International Journal of Epidemiologic Research, 2016; 3(4): 376-385.

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Determining the relationship between depression and brain waves in depressed subjects using Pearson correlation and regression

Babak Mohammadzadeh[1], Kazem Sattari[2], Masoud Lotfizadeh[3*]
[1]*Clinical Psychology Dept., Tehran Olum and Tahghighat Branch, Tehran, I.R. Iran;*
[2]*Allameh Tabataba'i University, Tehran, I.R. Iran;* [3]*Social Health Determinants Research Center, Sharekord University of Medical Sciences, Shahrekord, I.R. Iran.*
Received: 30/Jan/2016 Accepted: 5/Jul/2016

ABSTRACT

Background and aims: The aim of this study was to investigate the relationship between brain waves and Beck Depression Inventory(BDI) score in clinical cases with depression.
Methods: In this study, EEG was taken using neurofeedback device at the point F4 of dorsolateral prefrontal cortex (DLPFC) of the brain of 60 depressed patients referred to psychiatric clinic. At the same time, Beck Depression Inventory was performed to assess the severity of depression. With the condition of artifact lower than 50%, fourty one EEG related to the 41 subjects were remained after eliminating artifact.
Results: The findings of this study confirm the mean decrease in alpha and theta waves and increase beta wave in the brain waves of depressed patients. Comprehensive analysis of the data with a multi-regression indicates a predictable BDI score at F4, based on two variables (mean beta and mean alpha) which reflects the depression increase by increased mean beta and decreased mean alpha according to the following equation: Depression based on Beck at F4 point is equal to: Beck's depression score= mean beta (0.532)+mean Alpha (0.412).
Conclusion: Due to rapid growth of the elderly population in the country as well as Chaharmahal and Bakhtiari province, considering the needs of this age group is an important necessity.

Keywords: Depression, Brain waves, Alpha, Beta, Theta, Delta.

Original article

INTRODUCTION

Depression is one of the major disorders in psychology that attracts many researchers' attention. Researchers have examined several factors that have an effect on depression. The brain waves, due to their ease of access and non-invasive method, are the most important source of information from the brain and brain-origin diseases. Among previous methods, one has been a study on mental disorders and brain wave using QEEG device.

Some of studies conducted in this fields are: "Quantitative electroencephalography in schizophrenia and depression" and "The relation between frontal EEG asymmetry and the risk for anxiety and depression" and "Quantitative EEG findings in patients with acute, brief depression combined with other fluctuating psychiatric symptoms."[1-3] All of them have studied somehow the relationship between brain waves and depression.

[*]**Corresponding author:** Masoud Lotfizadeh, Social Health Determinants Research Center, Sharekord University of Medical Sciences, Shahrekord, I.R. Iran, Tel: 0098333347546, E-mail: masoud_lotfizadeh@yahoo.com

There are four types of brain waves called Alpha, Beta, Theta, Delta Demos.[4]

The mean of the waves in 40-second recordings without artifacts which were obtained from patients determine operational variables of the study. According to the four-waves, four hypotheses of the study, survay the presence or absence of the relationship between the patient's score of Beck test and each of the four brain wave at point F4. Considering the mentioned issues, the aim of this study was to find significant relationships between different brain waves at F4 of dorsolateral prefrontal cortex and the depression score of Beck's inventory.

Poursharifi et al, had used Procomp Infinity and SCL parameter of skin conductance to compare anger in an article entitled "Preliminary study on the effect of violence video games on male children exciting". Their study is similar experimentally to the present study considering the use of neurofeedback system as a QEEG system. Also, Ahamadi et al, in an article entitled "Studying the relationship between patterns of brain waves and the apparent aggressions", used the relationship between brain waves and concrete actions; they aimed to compare the brain waves activity of the aggressive subjects with the healthy subjects using QEEG. The aim of this study was to evaluate the use of QEEG brain wave activity in subjects with non-aggression and subjects using concrete actions. The method of this study was retrospective in which 30 patients with aggression problem were selected from subjects reffered to psychiatric clinic, and were compared to 30 healthy subjedcts in terms of gender and age. Artifact- free waves were analyzed using Fast Fourier Transform (FFT), and relative powers of alpha, theta, delta, and beta bands were obtained in different regions of the brain. The results showed that people with aggression have lower theta activity in the frontal, temporal, Central, and parietal regions compared with normal subjects. They also had higher rates of beta activity in the frontal, temporal, central and parietal regions. The results suggest that people with aggression have different patterns of brain waves activity.

