Beta	B	St. Err. of B	$t_{(10)}$	p-level
			Intercpt	2,52	,526	4,80	,001
ULF SP, ms^2	-0,49	-,615	,149	-,0163	,0040	-4,12	,002
LFnu, %	-0,45	-,385	,144	-,0784	,0293	-2,68	,023
Laterality α, %	0,48	,676	,147	,1112	,0243	4,58	,001

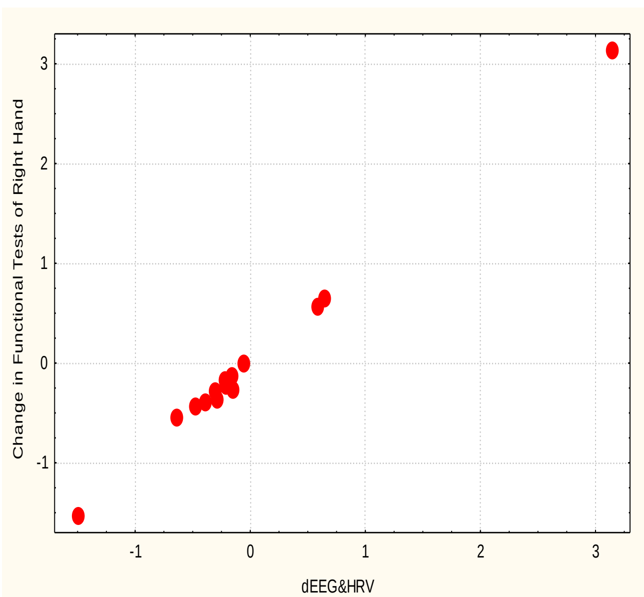


$R=0,894$; $R^2=0,799$; $\chi^2_{(3)}=16,9$; $p<10^{-3}$; Λ Prime=0,201
Fig. 11. Scatterplot of canonical correlation between changes in parameters of EEG&HRV (line X) and Dynamometry for Left hand (line Y)

Now compare the factor structures of the nerve structures (sorry for the pun), the changes in the activity of which cause changes in the functional tests of the Right and Left hands. It was found (Table 13 and Fig. 12) that improvement of functions of Right hand is due to increased vagus tone and SPD of generating θ-rhythm nerve structures that are projected to the Left Frontalis medialis locus in combination with a decrease in the index and frequency variation θ-rhythm as well as a decrease in sympathetic tone and activity of generating β-rhythm nervous structures that are projected to the Left Temporalis Anterior locus and probably in level of circulatig Cathecholamines.

Table 13. Factor Structure for changes in parameters of HRV and EEG (right set) and Function of Right Hand (left set)

Right set	R
HF/TP	**,757**
HF SP	**,562**
F3-θ SPDA	**,280**
Amplitude θ	**,221**
Index θ	**-,747**
LFnu	**-,609**
Deviation θ	**-,473**
T3-β SPDR	**-,433**
VLF SP	**-,391**
Left set	R
Dynamometry R	,957
Box&Block R	,785
9-Hole Peg R	-,607



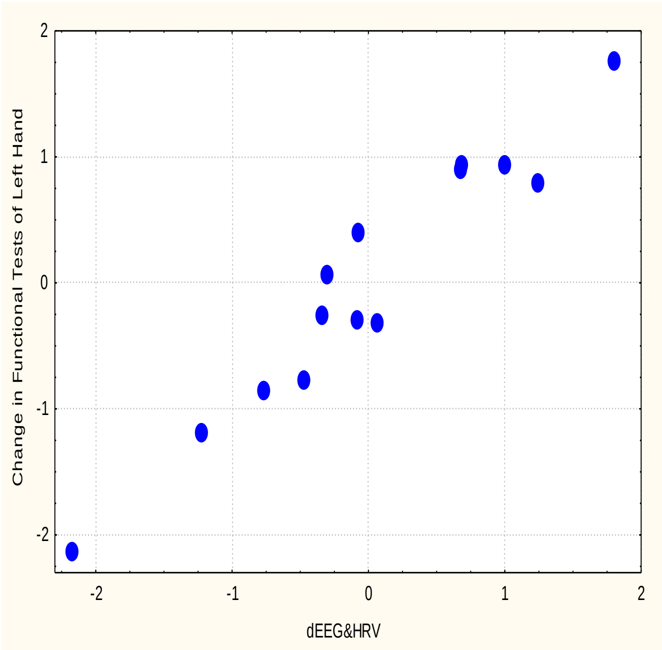
R=0,999; R^2=0,997; $\chi^2_{(27)}$=64; $p<10^{-4}$; Λ Prime$<10^{-4}$

Fig. 12. Scatterplot of canonical correlation between changes in parameters of EEG&HRV (line X) and Function of Right hand (line Y)

Instead, in improving the functions of the Left hand, judging by the factor loading, a greater role is played by the reduction of the level of catecholamines in blood, except for the decrease of the index and the deviation of θ-rhythm as well as decrease in SPD generating β-rhythm nervous structures that are projected to the Left and Right Temporalis Anterior loci (Table 14 and Fig. 13). Separately it should be noted the beneficial effect of Right lateralization of α-rhythm.

