DOI: 10.25696/ELSYS.VC1.EN.8

CLINICAL APPLICATION OF VIBRAIMAGE TECHNOLOGY AND SYSTEM FOR SCREENING OF ADHD CHILDREN

Choi Jin Kwan[1], *Jung Seung Pil*[2]
[1] VIBRASYSTEM Co., Ltd, South Korea (kwan.choi@vibrasystem.co.kr);
[2] Department of Family Medicine, Yeungnam University College of Medicine, Daegu, South Korea (spjung@ynu.ac.kr).

Abstract: *Attention deficit/hyperactivity disorder (ADHD) refers to a variable cluster of hyperactivity, impulsivity, and inattention symptoms. Its occurrence substantially affects normal cognitive and behavioral functioning of the individuals. Children's ADHD may be continued to adolescent and then, old ages. Therefore, it is very important not to be influenced to a lot of accidents and victims due to ADHD in all ages. For monitoring and tracking the severity of ADHD, in medical field for analysis and diagnosis about ADHD, we need to find out the easily comfortable and reliable diagnosis method to screen ADHD. Up to now, ADHD diagnosis criteria was suggested by quantitative electro- encephalography (QEEG) in the general inspection equipment. By comparing the acquisition data between EEG's criteria and vibraimage measurements used only by the captured real video image, we can extract the strongly co-related parameters in vibraimage technology.*

Keywords: *ADHD (Attention Deficit/Hyperactivity Disorder), Vibraimage technology, Quantitative electroencephalography (QEEG), Psychophysiology.*

1. Introduction

Attention deficit/hyperactivity disorder (ADHD) affects approximately three to 5% of school-age children in the United States [1, 2], and from 6% to 8% [3] in South Korea. ADHD refers to a variable cluster of hyperactivity, impulsivity, and inattention symptoms. Its occurrence substantially affects normal cognitive and behavioral functioning of the individuals.

Children and adolescents with ADHD are at risk for later delinquency problems [4], and some symptoms may persist through the lifespan. There have been reports that between 50% and 70% of children with ADHD will continue to suffer from the disorder as adults [5, 6]. The American Psychiatric Association's Diagnostic and Statistical Manual, Fifth edition (DSM-5) is used by mental health professionals to help diagnose ADHD [7].

The criteria used to diagnose ADHD have changed over time. Researchers who study ADHD have used different definitions to diagnose ADHD leading to disagreement about the number, characteristics, and outcomes of children with the disorder. Deciding if a child has ADHD is a multi-step process. There is no single test to diagnose ADHD, which is a common challenge for diagnosing many other mental problems such as anxiety, depression, and certain types of learning disabilities.

There are few objective assessment procedures available. Since ADHD is considered to result from a central nervous system dysfunction and since electroencephalography

(EEG) provides a direct measure of brain functioning, EEG appears to be an appropriate tool for assessing ADHD. A number of researchers have investigated the utility of EEG measures in the diagnosis of ADHD [8, 9]. Especially, the theta/beta ratio could discriminate ADHD from control subjects with high sensitivity and specificity [10].

Even though QEEG method can provide the diagnostic value by the high discriminant validity, there are some limitations, difficulties and inconveniences to diagnose ADHD. Therefore, to overcome the complicated diagnosis process, the new diagnosis or screening technology has been strongly demanded by the contactless method based on video image.

Recently, a new technology named "Vibraimage" is used not only in security system for detecting potentially dangerous passengers in aviation and airport, but also in psycho-physiological detection of deception (Lie detection system). This technology is based on the fact that there are direct correlations between the head micromobility and the emotional and functional states of human [11, 12]. Vibraimage technology provides functional and physiological diagnosis inferred from quantitative information about periodic movements at each point of the object [11, 12, 13]. In the present clinical study, we investigated the screening power of Vibraimage technology on ADHD children compared with quantitative electroencephalography (QEEG).