In this regard, Budzniski in his book "Introduction to quantitative EEG and neurofeedback: Advanced theory and applications " notes that in depressed patients decreased alpha and theta waves and increased beta waves in the frontal part of the patients' brain are observed.[6] There are other conducted studies on the relationship between brain waves and other parameters such as depression, anxiety, and schizophrenia scores. Some of the studies are as follows: Quantitative electroencephalography in schizophrenia and depression; The relation between frontal EEG asymmetry and the risk for anxiety and depression; Quantitative EEG findings in patients with acute, brief depression combined with other fluctuating psychiatric symptoms.[1-3]

Therefore, the aim of this study was to investigate the relationship between brain waves and Beck Depression Inventory score in clinical cases with depression.

METHODS

The present research is a correlational study that has been conducted using regression and correlation methods. Data was obtained as field collection. The study is a cross-sectional and applied one in terms of time and objective, respectively.

The population consisted of all patients with depressive disorder referred to the psychiatric clinic in the city of Tabriz during three month: February, March, and April. Sixty subjects from the population of depressed patients admitted to psychiatric clinics were introduced by Tabriz psychiatrists to the researhcer as accessible subjects with convenience sampling method. After introducing and explanation about the test, the

Beck test was conducted to assess baseline depression. Techniques and tools for data collection were: Beck inventory and Procomb Infiniti system, which were used in this study to record the EEG.

Reliability and validity of the Beck Depression Inventory-Second version (BDI-II) were assesed. The inventory consists of 21 groups of questions, and answers to them are scored between 0 and 3. Beck inventory has a 0.71 correlation with the Hamilton Depression Rating Scale and one week test-retest reliability is 0.93.[7]

Reliability and validity of procomp 2 were evaluated. In this study, a two-chanal Procomp 2 system with a frequency range of 0.5- 40 Hz (Infiniti) was used to record the EEG. Also, eight Hz sampling rates were used.[8] No previous research has examined the reliability and validity of the device. The reliability of the device, internal consistency was determined using SPSS software. So, the coefficient was measured as 0.745. Cronbach's alpha coefficient: Reliability statistics of the Procomp device are stated Deltamean (0.660), Thetamean (0.648), Alphamean (0.643), Betamean (0.628), BEK (0.755). All validities are higher than 0.6, and the Cronbach's alpha is high for all alphas. So, the device has had a good performance even about a minor reliability.

For data collection, the Neurofeedback system which has been used by Akgunduz, and Aurup in preference extraction from EEG, was used also in this study to record EEG.[9,10] However, the necessary changes had been applied on the device by the researcher to fit its soft and hard wares with the present study. In compliance with the professional ethics in referrals as well as at the top of the Beck questionnaire that was provided to patients. The researcher assured them that no electricity entered their body through the use of ProComm device electrode. Also, a written consent was received from each subject to conduct the test and publish the results. After completing the recording process, the noises which affected the EEG during recording process were removed using Artifact Rejection part of the device. Then, the cleaned EEG is changed to a word file according to Generate Text Report menu. The numerical value of variable was written in the word file.

SPSS software was used for data analysis. Pearson correlation and regression was used as statistical manners. Descriptive statistics results of variables in this section: the frequency, the frequency percentage and data mean have been reported.

Of the total sample of 41 subjects, 34.1% (n=14) were women and 65.9% (n=27) were men.

Age group frequency distribution from the entire sample of 41 subjects, 19.5%, 17.1%, 22%, 22%, 12.2, and 7.3% were 12-16, 17-21, 18-26, 27-31, 32-36, and 37-41 years old, respectively.

Descriptive statistics of Beck's depression variable in the Beck's descriptive the lowest, highest, mean, and standard deviation have been reported as 1, 36, 13.55, and 8.08.