Table 14. Factor Structure for changes in parameters of HRV and EEG (right set) and Function of Left Hand (left set)

Right set	R
Index θ	**,642**
ULF SP	**,546**
VLF SP	**,319**
T4-β SPDA	**,239**
T3-β SPDR	**,213**
Deviation θ	**,162**
Laterality α	**-,525**
Left set	R
Dynamometry L	-,834
9-Hole Peg L	,483
Box&Block L	-,166



R=0,965; R^2=0,931; $\chi^2_{(21)}$=34; p=0,035; Λ Prime=0,010

Fig. 13. Scatterplot of canonical correlation between changes in parameters of EEG&HRV (line X) and Function of Left hand (line Y)

Right lateralization of α-rhythm associated also with decrease in NCMT of Left hand (Fig. 14). This factor, coupled with a weakening of sympathetic effects and an increase in parasympathetic tone, determines the decline of the NCMT by 72% (Table 15 and Fig. 15).

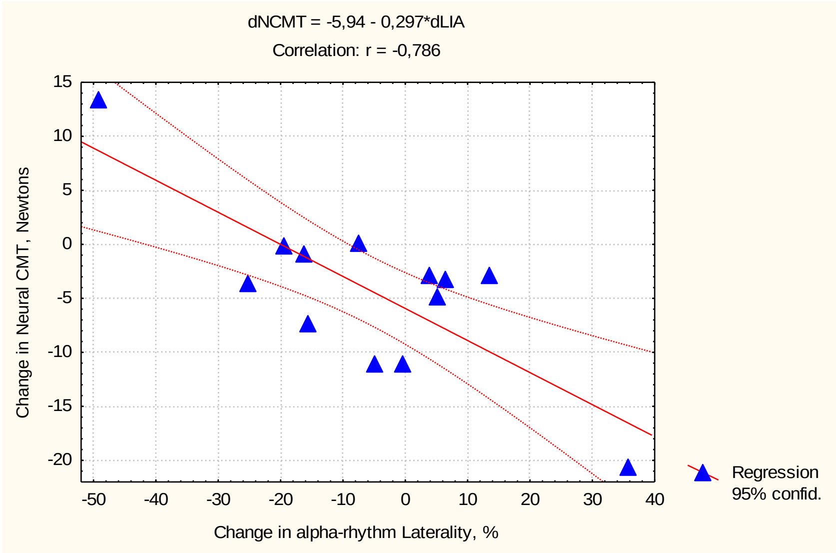
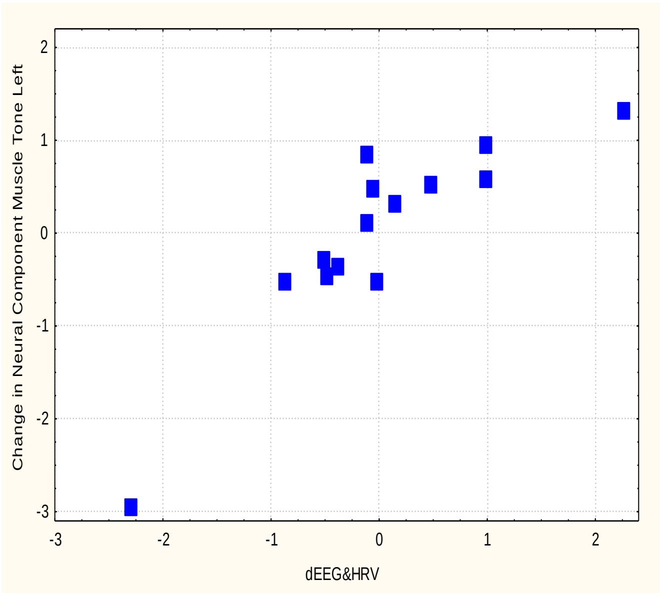


Fig. 14. Scatterplot of correlation between changes in α-rhythm Laterality (line X) and Neural Component of Muscle Tone of Left hand (line Y)

Table 15. Regression Summary for change in Dependent Variable: Neural Component of Muscle Tone
$R=0{,}887$; $R^2=0{,}786$; Adjusted $R^2=0{,}722$; $F_{(3,1)}=12{,}2$; $p=0{,}001$; SE of estimate:4,1 Newtons

Change in Independent Variables	r	Beta	St. Err. of Beta	B	St. Err. of B	$t_{(10)}$	p-level
			Intercpt	-5,03	1,23	-4,09	,002
Laterality α, %	**-0,76**	-,704	,160	-,2737	,0623	-4,39	,001
HF/TP, %	*-0,31*	-,286	,161	-,1650	,0931	-1,77	,107
VLF SP, ms^2	**0,60**	,268	,170	,0013	,0008	1,58	,146



$R=0{,}887$; $R^2=0{,}786$; $\chi^2_{(3)}=16{,}2$; $p=10^{-3}$; Λ Prime=0,214

Fig. 15. Scatterplot of canonical correlation between changes in parameters of EEG&HRV (line X) and Neural Component of Muscle Tone of Left hand (line Y)

Now detail the interactions between changes in manual tests and GDV parameters. But first we will discuss about the argument and function. If we adopt the paradigm of Occidental (Western) medicine, then changes in photoelectron emission of the skin should be interpreted as a result of neuroendocrine effects on metabolism. Instead, from the standpoint of the paradigm of Oriental medicine, photoelectric emission characterizes the state of Chakras as energy centers that control nervous, endocrine and other systems [cyt. by: 12]. We will consider GDV parameters as arguments (cause), while manual tests as a function (effect).