2. Research Study Aims and Objectives

As Children's ADHD may be continued in all ages, it is very important how to diagnosis and screen ADHD symptom by the easy and reliable equipment. Moreover, we need to monitor and track his state by treatment in hospital and family's intensive care because he may take an instantly impulsive accident. It is certainly a social problem in terms of security by a personal psychiatry's disorder. Therefore, the medical analysis and diagnosis about ADHD grows to require the specific followings through their life. By this research, the purpose is to develop and extract the diagnosis and screen criteria by comparing all the acquisition data between EEG and vibraimage technology. At the end, we will use and operate the vibraimage technology equipment in the general inspection of ADHD diagnosis or screen instead of the very limited operation and inspection by EEG machine. We can provide the reliable measurement data and criteria in ADHD diagnosis or screen by the captured real video image just for 1 minute operation [12, 22, 23].

3. Method

3.1. Study population

The study population consisted of 60 children with ADHD, and 50 healthy controls (8 and 16 years of age), recruited through advertisement to the local population and hospitals and through periodic school examination from the elementary and middle schools. The ADHD diagnosis was based on the DSM-IV criteria: semi-structured and standardized interview by a trained investigator. Subjects provided written informed consent prior to participation and they were reimbursed for their time and expenses. Exclusion criteria for subjects included extreme over- and under-weight, autism, epilepsy, general learning difficulties, brain disorders and any genetic or medical disorder associated with externalizing behavior that mimics ADHD.

3.2. Inattention/hyperactivity scale

The symptoms were assessed using questionnaires on 14-scales, including DSM-IV-based ADHD scales [13] (i.e. 9 inattention and 9 hyperactivity/impulsivity symptoms), by parents, school teachers and trained interviewers. The questions for inattention assessed the following symptoms: failure to provide close attention to detail; careless mistake; difficulty maintaining attention in play, school, or home activities; seems not to listen, even when directly addressed; fails to follow through; difficulty organizing tasks, activities, and belongings; avoids tasks that require consistent mental effort; loses objects required for tasks or activities; easily distracted by irrelevant stimuli; and forgetfulness in routine activities. The questions for hyperactivity and impulsivity assessed the following symptoms: excessive fidgetiness; difficulty remaining seated when sitting is required; feelings of restlessness or inappropriate running around or climbing; difficulty playing quietly; difficult to keep up with, seeming to always be “on the go”; excessive talking; difficulty waiting turns; blurting out answers too quickly; and interruption or intrusion of others.

3.3. Quantitative Electroencephalography (QEEG) theta/beta ratio (TBR)

We collected electroencephalography (EEG) data at baseline (Week 0), and during the second visit (Week 8). One hundred and ten subjects (ADHD group 60, Control group 50) were completely examined. All subjects were not allowed to take any medication the night before. QEEG was recorded by using MITSAR EEG 201 system, which is a PC-controlled 21-channel EEG system. This session lasted about one to one-half hour. The input signals were referenced to the linked ears and were filtered between 0,5 and 50 Hz. The signals were digitized at a sampling rate of 500 Hz. Impedance was kept below 5 kOhm for all electrodes that were placed according to the international 10–20 system, using electrode cap with 19 electrodes (Electro-cap International Inc.). Two reference input connectors (A1 and A2) and two ground input connectors were used for successful EEG recordings. Quantitative data were obtained by using WIN-EEG software. The band ranges for theta and beta were set at 4–8 Hz and 13–21 Hz respectively, registered at Cz, in the eyes-opened (EO) condition measured for 5 minutes, in accordance with the literature [14].

3.4. Vibraimage monitoring

For Vibraimage fixation standard systems, such as web-camera, or digital camcorder were used [12]. Fixed resolution of camera was 640 x 480, although Vibraimage quality significantly depended on noise parameters. Standard notebook PC with processor Intel Core Ivy Bridge i5 and Vibraimage software 10 of ELSYS Corp. was used [22]. Web-camera was installed at the distance of approximately 0,5 m in front of the head of the subject so that the facial image filled more than 30% of the screen for one minute. Also, low-frequency video camera (frame rate, 20–30 Hz) was used in order to increase accuracy of micromovement monitoring.

