Decrease Alpha Waves In Depression: An Electroencephalogram(EEG) Study

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Abstract— **There was no affirm study that differentiates the brainwaves between depression subjects and healthy subjects until today. Hyperactivity and low activity of the brain activities in various parts and regions could be evaluated and studied though the brainwaves measured from the electroencephalogram (EEG). The losing ability of the brain to transmit signals and information that caused a person to be depressed makes a person influences their normal daily activities. Depression is a mood disorder which may affect our daily work, sleep, eating habits and general health. Therefore, it is a general term and commonly infected by anyone. The aim of this study was to determine the differences of alpha waves between normal and depression groups. Throughout the research, depression screening measurements of Patient Health Questionnaire-9 (PHQ-9) and Depression Anxiety Stress Scale-21 (DASS-21) were taken into accounts in order to identify the normal and depression groups. A total of 4 normal subjects and 4 depressed subjects participated in this study. A 32 channels EEG was used to detect the difference of alpha waves in depression and normal groups. The alpha waves in depression group were found out to be lower compared to the normal group in both close eyes and open eyes conditions. The T-Test statistical analysis shown that there were significant differences in the alpha-1 waves in close eyes condition and alpha 1 and alpha-2 waves in the open eyes condition for depression group. In addition, the frontal lobe, parietal lobe, occipital lobe and temporal lobe had found out to have much lower alpha waves in the depression group compared to the normal group. In short, by measuring the alpha waves of a person using EEG may be a biomarker in differentiating a healthy or depressed person in the future.**

Keywords—Electroencephalogram(EEG), Depression, Alpha waves, PHQ-9, DASS

I. INTRODUCTION

This According to the World Health Organization, it is now estimated that 350 million people globally are affected by depression and depression will be the leading cause of burden of disease by 2030 [1]. Depression is referring to negative thoughts and behaviour and loss of positive affect. Negative behaviour and emotions like consistently low mood for more than two weeks and loss of pleasure and interest of doing most of the activities are described as depression. Depression usually comes along with changes of emotional, cognitive, physical, thinking and behavioural symptoms. Anyone could be the victim and patient of depression, from young people to seniors. The depression may be caused by different factors including biochemical factor, light, biogenetic factor, psychosocial factor, psychological factor and organic factor. Counselors and psychologies might be the group of professional people who can help those victims of depression. As an alternative, electroencephalogram (EEG) measuring on depression brainwave pattern might be able to be used to alert those victims from walking too deep into depression without notice.

In the present study, electroencephalography (EEG) will be used to monitor the brain waves of subjects. EEG is a device to measure the electrical activity of the brain. Hyperactivity and low activity of the brain activities in various parts and regions could be evaluated and studied though the brainwaves measured from the EEG. EEG is widely used in clinical diagnosis of brain electrical activity. It is a non-invasive method and technique which is easy and safely to use for brain electrical activity detection and measurement. The rhythmic EEG spectrum is categorized into various oscillation frequencies: delta waves (<4 Hz) accompany slow wave sleep, theta waves (4-8 Hz) reflect a state of drowsiness, alpha waves (8-12 Hz) accompany a relaxed state, and beta waves (12-30 Hz) reflect an engaged or active brain [2]. The losing ability of the brain to transmit signals and information that caused a person to be depressed influences their normal daily activities. Both wake and sleep EEG are believed to provide biomarkers in depression [3]. Thus, EEG may be a useful tool in detecting depression patients and symptoms before the depression had gone severed.

Many studies to study the differences in brain waves pattern between depression and healthy subjects have been performed. Some EEG studies find out that 20-40% of patients with depression have abnormal EEG findings [4], [5]. Studies reported that asymmetry in EEG activity over frontal regions in depression [6]-[9]. According to Hosseinifard, alpha power

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had the highest accuracy in classifying depressed with healthy groups. The study reported that the depressed subjects had higher mean alpha powers at channel T3, F7, O1, P3, C4 in the left hemisphere and O2 in the right hemisphere [10]. This finding was correlated with the Henriques and Davidson findings that depressed subjects had less left sided activation (increase alpha power) than healthy control subjects [11].