Already after a quick glance at the correlation matrix (Table 16), it seems that the favorable changes in the manual functions are accompanied by a **decrease**, first of all, in the Entropy of the Gas-discharge Image (GDI) in Right projection recorded through the filter (f) as well as its Symmetry and Area in Frontal and Left projections, on the one hand, instead of an **increase** in Entropy in the same projection without a filter, and also in other projections (Fig. 16) and in Shape Coefficients of GDI, on other hand.

Table 16. Correlation matrix for changes in parameters of Manual Function and GDV

Variables	B&B R	B&B L	9-HP R	9-HP L	D R	D L	NCMT L	Mean |r|
Entropy R f	**-,57**	*-,34*	**,58**	,46	**-,64**	-,75	**,58**	**0,560**
Symmetry f	*-,31*	*-,43*	*,40*	*,28*	*-,24*	*-,41*	*,41*	**0,354**
Symmetry	*-,42*	-,44	*,12*	,51	-,44	*-,12*	*-,23*	**0,326**
Area F	*-,42*	-,48	,51	*,33*	*,00*	*-,18*	*,41*	**0,333**
Area L	*-,25*	-,50	*,37*	*,26*	*-,10*	*-,24*	*,21*	**0,276**
Entropy F f	**,64**	,49	**-,60**	-,52	,50	*,37*	*-,29*	**0,487**
Shape Coef R	,52	,52	*-,36*	**-,61**	,52	*,26*	*-,02*	**0,401**
Entropy L f	*,35*	,51	*-,42*	-,52	*,20*	*,37*	*-,42*	**0,399**
Entropy R	**,62**	**,60**	*-,37*	-,52	*,37*	*,12*	*-,08*	**0,383**
Shape Coef F	,48	,50	*-,35*	-,51	,50	*,29*	*,05*	**0,383**
Entropy F	*,38*	*,22*	*-,21*	*-,34*	,50	*,09*	*-,03*	**0,253**

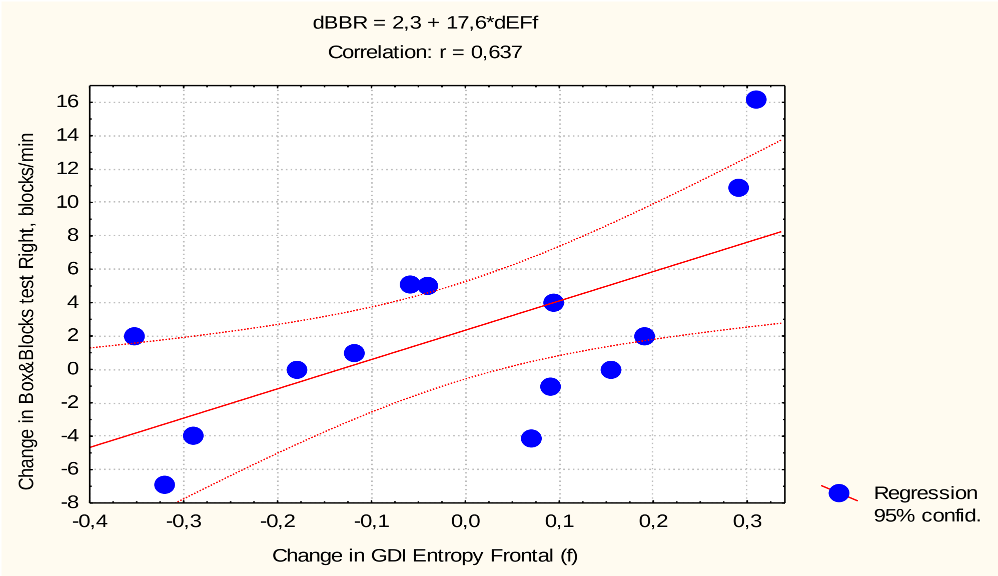
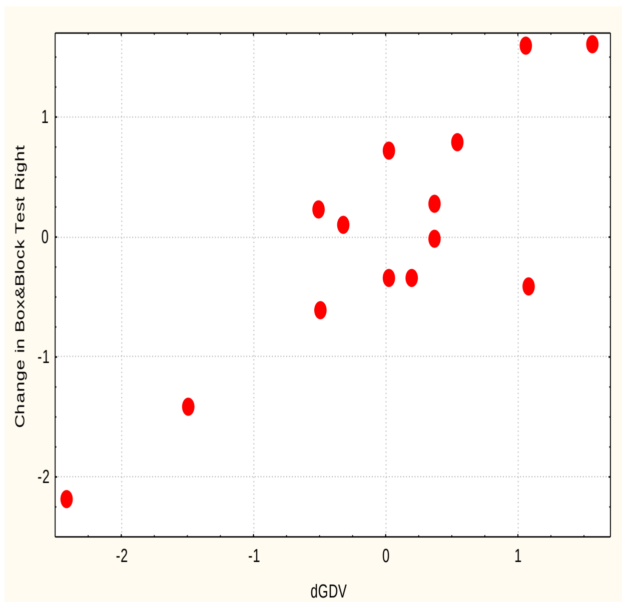


Fig. 16. Scatterplot of correlation between changes in Entropy of GDI in Frontal projection with filter (line X) and Box&Block test for Right hand (line Y)

We give no comments regressive models for changes in manual tests (Tables 17-22 and Figures 17-24).