The lowest, highest, and mean values of each parameter of brain waves have been reported in Table 1.

Table 1: Descriptive statistics of brain waves

Variable	N	Lowest value	Highest value	Mean	SD
Alpha mean	41	3.39	9.69	6.23	1.57
Beta mean	41	3.80	10.43	7.25	2.14
Theta mean	41	4.48	10.60	7.21	1.57
Delta mean	41	6.14	11.72	8.45	1.33

Data analysis was conducted using Pearson correlation tests and multiple regressions. Hypotheses in this research were: The depression score of depressed subjects is associated with the DLPFC region alpha wave mean, the depression score of depressed subjects is not associated with the DLPFC region alpha wave mean, and the depression score of depressed subjects is associated with the DLPFC region alpha wave mean.

Pearson correlation test between alpha mean and Beck's depression -0.461, P=0.002, and N=41. The relationship between depression in becke's score and alpha mean at F4 (DLPFC) was measured with neurofeedback system and was analyzed using Pearson correlation coefficient. Preliminary analysis to ensure no violation from linear normality assumptions and uniform distribution was conducted. There was a moderate negative correlation between the two variables. r=-0.461, N=41, and P<0.05, such that with increased beck's depression, alpha mean is reduced at F4. To test the impact of the independent variable on the dependent variable, multiple regression test was used.

As P of the test is 0.002; so, it can be argued that the above test is significant with a confidence level of 0.95 or error of 0.05. Then, hypothesis H1 is confirmed and H0 is rejected. According to the R2 determination coefficient which is the ratio of changes by variable X to the total changes (0.212), it can be said that 21.1% of alpha mean changes in DLPFC region is explained by the Beck's depression (Table 2).

Table 2: Analysis of the impact of the first hypothesis variance related to regression model of alpha mean variables in DLPFC region on Beck's depression

SD		**Modified determination coefficient**		**R^2 determination coefficient**		**R**
7.26		0.192		0.212		0.461
P (sig. value)	Confidence level	F	Squares mean	Total squares	FD	Changes sources
0.002	95%	10.521	555.899	555.899	1	Regression
			52.838	2060.664	39	Remain
				2516.563	40	Total

So, it is concluded that one unit increase in the independent variable of alpha mean in DLPFC region causes -2.374 unit reduction in depressive people. So, depression score of the depressed subjects is associated with the alpha mean of DLPFC region.Therefore, the mathematical relationship of the effect of alpha wave mean in DLPFC region on Beck's depression will be as follow: Y=28.362-2.374 X1.

Table 3: Coefficients of the first hypothesis alphs mean in DLPFC region

Test result	**P**	**Calculated T**	**Line slope β**	**Variable**
H0 hypothesis rejection	0.000	6.028	28.362	Intercept
H0 hypothesis rejection	0.002	-3.244	-2.374	Beck's depression

Hypothesis 2: The depression score of depressed subjects is associated with the DLPFC region beta wave mean; H0: The depression score of depressed subjects is not associated with the DLPFC region beta wave mean; H1: The depression score of depressed subjects is associated with the DLPFC region alpha wave mean.

Pearson correlation test between beta mean and Beck's depression N=41, P=0.0000, and Pearson correlation coefficient is 534. The relationship between depression in becke's score and beta mean at F4 (DLPFC) was measured with neurofeedback system and was analyzed using Pearson correlation coefficient. Preliminary analysis to ensure no violation from linear normality assumptions and uniform distribution was conducted. There was a moderate negative correlation between the two variables. r=-0.534, n=41, and P<0.05, such that with increased beck's depression, beta mean is reduced at F4. To test the impact of the independent variable on the dependent variable, multiple regression test was used. As it was observed in Table 4, the p value of the test is 0.002. So, it can be argued that the above test is significant with a confidence level of 0.95 or error of 0.05. Then, hypothesis H1 is confirmed and H0 is rejected. According to the R2 determination coefficient which is the ratio of changes by variable X to the total changes (0.285), it can be said that 28.5% of beta mean changes in DLPFC region is explained by the Beck's depression (Table 4).