3.5. Statistical analysis

The mean (M) values between ADHD group and normal control group were compared using the student's t-test analysis. The most predictive Vibraimage parameters were selected by discrimination analysis. All analyses were conducted using XLSTAT software developed in Addinsoft company and p-value less than 0,05 was considered statistically significant.

4. Result

4.1. Baseline Characteristics of the Subjects

The subjects' baseline characteristics are summarized in Table 1. The mean age of the ADHD group and the healthy control group were 11,40 ± 1,90 (mean ± S.D.) (from age 8 to 16 years old) and 11,32 ± 1,52 (from age 8 to 14 years old), respectively. Although there were more males than females in the ADHD group, there were no significant differences in the gender ratio between the two groups.

Table 1

Baseline characteristics of the subjects

	ADHD group (n = 60)	Control group (n = 50)	*P*-value*
Age (years)	11,40 ± 1,90	11,32 ± 1,52	0,867
Gender			
Male	35 (58,3)	25 (50,0)	
Female	25 (41,7)	25 (50,0)	

Data is presented as mean ± standard deviation and number (%)
*Student's t-test analysis.

4.2. Comparisons of the mean QEEG theta/beta ratio (TBR) between the groups

QEEG TBR (Cz score) of the ADHD group and the control group were 5,42 ± 2,87 and 2,48 ± 0,25, respectively. The Cz scores of the male children in the ADHD group and the control group were 5,11 ± 2,65 and 2,43 ± 0,26, respectively. Similarly, in female children, the Cz scores were 5,85 ± 3,09 and 2,54 ± 0,22, respectively. (Table 2) There were significant differences in the Cz score between the two groups (Fig. 1).

Table

Comparisons of the mean QEEG theta/beta ratio (TBR)

	ADHD group	Control group
Cz score (Total)	5,42 ± 2,87	2,48 ± 0,25
Male	5,11 ± 2,65	2,43 ± 0,26
Female	5,85 ± 3,09	2,54 ± 0,22

Data is presented as mean ± standard deviation.

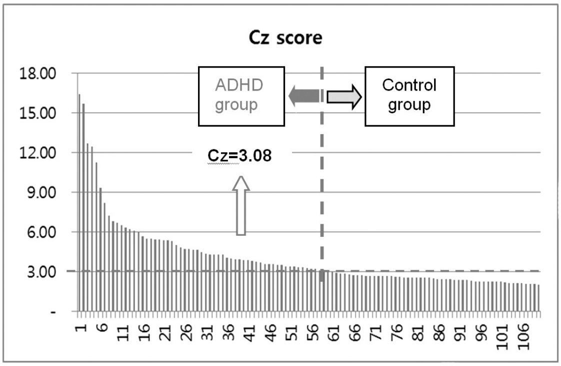

Fig. 1. Comparison of Cz score between ADHD and Control group

4.3. Comparisons of mean (M) value of Vibraimage parameters between the groups

The main objective of this study was to find out the efficiency of Vibraimage system as a diagnosing tool for ADHD when compared to QEEG TBR (Cz score). In order to deduce the discriminant, the test sample and the holdout sample were selected as shown in Table 3. They were selected randomly, using random number table.

Table 3

Compositions of Sample group

	Test sample	Holdout sample	Total
Control group	37	13	50
ADHD group	48	12	60
	85	25	110

The mean (M) values for each of the ten Vibraimage parameters, for the 60 children in the ADHD group and for the 50 children in the control group, are shown on Figure 2.