Besides that, there are studies that have investigated the asymmetry of frontal alpha wave in depression group. The decreased of left sided frontal alpha activation has interpreted as the consequence of negative emotions and depressive disorder symptoms [12]. Another study further investigated that the current and previously depressed subjects showed left frontal hypoactivation relative to never depressed subjects [13]. Alpha power in the resting state may be interpreted as an index of neural inactivity, while power suppression reflects active cognitive processing [14]. It is known that alpha power is reversely proportional with cortical activity in patients with depression [15]. Major disorder depression (MDD) patients had reduced left frontal activation and increased global alpha power relative to controls, findings interpreted as reduced approach motivation and generalised cortical deactivation, respectively [16]. However, other studies found out that MDD patients had increased alpha power/amplitude over right parieto temporal regions [17]-[19]. However, recent research found out that patients with depression had higher alpha activity compared to healthy subjects [20]. There was no specific or affirm study that differentiates the brainwaves between depressed subjects and normal healthy subjects until now.

The aim of the study was to compare the EEG findings in subjects with depression and healthy subjects. The EEG data was recorded during resting state with close eyes and open eyes conditions. The hypothesis was that there was a difference in the alpha waves (8-12 Hz) in between depression and healthy subjects. In the present study, Patient Health Questionnaire-9 (PHQ-9) and Depression, Anxiety, and Stress Scale-21 (DASS-21) questionnaires were given to the subjects before the EEG measuring. The scoring from the questionnaires was used to determine the level of depression for each individual to categorize them into normal and depression group.

I. Methodology

A. Participants

The study was performed at the Faculty of Engineering and Science, University Tunku Abdul Rahman in 2014. Subjects were recruited from the final year undergraduate students. Eight students with 3 female and 5 male aged from 23 to 25 with a mean age of 23.38 took part in this experiment and their participation were voluntary. Participant consent was obtained before the study began.

B. Depression Screening Measures

The Depression screening measures provide an indication of the severity of depression symptoms and assess the severity within a given period of time (the pass 7 to 14 days). There are various questionnaires provided by Diagnostic and Statistical Manual of Mental Disorders, 4th Edition (DSM-IV) to evaluate and assess the severity of depression. In this research, Patient Health Questionnaire-9 (PHQ-9) and Depression, Anxiety, and Stress Scale-21 (DASS-21) will be used to determine the level of depression for each individual to categorize them into healthy and depression group. These two questionnaires are in the public domain and this measurement and evaluation could be used without causing any charge. The questionnaires were given to the subject before the EEG experiment started.

These two questionnaires were chosen to be used as their validity and reliability are high and common among the clinical screenings [21]. PHQ-9 has been recommended to be one of the best screening and research purposes questions to know the depression severity and the criteria of depression diagnostic [22]. PHQ-9 consists of nine questions and having the questions to determine the different symptoms of depression and the severity. The PHQ-9 refers to symptoms experience by the subject during the past two weeks. The scores range from 0-27, as each item was scored from 0 (not at all) to 3 (nearly every day). PHQ scores 5, 10, 15, and 20 represented mild, moderate, moderately severe, and severe depression, respectively [23]. In this study, subjects with a positive score of 10 and above for PHQ were categorised as having depression.

Meanwhile, DASS-21 is a questionnaire which consists of 21 questions involving the questions related to the daily condition and situation to determine the depression, anxiety and stress level of an individual. DASS-21 has a wide usage in UK clinicians and its reliability and validity are high among the self assessment tools and also research based purposes [24]. The DASS scores range from 0 (did not apply to me at all) to 3 (applied to me very much, or most of the time). The depression scores of 10, 14, 21 and 28 represented normal, mild, moderate, severe and extremely severe, respectively. Same goes to anxiety scores of 8, 10, 15, 20 and stress scores of 15, 19, 26 and 34. In this study, the depression scores of 14 and above were categorized as subject having depression. The results from both depression screening measures were taken into consideration to categorise the subjects into depression or normal control groups.