Table 4: Analysis of the impact of the second hypothesis variance related to regression model of beta mean variables in DLPFC region on Beck's depression

SD		**Modified determination coefficient**		**R2 determination coefficient**		**R**
6.92			0.267	0.285		-0.534
P (sig. value)	Confidence level	F	Squares mean	Total squares	FD	Changes sources
0.000	95%	15.540	745.530	745.530	1	Regression
			47.975	1871.034	39	Remain
			-	2616.563	40	Total

Therefore, the mathematical relationship of the effect of beta wave mean in DLPFC region on Beck's depression will be as follow: Y=-1.026+2.010 X1.

Table 5: Coefficients of the first hypothesis beta mean in DLPFC region

Test result	**P**	**Calculated T**	**Line slope β**	**Variable**
H0 hypothesis rejection	0.000	-0.266	-1.026	Intercept
H0 hypothesis rejection	0.000	3.94	2.010	Beck's depression

So, it is concluded that one unit increase in the independent variable of beta mean in DLPFC region causes 2.010 unit increase in depressive people. Therefore, depression score of the depressed subjects is associated with the beta mean of DLPFC region.

Hypothesis 3: The depression score of depressed subjects is associated with the

DLPFC region theta wave mean; H0: The depression score of depressed subjects is not associated with the DLPFC region theta wave mean; H1: The depression score of depressed subjects is associated with the DLPFC region theta wave mean.

Pearson correlation test between theta mean and Beck's depression N=41, P=0.019, and pearson correlation coefficient is -0.364.

The relationship between depression in becke's score and theta wave mean at F4 (DLPFC) was measured with neurofeedback system and was analyzed using Pearson correlation coefficient. Preliminary analysis to ensure no violation from linear normality assumptions and uniform distribution was conducted. There was a moderate negative correlation between the two variables. r=-0.364, n=41, and P<0.05, such that with increased beck's depression, theta wave mean is reduced at F4. To test the impact of the independent variable on the dependent variable, multiple regression test was used. The P of the test is 0.019. So, it can be argued that the above test is significant with a confidence level of 0.95 or error of 0.05. Then, hypothesis H1 is confirmed and H0 is rejected. According to the R2 determination coefficient which is the ratio of changes by variable X to the total changes (0.132), it can be said that 13.2% of theta wave mean changes in DLPFC region is explained by the Beck's depression (Table 6).

Table 6: Analysis of the impact of the third hypothesis variance related to regression model of theta mean variables in DLPFC region on Beck's depression

SD		**Modified determination coefficient**		**R^2 determination coefficient**		**R**
7.62			0.110	0.132		-0.364
P (sig. value)	Confidence level	F	Squares mean	Total squares	FD	Changes sources
0.019	95%	5.956	346.663	346.663	1	Regression
			58.203	2269.900	39	Remain
			-	2616.563	40	Total

Therefore, the mathematical relationship of the effect of theta wave mean in DLPFC region on Beck's depression will be as follow: Y=27.037-1.870 X1.

Table 7: Coefficients of the first hypothesis theta mean in DLPFC region

Test result	**P-value**	**Calculated T**	**Line slope β**	**Variable**
H0 hypothesis rejection	0.000	4.783	27.037	Intercept
H0 hypothesis rejection	0.019	-2.441	-1.870	Beck's depression

So, it is concluded that one unit increase in the independent variable of theta wave mean in DLPFC region causes 1.870 unit reduction in depressive people. Therefore,

depression score of the depressed subjects is associated with the theta wave mean of DLPFC region.

Hypothesis 4: The depression score of depressed subjects is associated with the DLPFC region delta wave mean; H0: The depression score of depressed subjects is not associated with the DLPFC region delta wave mean; H1: The depression score of depressed subjects is associated with the DLPFC region delta wave mean.

Pearson correlation test between delta mean and Beck's depression N=41, P=0.235, pearson correlation coefficient depression is -0.190.