Table 17. Regression Summary for change in Dependent Variable: Box&Block test for Right hand
$R=0,840$; $R^2=0,706$; Adjusted $R^2=0,618$; $F_{(3,1)}=8,0$; $p=0,005$; SE of estimate: 3,7 blocks/min

Change in Independent Variables	r	Beta	St. Err. of Beta	B	St. Err. of B	$t_{(10)}$	p-level
			Intercpt	2,38	1,12	2,12	,060
Entropy F f	**0,64**	,347	,201	9,57	5,54	1,73	,115
Entropy R	**0,62**	,387	,198	12,03	6,15	1,96	,079
Entropy R f	**-0,57**	-,437	,176	-25,35	10,21	-2,48	,032

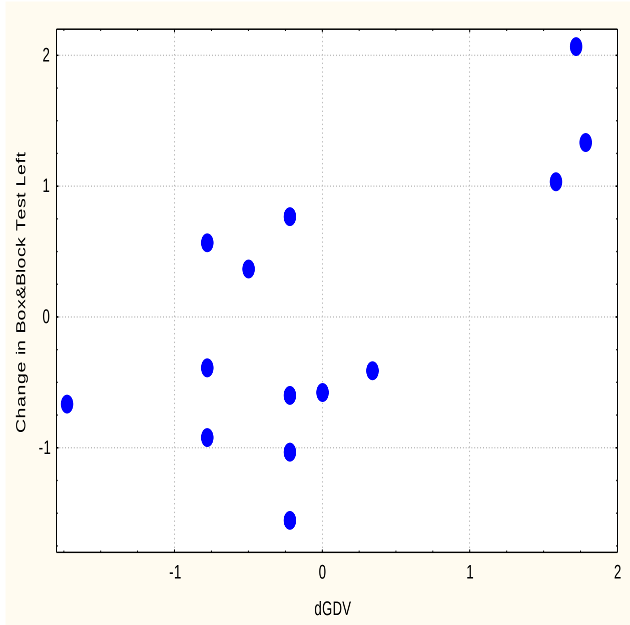


$R=0,840$; $R^2=0,706$; $\chi^2_{(3)}=12,9$; $p=0,005$; Λ Prime=0,294

Fig. 17. Scatterplot of canonical correlation between changes in parameters of GDV (line X) and Box&Block test for Right hand (line Y)

Table 18. Regression Summary for change in Dependent Variable: Box&Block test for Left hand
$R=0,680$; $R^2=0,462$; Adjusted $R^2=0,364$; $F_{(2,1)}=4,7$; $p=0,033$; SE of estimate: 2,9 blocks/min

Change in Independent Variables	r	Beta	St. Err. of Beta	B	St. Err. of B	$t_{(11)}$	p-level
			Intercpt	1,81	,85	2,14	,056
Entropy L f	0,51	,485	,222	9,46	4,32	2,19	,051
Area F, pixels	-0,48	-,447	,222	-,00043	,00021	-2,02	,069



R=0,680; R^2=0,462; $\chi^2_{(2)}$=6,8; p=0,033; Λ Prime=0,538

Fig. 18. Scatterplot of canonical correlation between changes in parameters of GDV (line X) and Box&Block test for Left hand (line Y)

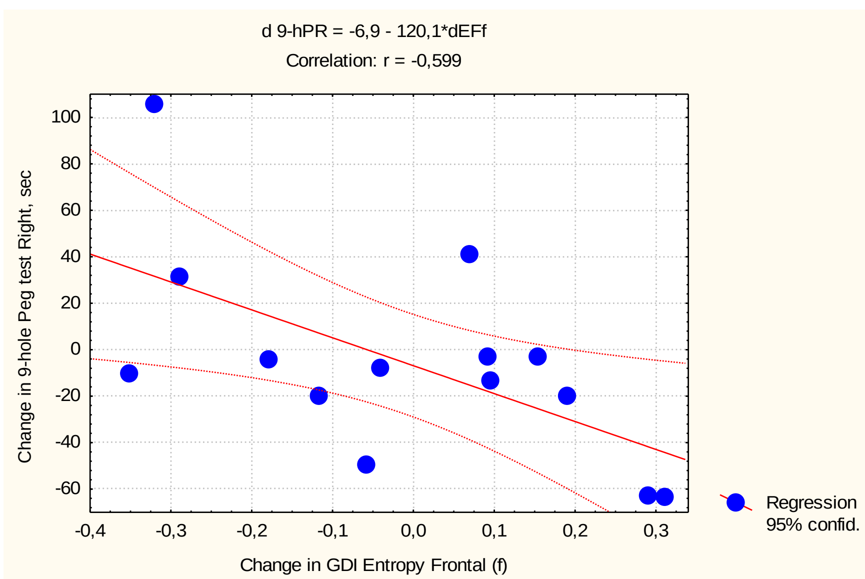
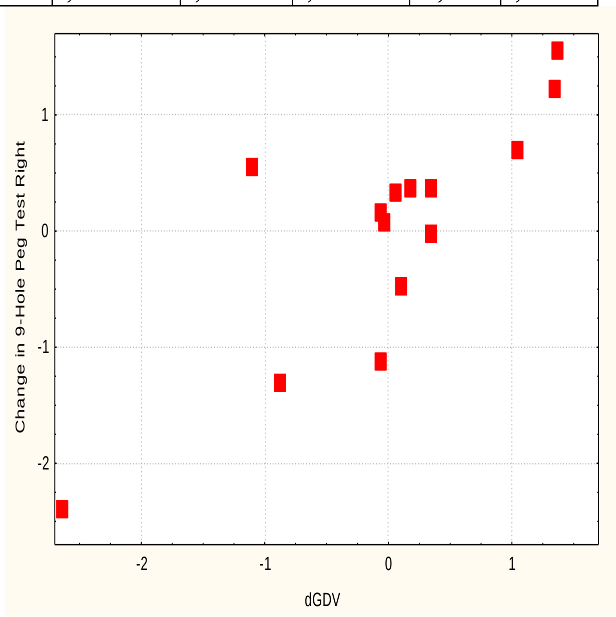