C. Method

A NCC Medical 32-channel electroencephalogram (EEG) was used in this study. The EEG was recorded at 32 scalp loci, reference to vertex (Cz) with compliance with the international 10-20 electrode placement system as shown in *Fig.1*. The study was carried out in a quiet room with control environment and all study participants underwent conventional EEG registration [25]. Firstly, the subject was seated comfortable and calmed to relax for 2 minutes before the EEG recording started. The EEG recording was collected from each subject in two conditions: (1) closed eyes during resting state for 2 minutes and (2) open eyes during resting state for 2 minutes. The EEG signals were band-pass filter within 0.5-40 Hz range with a notch filter of 50 Hz to eliminate the noise and artefacts caused by power line. EEG

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data were then analysed using Fast Fourier Transform (FFT) to obtain the result in absolute spectral values ($k\mu V^2$) for individual segments of the EEG spectrum (delta (1-4 Hz), theta (4-8 Hz), alpha-1 (8-10 Hz), alpha-2 (10-12 Hz) and beta (12-40 Hz). This study is investigating the difference in alpha waves (8-14 Hz) between depression and normal subjects. The mean absolute spectral values of alpha-1 and alpha-2 for each electrodes channel were tabulated for both close eyes and open eyes conditions. All the data were presented in graph to compare the results between depression and normal control group.

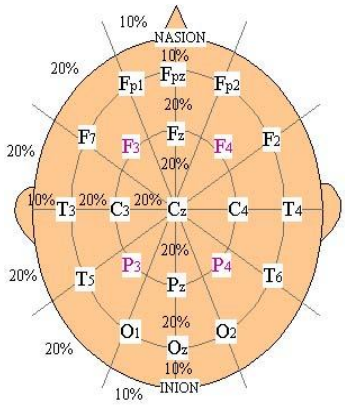

Fig. 1. Example International 10-20 Electrode Placement System [25].

D. Statistically Analysis

Paired T-Test was used to evaluate the significant differences in alpha frequency energy level between the healthy and depression groups for close eyes and open eyes conditions. The level of significant values was set at $p<0.005$. Data were analysed with Statistical Package for the Social Science (SPSS), ver. 11.5. (SPSS Inc., Chicago, IL, USA).

III. RESULT AND DISCUSSION

A total of 8 subjects with 4 subjects categorised as normal subjects and the remaining 4 as depressed subjects. The means and standard deviation of each category was showed in Table I. In this study, we compared the EEG alpha waves between subjects with depression and healthy subjects. The mean values of alpha-1 (8-10 Hz) and alpha-2 (10-12 Hz) waves in subjects with depression and normal groups were shown in Table II and Table 3. *Fig. 2* and *Fig. 3* showed the alpha-1 waves of depression and normal groups in close eyes and open eyes conditions respectively. The alpha-1 waves in subjects with depression was decreased with comparison with that in normal subjects over P3, P4, O1 and T5 regions for close eyes conditions. Subjects with depression had significantly lower alpha-1 waves over Fp1, F3, F4, P3, P4, O1, O2, F7, F8, T3, T4, T5 and T6 regions than normal subjects for open eyes conditions. The alpha-2 waves of both groups in close eyes and open eyes were shown in *Fig. 4* and *Fig. 5*. In comparison with normal subjects, subjects with depression had significantly decreased alpha-2 waves in all regions except C4 for the close eyes condition. For open eyes condition, depression group had lower alpha-2 waves over all regions except C3 and C4 regions.