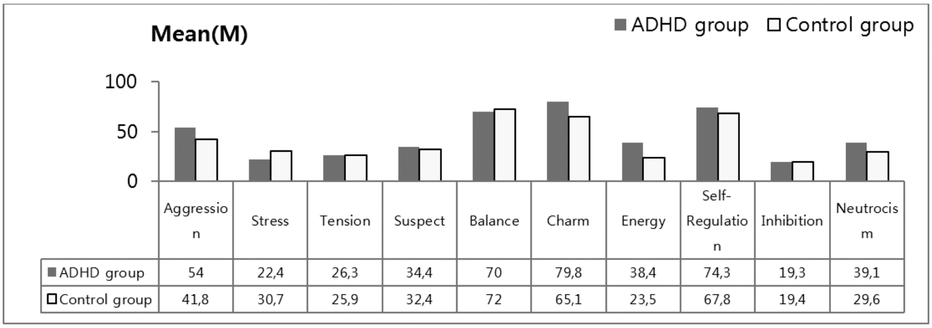

Fig. 2. Mean (M) comparisons between ADHD and Control group

4.4. The predictive Vibraimage parameters to discriminate ADHD

One of the objectives of this study was to verify whether it is possible to diagnose ADHD only using the Vibraimage parameters, and if it is possible, to find out the discrimination equation. The statistical analysis that is suited to this purpose is the discriminant analysis: It is a technique used (a) in deducing the linear combination of independent variables that can best discriminate a distinct group among the grouping variables and (b) in predicting the group to which new cases will belong. Therefore, this study tried to verify the discrimination accuracy when using the discriminant function that classifies the ADHD and the control group.

Table 4 shows the T-test result for the subjects' mean (M) values of Vibraimage parameters, classified as the ADHD and the control group. There were seven mean (M) variables that were significantly different between the two groups at the 5% level: aggression (T1), stress (T2), suspect (T4), charm (T6), energy (T7), self-regulation (T8) and neuroticism (T10). On the other hand, the other three M variables — tension (T3), balance (T5) and inhibition (T9) — were not statistically significant.

Table 4

Mean (M) value comparisons between ADHD and control group for Test sample

Item	Mean (M) between groups			T-test		
	ADHD group (N = 48)	Control group (N = 37)	Mean differentiation	t-value	DF (degree of freedom)	p-value
Aggression (T1)	54,0	41,8	12,2	10,062	83	0,0001
Stress (T2)	224	30,7	–8,3	–8,366	83	0,0001
Tension (T3)	26,3	25,9	0,4	0,198	83	0,844
Suspect (T4)	34,4	32,4	1,9	2,446	83	0,017
Balance (T5)	70,0	72,0	–1,9	–1,295	83	0,199
Charm (T6)	79,8	65,1	14,7	9,144	83	0,0001

Table 4 (*the end*)

Item	Mean (M) between groups			T-test		
	ADHD group (N = 48)	Control group (N = 37)	Mean differ-entiation	t-value	DF (degree of freedom)	p-value
Energy (T7)	38,4	23,5	14,9	6,847	83	0,0001
Self regulation (T8)	74,3	67,8	6,5	4,247	83	0,0001
Inhibition (T9)	19,3	19,4	-0,1	-0,065	83	0,948
Neuroticism (T10)	39,1	29,6	9,5	3,361	83	0,001

The measured Vibraimage parameters are put as independent variables and the holdout sample was applied. The discriminant function derived from discriminant analysis is determined from the number of dependent variable groups and from the number of independent variables. The smaller one between the number of independent variable and the number dependent variable group — 1 is the number of discriminant functions. For this study, the number of dependent variable groups was 2 (control group, ADHD group) and the number of dependent variable was 10. Therefore, one (2–1) discriminant function was derived. As the correlation result of discriminant analysis on test sample, the canonical correlation coefficients was 0,816, which represents a high correlation. When this value is high and gets closer to 1, it means that the classification accuracy is also high.

Standardized and unstandardized discriminant coefficients for the discriminant function were derived. Standardized coefficients are used in determining the importance of each input variables, and they were used in the classification of unstandardized coefficients. The results showed that among the Vibraimage parameter variables, charm (T6) and suspect (T4) had the greatest influence. Stress (T1), tension (T3) and self-regulation (T8) parameters also had influence to some degree. On the contrary, inhibition (T9) and neuroticism (T10) had little influence. The discriminant function coefficients are shown on Table 5.