Fig. 19. Scatterplot of correlation between changes in Entropy of GDI in Frontal projection with filter (line X) and 9-Hole Peg test for Right hand (line Y)

Table 19. Regression Summary for change in Dependent Variable: 9-Hole Peg test for Right hand
$R=0,824$; $R^2=0,679$; Adjusted $R^2=0,583$; $F_{(3,1)}=7,1$; $p=0,008$; SE of estimate: 28 sec

Change in Independent Variables	r	Beta	St. Err. of Beta	B	St. Err. of B	$t_{(10)}$	p-level
			Intercpt	-11,47	8,00	-1,43	,182
Entropy F f	**-0,60**	-,456	,185	-91,4	37,1	-2,46	,033
Entropy R f	**0,58**	,399	,187	168,7	79,2	2,13	,059
Area F, pixels	0,51	,346	,185	,0039	,0021	1,87	,091

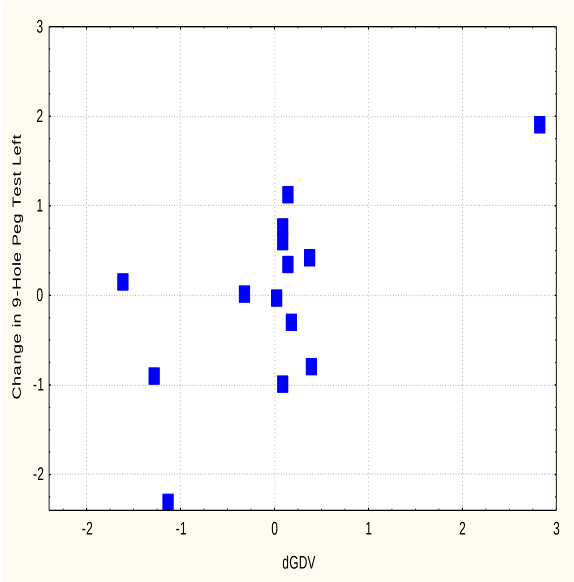


$R=0,824$; $R^2=0,679$; $\chi^2_{(3)}=11,9$; $p=0,008$; Λ Prime=0,321

Fig. 20. Scatterplot of canonical correlation between changes in parameters of GDV (line X) and 9-Hole Peg test for Right hand (line Y)

Table 20. Regression Summary for change in Dependent Variable: 9-Hole Peg test for Left hand
$R=0,637$; $R^2=0,405$; Adjusted $R^2=0,297$; $F_{(2,1)}=3,7$; $p=0,057$; SE of estimate: 44 sec

Change in Independent Variables	r	Beta	St. Err. of Beta	B	St. Err. of B	$t_{(11)}$	p-level
			Intercpt	-5,5	13,5	-0,40	,694
Entropy L f	-0,52	-,406	,244	-113,3	68,2	-1,66	,125
Symmetry, %	0,51	,383	,244	7,8	5,0	1,57	,145

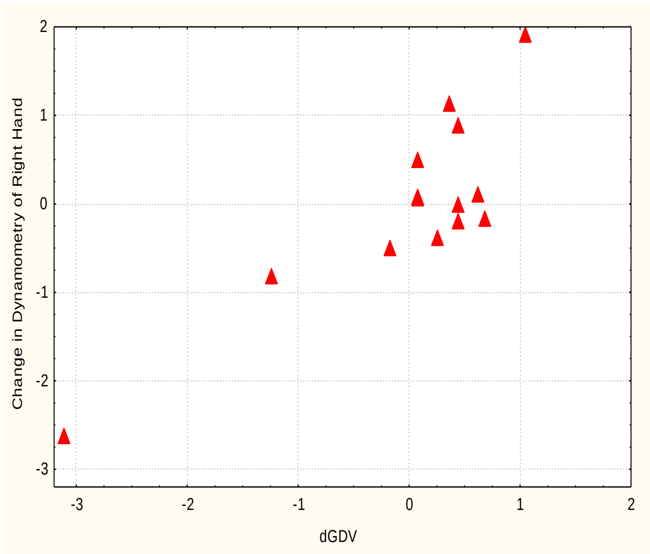


$R=0,637; R^2=0,405; \chi^2_{(2)}=5,7; p=0,057; \Lambda$ Prime=0,598

Fig. 21. Scatterplot of canonical correlation between changes in parameters of GDV (line X) and 9-Hole Peg test for Left hand (line Y)

Table 21. Regression Summary for change in Dependent Variable: Dynamometry for Right hand $R=0,848; R^2=0,719$; Adjusted $R^2=0,668; F_{(2,1)}=14,1; p=0,0009$; SE of estimate: 3,3 kG