A paired T-test was conducted to compare the alpha waves of depression and normal groups. For close eyes condition, there was a significant difference in alpha-2 waves ($t(15) = 3.784$, $p < 0.005$) but not in alpha-1 waves ($t(15) = 0.307$, $p = 0.763$). This indicated that the alpha-2 waves in close eyes conditions were higher in normal subjects than the depressed subjects. Alpha-1 showed no difference in close eyes condition between depression and normal groups. Besides that, the paired T-test of alpha-1 ($t(15) = 4.4421$, $p< 0.05$) and alpha-2 ($t(15) = 2.796$, $p< 0.05$) during open eyes condition revealed that there was significant interaction between depressed and normal group. The depression group has decreased alpha-1 and alpha-2 waves for open eyes condition.

Researchers had found that the prefrontal area cortex of the brain is being affected in depression. The alpha wave of the prefrontal cortex will tend to be less active compare to the normal individuals [26]. This is due to this area of the prefrontal cortex is associated with the emotional traits. Hammond, 2005 had stated that the frontal area of the brain has lower alpha activity as they involved in the least awareness of the positive emotions and being more in the negative emotions. The electrode channels in the prefrontal cortex area are the Fp1, Fp2, F3 and F4. These 4 channels had shown lower alpha-2 waves for depression groups during the close eyes condition, and lower alpha-1 and alpha-2 waves for depression group during the open eyes condition.

Moreover, there was a significant difference at the electrode channels of P3, P4, O1, O2, T5 and T6 in alpha brainwaves for depression group inclusive both close and open eyes conditions as compared to the normal group. These electrode channels located at the back part of the brain which are the parietal lobe, occipital lobe and temporal lobe. These areas of lobes involve in the reception and sensory input from the outer world. Low alpha frequency in these areas for depression group could be due to the less attentiveness to the outer world. They tend to focus inward on own negative emotions and dark thoughts. They would pay less attention on receiving the information from the outer world. Negative emotions and dark thoughts then lead to low alpha frequency in these parts of the brain area.

TABLE I. MEANS AND STANDARD DEVIATION OF THE SCORES IN PHQ-9 AND DASS-21 IN NORMAL AND DEPRESSION GROUPS.

Category	**PHQ-9**	**DASS-21**		
		Depression	***Anxiety***	***Stress***
Normal	3.0 (1.414)	4.0 (2.828)	2.5 (2.517)	6.5 (5.745)
Depression	15.25 (6.238)	22 (9.092)	20 (8.0)	26 (7.303)

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TABLE II. MEAN VALUES (KμV^2) OF EEG ALPHA WAVES IN SUBJECTS WITH DEPRESSION, AND HEALTHY SUBJECTS (CLOSE EYES)

Electrode Channels	α1[a]		α2[b]	
	Depression	*Normal*	*Depression*	*Normal*
Fp1	17.2	17.0	7.9	14.3
Fp2	17.6	15.7	8.2	14.3
F3	13.1	9.5	6.2	9.4
F4	13.3	13.3	6.4	10.3
C3	8.2	5.5	4.2	5.7
C4	5.1	4.0	3.2	3.1
P3	29.6	46.6	11.2	50.6
P4	29.6	32.1	12.7	30.8
O1	27.0	26.4	11.8	21.3
O2	26.0	24.7	12.1	19.9
F7	16.9	15.7	7.4	12.6
F8	16.3	14.9	6.8	12.5
T3	15.3	13.8	5.8	11.0
T4	15.1	15.4	5.6	12.1
T5	25.7	26.7	10.2	21.6
T6	24.8	25.0	10.6	19.7

[a] *α1 – Alpha-1 waves (8-10 Hz)*

[b] *α2 – Alpha-2 waves (10-12 Hz)*

TABLE III. MEAN VALUES (KμV^2) OF EEG ALPHA WAVES IN SUBJECTS WITH DEPRESSION, AND HEALTHY SUBJECTS (OPEN EYES)