Table 5

Canonical discriminant function coefficients

Parameter	Standardized	Unstandardized
Aggression (T1)	0,208	0,038
Stress (T2)	–0,361	0,079
Tension (T3)	–0,406	–0,046
Suspect (T4)	0,734	0,202
Balance (T5)	0,230	0,034
Charm (T6)	0,791	0,108
Energy (T7)	0,109	0,011

Table 5 (*the end*)

Parameter	Standardized	Unstandardized
Self-regulation (T8)	–0,530	0,076
Inhibition (T9)	–0,040	0,006
Neuroticism (T10)	0,186	0,014
Intercept	None	10,950

As shown on Figure 3, the median for the ADHD group is 1,226, and for the control group, –1,591. If the value calculated from the discriminant function of the unstandardized coefficient is close to 1,226, the case would be diagnosed as ADHD, and if the value is close to –1,591, the case would be diagnosed as normal.

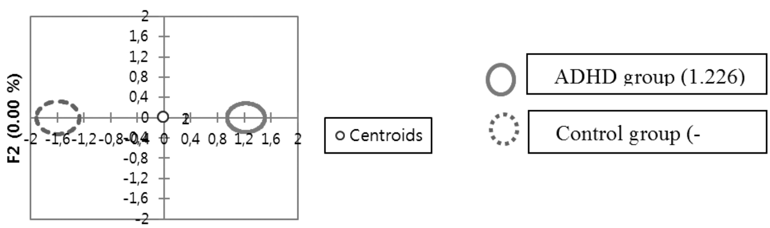

Fig. 3. Centroids and Functions at the centroids

The accuracy of the discriminant function was evaluated based on the correctness of classification of the confusion matrices of both estimation sample (Table 6) and the holdout sample (Table 10). The correctness of classification of the test sample from this study is 92,9%, which is fairly high. The correctness of classification of the holdout sample was 92,3%.

Table 6

Confusion matrix for the test sample and the holdout sample

to / group	Diagnosed ADHD		Diagnosed normal		Total		% correct	
Sample	Test sample	Holdout sample	Test sample	Holdout sample	Test sample	Holdout sample	Test sample	Holdout sample
ADHD group	48	12	0	0	48	12	100,0%	100,0%
Control group	6	2	31	11	37	13	83,78%	84,62%
Total	54	14	31	11	85	25	92,94%	92,31%

As a result, seven parameters among Vibraimage ten parameters were shown to better discriminate ADHD. Seven parameters were the mean (M) values of aggression (T1), stress (T2), suspect (T4), charm (T6), energy (T7), self-regulation (T8) and neuroticism (T10) parameter, respectively.

5. Discussion and Conclusion

Currently, no single diagnostic test for ADHD exists. A proper diagnostic evaluation for ADHD (and all other childhood psychiatric disorders) generally involves a process of collecting data on the history, course, and duration of symptoms, both at home and at school, using clinical interviews and behavior rating scales. Because inattention is pathognomic to nearly all childhood psychiatric disorders, it is often difficult to make differential diagnoses between ADHD and other disorders that can have a similar presentation, including autism spectrum disorders, mood and anxiety disorders, and learning disabilities.

Thus, a biologically based diagnostic test or biological marker (i.e., biomarker) that is sensitive and specific to ADHD would be of great assistance. Based on the findings reviewed above, EEG measures have been viewed as a promising biomarker for ADHD. The diagnostic utility of EEG is usually examined by comparing it to the gold standard for diagnosis (conclusions from a structured clinical interview) and calculating clinical group statistics including sensitivity and specificity. There were previously some reports of increased theta to beta ratio (TBR) in adults and children with ADHD [14]. Moreover, there are a number of studies on the discriminant validity of TBR for ADHD discrimination [16, 17, 18].