Change in Independent Variables	r	Beta	St. Err. of Beta	B	St. Err. of B	$t_{(11)}$	p-level
			Intercpt	4,38	,94	4,68	,001
Entropy R f	**-0,64**	-,668	,160	-37,1	8,9	-4,17	,002
Shape Coef R	0,52	,552	,160	1,34	,39	3,45	,005



$R=0,848; R^2=0,719; \chi^2_{(2)}=14,0; p<10^{-3}; \Lambda$ Prime=0,281

Fig. 22. Scatterplot of canonical correlation between changes in parameters of GDV (line X) and Dynamometry for Right hand (line Y)

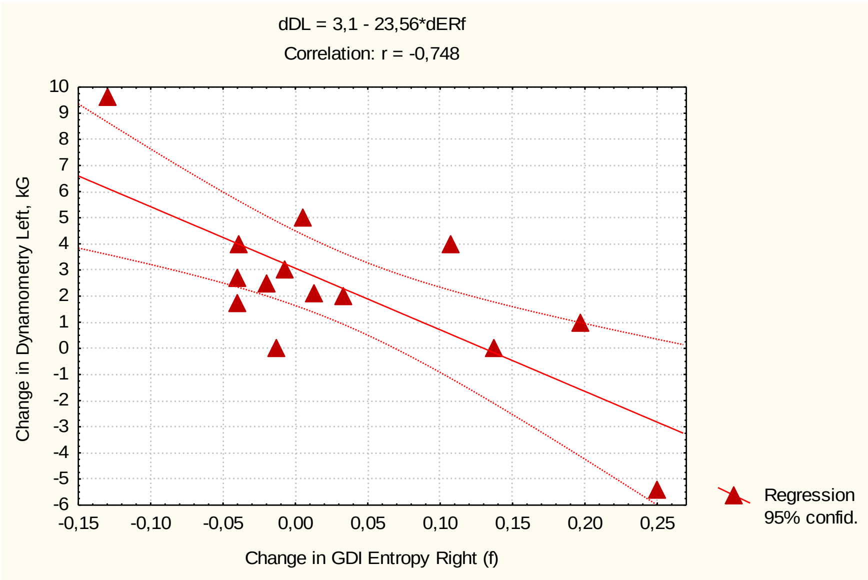
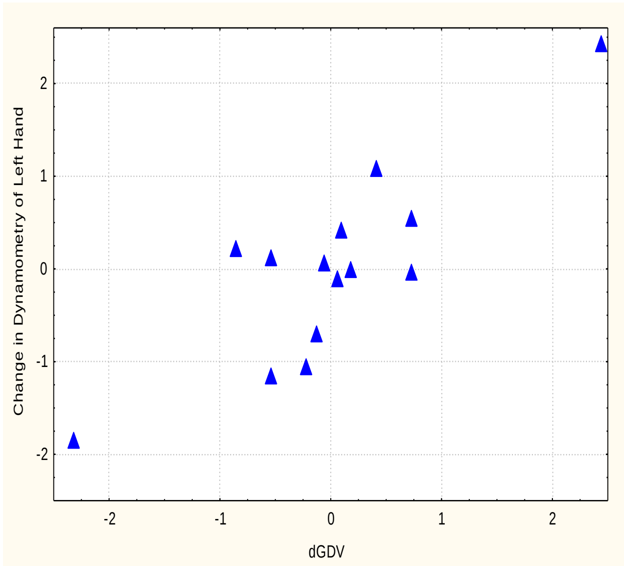


Fig. 23. Scatterplot of correlation between changes in Entropy of GDI in Right projection with filter (line X) and Dynamometry for Left hand (line Y)

Table 22. Regression Summary for change in Dependent Variable: Dynamometry for Left hand

$R=0{,}842$; $R^2=0{,}709$; Adjusted $R^2=0{,}622$; $F_{(3,1)}=8{,}1$; $p=0{,}005$; SE of estimate: 2,0 kG

Change in Independent Variables	r	Beta	St. Err. of Beta	B	St. Err. of B	$t_{(10)}$	p-level
			Intercpt	3,35	,60	5,60	,0002
Entropy R f	**-0,75**	-,651	,181	-20,5	5,7	-3,60	,0048
Symmetry f, %	*-0,41*	-,232	,181	-,28	,22	-1,28	,2288
Entropy L f	*0,37*	,342	,172	5,89	2,96	1,99	,0743



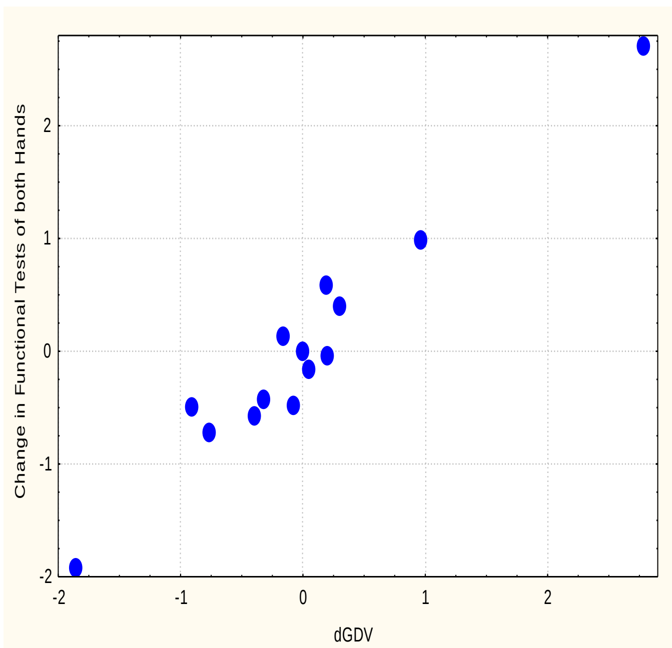
$R=0{,}842$; $R^2=0{,}709$; $\chi^2_{(3)}=13{,}0$; $p=0{,}005$; Λ Prime=0,291