Electrode Channels	α1[c]		α2[d]	
	Depression	*Normal*	*Depression*	*Normal*
Fp1	17.2	17.0	7.9	14.3
Fp2	17.6	15.7	8.2	14.3
F3	13.1	9.5	6.2	9.4
F4	7.1	8.9	4.5	6.2
C3	6.7	5.9	4.1	5.2
C4	2.1	2.6	2.5	3.1
P3	1.9	2.6	1.9	3.3
P4	1.2	1.2	2.0	1.8
O1	0.9	0.9	1.3	1.1
O2	3.0	6.8	3.0	19.8
F7	3.2	5.6	3.3	14.7
F8	5.1	8.2	5.7	10.9
T3	4.9	6.6	6.4	8.7
T4	3.8	4.6	3.4	4.1
T5	3.3	4.4	2.8	4.0
T6	2.8	3.8	2.7	3.3

[c] *α1 – Alpha-1 waves (8-10 Hz)*

[d] *α2 – Alpha-2 waves (10-12 Hz)*

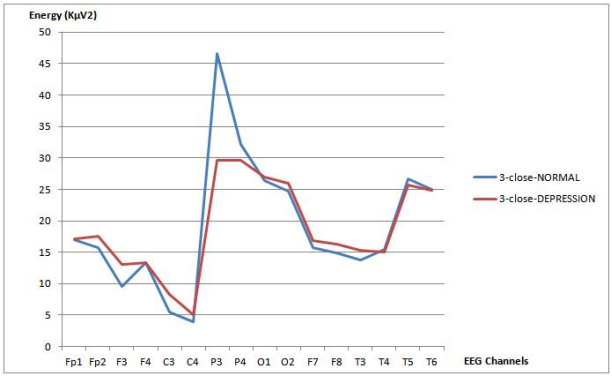

Fig. 2. Alpha-1 (α1) waves for both normal and depression during close eyes condition.

Fig. 3. Alpha-1 (α1) waves for both normal and depression during open eyes condition.

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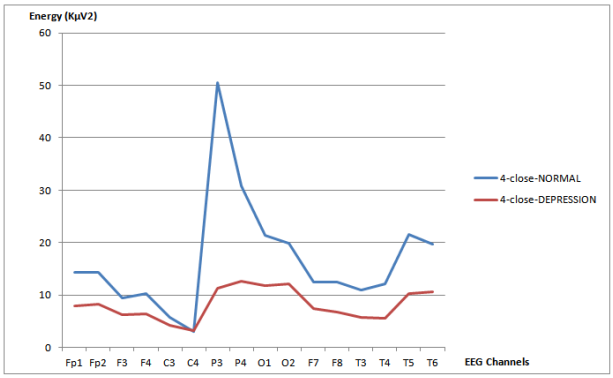

Fig. 4. Alpha-2 (α2) waves for both normal and depression during close eyes condition.

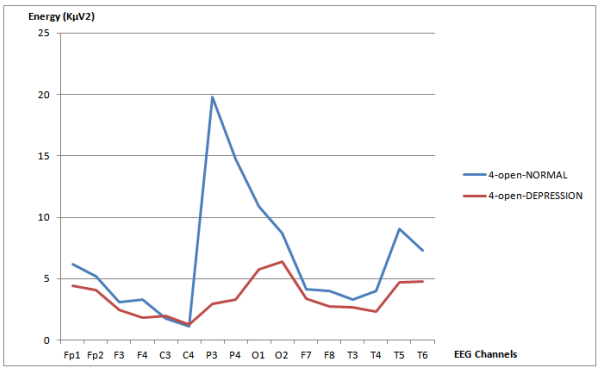

Fig. 5. Alpha-2 (α2) waves for both normal and depression during open eyes condition.

II. Conclusion

From this study, we found out that the alpha waves of depressed subjects was lower than the normal control subjects. The regions of P3, P4, O1, O2, T5 and T6 may be the significant region in differentiating a healthy or depressed person. EEG can be a biomarker in detecting depression in the future. However, the sample six of depression and normal groups are relatively small which may influence the stability of the data. Future studies should use a larger sample size in order to provide more accurate answers about the use of EEG in differentiating the subjects with depression and healthy subjects.

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