A study conducted by Snyder and Hall reported 94% sensitivity and specificity in predicting ADHD when the TBR effect size was 3,08. In this study, the mean TBR for ADHD group was 5,4 and for the control group — 2,5. Despite the discriminant validity of qEEG TBR, this study has some limitations. First of all, we cannot differentiate the presence of ADHD only with the abnormally elevated TBR using QEEG [20].

In addition, the elevated TBR resulted in a misclassification rate of 16% [16], meaning that by using the EEG marker alone, 16% of actual ADHD cases would be missed because they produce a normal EEG θ/β ratio. Even though QEEG has promising diagnostic value and discriminant validity, this method has limitations to be used towards screening children in which it requires a lot of time and effort. Despite the diagnostic limitations of QEEG TBR, a lot of studies until present concluded that it has high discriminant validity. Thus this study classified the presence of ADHD using TBR.

Vibraimage technology utilizes micromovements around head in order to diagnose the overall mental health state of the patient objectively, accurately, quickly and quantitatively [11]. The technology: a) measures human biological variables in a non-invasive and contactless manner; b) performs statistical analysis on the collected information and; c) diagnoses the state of the patients based on the statistics [15].

Vestibular system is related to all other functional systems [21] of human body, and effectively reacts to all mechanic, nociceptive or emotional changes. Also, vestibulo-emotion reflex draws reflective changes of micro-movements around the head in free standing position, through the constriction of muscles supporting the neck in the skeletomuscular system [15]. It can be said that the anatomical structure of all human species is essentially identical. Vestibular reflex about partial changes in the state is identical in standard situations. The informative nature of vestibular system in diagnosing various forms of pathological changes of the body enables a characteristic analysis of human psychological state through the processing of information about vestibulo-emotional reflex [11]. Using Vibraimage in actual diagnosis requires an establishment of criteria on the parameters. Vibraimage reads out the signal changes of the human organ systems.

Ten vibraimage parameters were measured based on videos of children, classified into two groups (ADHD or control) according to qEEG TBR. The ten parameters were aggression (T1), stress (T2), tension (T3), suspect (T4), balance (T5), charm (T6), energy (T7), self regulation (T8), inhibition (T9), neuroticism (T10). Mean (M) values for each parameter were obtained by Vibraimage system with Vibraimage 10 software [22].

Among mean (M) of Vibraimage parameters, the ones that best represent and have the highest correlations with psychophysiological state were selected based on statistical significance. Also, through discriminant analysis on these variables, using M score as input functions, 92,94% accuracy rate was obtained in diagnosing ADHD. A total of 7 (seven) variables that were M (mean) values of 10 Vibraimage parameters — aggression (T1), stress (T2), suspect (T4), charm (T6), energy (T7), self-regulation(T8), neuroticism (T10) — had p-value lower than 0,017 and were shown to best reflect QEEG TBR.

Based on these results, it is expected that a more advanced discriminant analysis for ADHD which is easy to use would be developed.

6. Conflict of Interest

No potential conflict of interest relevant to this article was reported.

References:

1. *Fox D. J., Tharp D. F., Fox L. C.* Neurofeedback: an alternative and efficacious treatment for attention deficit hyperactivity disorder. *Appl Psychophysiol Biofeedback* 2005; 30: 365–373.
2. *Biederman J.* Attention-deficit/hyperactivity disorder: a selective overview. *Biol Psychiatry* 2005; 57: 1215–20.
3. *Cho S., Kim B., Kim J., Rohde L. A., Hwang J., Chungh D. et al.* (2009). Full syndrome and subthreshold attention-deficit/hyperactivity disorder in a Korean community sample: Comorbidity and temperament findings. *European Child and Adolescent Psychiatry, 1:* 447–457.
4. *Satterfield J. H., Faller K. J., Crinella F. M., Schell A. M., Swanson J. M., Homer L. D.* A 30-year prospective follow-up study of hyperactive boys with conduct problems: adult criminality. *J Am Acad Child Adolesc Psychiatry*. 2007 May; 46 (5): 601–10.
5. *Mannuzza S., Gittelman-Klein R., Bonagura N., Malloy P., Giampino T., Addalli K.* Hyperactive boys almost grown up: V. Replication of psychiatric status. *Arch Gen Psychiatry* 48 (1991): 77–83.