Fig. 24. Scatterplot of canonical correlation between changes in parameters of GDV (line X) and Dynamometry for Left hand (line Y)

According to the outcome of the canonical analysis, the maximum **negative** (here, absolutely unnecessarily, the mathematical sign reflects just the **adverse** effect) factor load on the root of the changes in GDV gives Entropy of GDI in Right projection registered **with the filter** (Table 23).

Table 23. Factor Structure for changes in parameters of GDV (right set) and Manual Function (left set)

Right set	**R**
Entropy R f	**-,768**
Entropy F f	**,446**
Shape Coef R	**,368**
Entropy L f	**,260**
Entropy R	**,107**
Area F	**-,008**
Left set	**R**
D R	,898
D L	,866
9-HP L	-,657
9-HP R	-,494
B&B R	,523
B&B L	,352



$R=0{,}974$; $R^2=0{,}949$; $\chi^2_{(36)}=53$; $p=0{,}035$; Λ Prime=0,0003

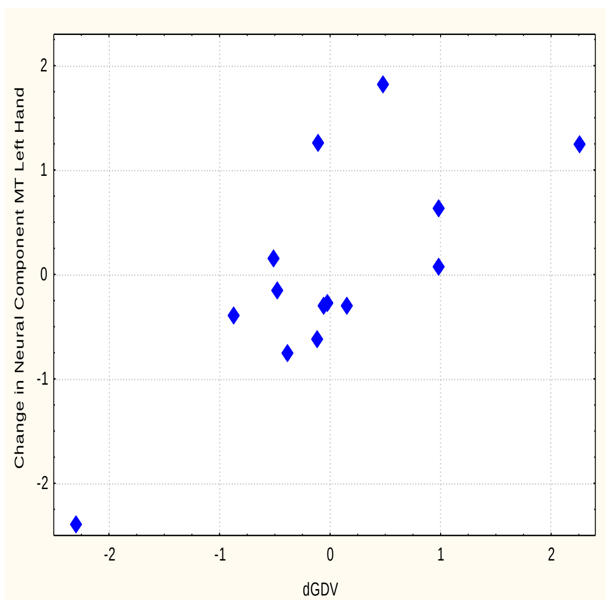
Fig. 25. Scatterplot of canonical correlation between changes in parameters of GDV (line X) and Functional tests for both hands (line Y)

Instead, Entropy, registered in the same projection **without a filter**, as well as in the Frontal and Left projections **with the filter,** give **positive (favorable)** factor loads. Our data are not entirely consistent with the statement KG Korotkov [12] that GDI, taken off **without** filter, characterizes the **current** (functional) vegetative status and psychophysiological condition of organism while registered **with** a filter characterizes vegetative regulation at the level of **stable** (organic) physiological processes.

The same applies also to the role of changes in Entropy in changes in Neural Component of Muscle Tone (Table 24 and Fig. 26). Now our data on an example of changes in Symmetry of GDI confirm the position on the normality of asymmetry and abnormality of symmetry.

Table 24. Regression Summary for change in Dependent Variable: Neural Component of Muscle Tone for Left hand
$R=0{,}746$; $R^2=0{,}556$; Adjusted $R^2=0{,}423$; $F_{(3,1)}=4{,}2$; $p=0{,}037$; SE of estimate: 5,9 Newtons

Change in Independent Variables	r	Beta	St. Err. of Beta	B	St. Err. of B	$t_{(10)}$	p-level
			Intercpt	-5,93	1,75	-3,39	,007
Entropy R f	**0,58**	,458	,223	34,2	16,6	2,05	,067
Symmetry f, %	*0,41*	,294	,223	,83	,63	1,32	,218
Entropy L f	*-0,42*	-,407	,212	-16,6	8,6	-1,92	,084



$R=0{,}746$; $R^2=0{,}556$; $\chi^2_{(3)}=8{,}5$; $p=0{,}036$; Λ Prime=0,444
Fig. 26. Scatterplot of canonical correlation between changes in parameters of GDV (line X) and Neural Component of Muscle Tone of Left hand (line Y)

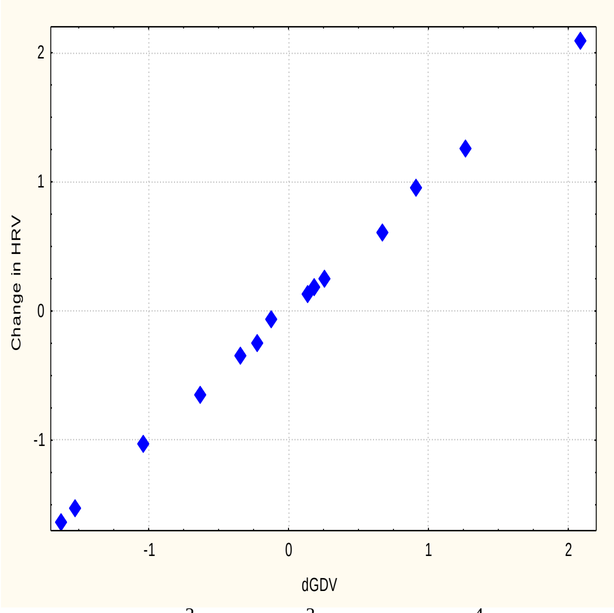
In conclusion, we are pleased to present new evidence of the interelationships between changes in GDV parameters, on the one hand, and HRV and EEG parameters, on the other hand. Regarding HRV, the following is revealed (Table 25 and 26, Fig. 27).