The relationship between depression in beck's score and delta wave mean at F4 (DLPFC) was measured with neurofeedback system and was analyzed using Pearson correlation coefficient. Preliminary analysis to ensure no violation from linear normality assumptions and uniform distribution was conducted. There was a moderate negative correlation between the two variables. r=-0.190, N=41, and P<0.05, such that with increased beck's depression, delta wave mean is reduced at F4. To test the impact of the independent variable on the dependent variable, multiple regression test was used. The P of the test is 0.235; so, it can be argued that the above test is not significant with a confidence level of 0.95 or error of 0.05. Then, hypothesis H0 is confirmed and H1 is rejected (Table 8).

Table 8: Analysis of the impact of the fourth hypothesis variance related to regression model of delta wave mean variables in DLPFC region on Beck's depression

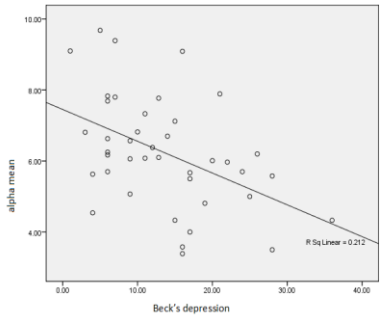
SD		**Modified determination coefficient**		**R2 determination coefficient**		**R**
8.04			0.011	0.036		-0.190
P (sig.value)	Confidence level	F	Squares mean	Total squares	FD	Changes sources
0.235	95%	1.453	93.982	93.982	1	Regression
			64.682	2522.581	39	Remain
			-	2616.563	40	Total

Therefore, the mathematical relationship of the effect of delta wave mean in DLPFC region on Beck's depression will be as follow: Y=23.259-1.148 X1.

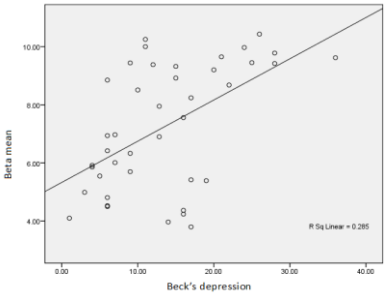
Table 9: Coefficients of the fourth hypothesis delta wave mean in DLPFC region

Test result	**P**	**Calculated T**	**Line slope β**	**Variable**
H0 hypothesis rejection	0.007	2.854	23.259	Intercept
H0 hypothesis rejection	0.235	-1.205	-1.148	Beck's depression

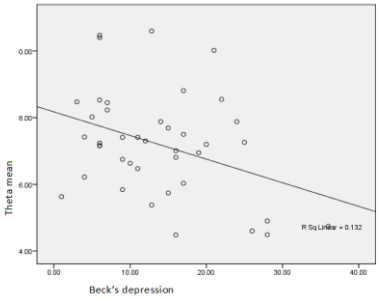
So, it is concluded that one unit increase in the independent variable of delta wave mean in DLPFC region doesn't cause -1.148 unit reduction in depressive people. Therefore, depression score of the depressed subjects is not associated with the delta wave mean of DLPFC region.



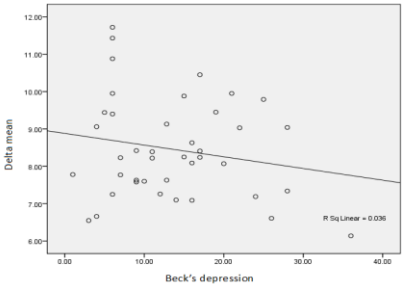
A: Alpha



B: Beta



C: Theta wave



D: Delta wave

Figure 1: The distribution between the means and the Beck's depression

There is comprehensive regression analysis between the predictive parameters of the brain waves of depressed subjects at F4.

Input of the analysis is coincident regression of alpha, beta, theta, and delta mean value. The results of multiple regression analysis showed that multiple regression coefficient equals 0.718 (R=0.718), the coefficient of determination equals 0.515, and modified determination coefficient equals 0.461. This means that 46.1% of the total changes are related to subjects with sever depression as well as the brain waves which are related to alpha and beta changes that have remained in the model. In addition, the results of regression variance analysis showed that the effect of regression or independent variables is quite significant compared with the remained effect. The value of which for this model equals 1.991 and shows that the remains for the regression model are independent from each other.