6. *Bellak L. and Black R.* Attention-deficit hyperactive disorder in adults. *Clin Ther* 14 (1992): 138–147.
7. American Psychiatric Association: Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition, Washington, DC, American Psychiatric Association, 2013.
8. *Mann C., Lubar J., Zimmerman A., Miller C. and Muenchen R.* Quantitative analysis of EEG in boys with attention deficit hyperactivity disorder: controlled study with clinical implications. *Pediatr Neurol* 8 (1992): 30–36.
9. *Chabot R. and Serfontein G.* Quantitative electroencephalographic profiles of children with attention deficit disorder. *Biol Psychiatry* 40 (1996): 951–963.
10. *Monastra V., Lubar J., Linden M., VanDeusen P., Green G., Wing W. et al.* Assessing attention deficit hyperactivity disorder via quantitative electroencephalography: an initial validation study. *Neuropsychology.* 13 (1999): 424–433.
11. *Minkin V. A., Nikolaenko N. N.* Application of Vibraimage Technology and System for Analysis of Motor Activity and Study of Functional State of the Human Body. *Biomedical Engineering,* 2008; Vol 42, No. 4: pp. 196–200.
12. United States Patent 7,346,227 — Minkin, et al. March 18, 2008. Method and device for image transformation.
13. American Psychiatric Association: Diagnostic and Statistical Manual of Mental Disorders, fourth edition (DSM-IV). Volume 4th. Washington, DC: American Psychiatric Association, 1994.
14. *Monastra V. J., Lubar J. F., Linden M., Van Deusen P., Green G., Wing W., Phillips A., Fenger T. N.,* 1999. Assessing attention deficit hyperactivity disorder via quantitative electroencephalography: an initial validation study. *Neuropsychology* 13, 424–433.
15. *Minkin V. A, Nikolaenko N. N.* Research of psychophysiological dependence from vestibular reflex system distributed deceleration based on vibraimage method. *Kubanskiy Scientific Medical Herald* 2007; (6); 99: 23–28.
16. *Monastra V. J., Lubar J. F., Linden M.* The development of a quantitative electro-encephalographic scanning process for attention deficit-hyperactivity disorder: reliability and validity studies. *Neuropsychology* 2001; 15: 136–144.
17. *Magee C. A., Clarke A. R., Barry R. J., McCarthy R., Selikowitz M.* Examining the diagnostic utility of EEG power measures in children with attention deficit/hyperactivity disorder. *Clin Neurophysiol* 2005; 116(5): 1033–1040.
18. *Chabot R. J., Merkin H., Wood L. M., Davenport T. L., Serfontein G.* Sensitivity and specificity of QEEG in children with attention deficit or specific developmental learning disorders. *Clin Electroencephalogr* 1996; 27: 26–34.
19. *Snyder S. M., Hall J. R.* A meta-analysis of quantitative EEG power associated with attention deficit hyperactivity disorder. *J Clin Neurophysiol* 2006; 23: 440–455.
20. *Snyder S. M., Quintana H., Sexson S. B.,* et al. Blinded, multi-center validation of EEG and rating scales in identifying ADHD within a clinical sample. *Psychiatry Res* 2008; 159: 346–358.
21. *Tamar G*. Basics of sensorial physics. M., 1976. 520 p.
22. Vibraimage system for human psychophysiological behavioral control, Vibraimage 10, ELSYS Co. Ltd., Russia
23. Pub. No.: Korea 10-1500888 Method for obtaining information about the psychophysiological state a living being, Viktor Minkin, VIBRASYSTEM Co.,Ltd, Date March 3, 2015.