Table 25. Correlations between changes in parameters of GDV and HRV

Variables	Entropy F f	Shape Coef R	Entropy L f	Entropy R f	Symmetry	Area F
VLF	**-,70**	*-,39*	*-,33*	*,39*	*-,13*	*,29*
ULF	-,45	**-,65**	*-,30*	*,19*	,50	*-,12*
LF	**-,59**	*-,35*	*-,25*	*,24*	*-,07*	**,54**
LF/(LF+HF)	*-,23*	*-,28*	*,09*	,52	*,42*	,45
HF/TP	,46	*,40*	*,04*	**-,54**	*-,34*	*-,25*
HF	*,15*	*,15*	*,02*	*-,29*	*-,41*	*,19*

Table 26. Factor Structure for changes in parameters of GDV (right set) and HRV (left set)

Right set	**R**
Entropy F f	**,939**
Shape Coef R	**,692**
Entropy L f	**,642**
Entropy R f	**-,407**
Symmetry	**-,364**
Area F	**-,035**
Left set	**R**
VLF	**-,650**
ULF	**-,543**
LF	**-,461**
LF/(LF+HF)	**-,248**
HF/TP	**,491**
HF	**,264**



R=0,9996; R^2=0,999; $\chi^2_{(36)}$=75; p=10^{-4}; Λ Prime<10^{-5}

Fig. 27. Scatterplot of canonical correlation between changes in parameters of GDV (line X) and HRV (line Y)

As you can see, there is a very strong dependence between changes in vagal and sympathetic tones as well as circulating cathecholamines level, on the one hand, and in parameters of GDV on the other hand.

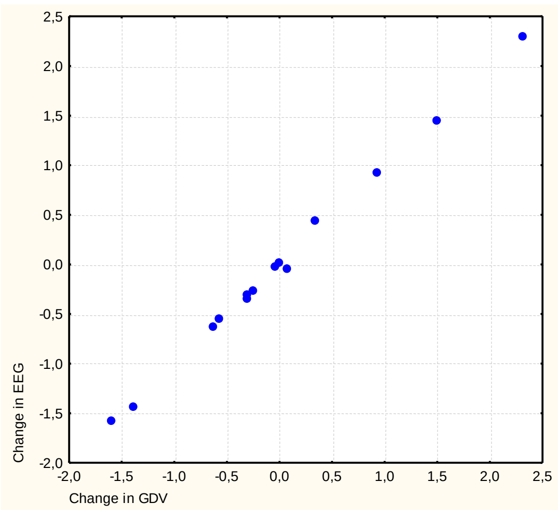
With regard to EEG, the canonical correlation coefficient is also similar to 1, but the factor structure for GDV includes only three variables from the six previous ones (Table 27 and 28, Fig. 28).

Table 27. Correlations between changes in parameters of GDV and EEG

Variables	Area F	Entropy F f	Entropy R f
T4-β SPDA	**-,55**	,47	*,08*
Asymmetry θ	-,45	,45	*,03*
F4 Entropy	,46	*-,26*	*-,06*
F8-α SPDA	-,43	*,23*	*-,23*
Fp1 Entropy	,44	*,11*	*,10*
Index θ	*,20*	*-,30*	**,54**
T3-β SPDR	*,14*	*-,39*	,46
Laterality α	*-,16*	*-,01*	**-,60**
T6 Entropy	*,15*	*,14*	**,61**

Table 28. Factor Structure for changes in parameters of GDV (right set) and EEG (left set)

Right set	**R**
Area F	**,930**
Entropy R f	**,183**
Entropy F f	**-,494**
Left set	**R**
T4-β SPDA	**-,672**
Asymmetry θ	**-,574**
F8-α SPDA	**-,446**
Laterality α	**-,078**
F4 Entropy	**,508**
Fp1 Entropy	**,337**
Index θ	**,235**
T3-β SPDR	**,228**
T6 Entropy	**,016**



$R=0{,}9989$; $R^2=0{,}998$; $\chi^2_{(27)}=68$; $p=10^{-4}$; Λ Prime$<10^{-4}$

Fig. 28. Scatterplot of canonical correlation between changes in parameters of GDV (line X) and EEG (line Y)

CONCLUSION

Despite the small contingent of the observed children with spastic form of cerebral palsy, we have proved that the differently directed changes in the parameters of manual tests caused by two-week rehabilitation course by Kozyavkin© method are due to differently directed changes in parameters of EEG, HRV as well as GDV. Increasing the effectiveness of rehabilitation, perhaps, is possible through additional electrostimulation of the vagus nerve and/or certain scalp loci. GDV is a completely suitable non-invasive method for assessing the effectiveness of rehabilitation.

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ACCORDANCE TO ETHICS STANDARDS

Tests in patients are conducted 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 parents all participants the informed consent is got and used all measures for providing of anonymity of participants.

For all authors any conflict of interests is absent.

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