The Anova analysis with a significance level of 0.000, which is less than 0.05 shows that the used regression model is a good predictor for the depression variable. That means a regression model with P of 0.000 is significant (Table 10).

Table 10: Multivariate analysis of variance between brain waves and beck's depression

Changes source	Changes square	FD	Squares mean	F statistic	P
Regression	1348.330	4	337.082	9.568	0.000
Remain	1268.233	36	35.229		
Total	2616.563	40			

Therefore, the regression equation is as follows: BDI= beta mean (0.532)+Alpha mean (-0.412)

Considering the resulted beta in the Table, it is observed that the beta mean has highest effect on the predictive variable, i.e Beck depression, which has a direct relationship with the predictor variable; it means that the depression is increased as the beta mean increase. Conversely, it is followed by alpha mean which has actually an inverse relationship with predictive variable, i.e an increase in the alpha mean causes reduction in depression, and vice versa (Table 11).

Table 11: The remaining variables in the regression model between the brain waves and Beck depression

Variables	B	SD	Beta	T	Sig
Intercept	17.496	7.432		2.354	0.024
Alpha mean	-2.122	0.711	-0.412	20.983	0.005
Beta mean	2.004	0.439	0.532	4.570	0.000

DISCUSSION

The present study aimed to determine the relationship between quantitative analyzed parameters of EEG of depressed patients with the depression equals Beck score. it was designed and conducted at point F4 of the brain. This study is confirmed with the studies conducted by researcher terms of the location of EEG at F4 or F3 in Dorsa lateral prefrontal cortex. One of the most frequent findings is generally the prefrontal cortex involvement and typically the dorsolateral prefrontal cortex (DLPFC) in depressive illness Nitsche.[9-13]

In this study, analysis of the recorded data by Pearson correlation showed that theta, beta, and alpha waves of depressed subjects have a significant relationship with the Beck Depression Inventory score on F4 point of the brain, but there is no significant relationship between Delta wave of depressed subjects and the Beck Depression Inventory score on F4 point. The findings of this study confirm the mean decrease in alpha and theta mean and simultaneously beta wave increase in depressed patients. Comprehensive regression analysis suggests predictable Beck test scores at point F4 accoeding to 2 variables (mean beta and mean alpha), which showed an increased depression by increasing the beta value and decreasing the alpha value.

Then, BDI= mean beta (0.532)+mean alpha (-0.412); Overall, the results of this study are stated in the first, second and third hypothesis: Hypothesis 1: The depression score of depressed subjects is associated with the DLPFC region alpha wave mean; Hypothesis 2: The depression score of depressed subjects is associated with the DLPFC region beta wave mean; Hypothesis 3: The depression score of depressed subjects is associated with the DLPFC region theta wave mean; Hypothesis 4: The depression score of depressed subjects is associated with the DLPFC region delta wave mean. The fourth hypothesis was rejected.

CONCLUSION

Some of the studies conducted in this fields are: "Quantitative electroencephalography in schizophrenia and depression " and " The relation between frontal EEG asymmetry and the risk for anxiety and depression " and " Quantitative EEG findings in patients with acute, brief depression combined with other fluctuating psychiatric symptoms".[1-3] All of them have studied somehow the relationship between brain waves and depression.

Based on the regression analysis, the overall results of the present study suggest a strong relationship among some of the

understudied waves (two of four waves) with depression score at F4. Therefore, the results are similar to the study conducted by Budzynski.[5] In similar studies, also a significant relationship between frontal brain waves and depression has been reported.

In his book "Introduction to Quantitative EEG and neurofeedback", Budzynski notes that in depressed patients an increase in beta wave in the frontal part of the brain and a decrease in alpha and theta waves are observed.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGEMENT

Special thanks to Psychiatrists who cooperated with us in patients' referral to conduct the present study.

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How to cite the article: Mohammadzadeh B, Sattari K, Lotfizadeh M. Determining the relationship between depression and brain waves in depressed subjects using Pearson correlation and regression. Int J Epidemiol Res. 2016; 3(4): 376-385.