STUDY ON ELECTROENCEPHALOGRAM SIGNALS FOR NORMAL AND DEPRESSIVE SYMPTOMS AMONG YOUNG ADULTS

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JANUARY 2018

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By

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A dissertation submitted to the Department of Biomedical and Mechatronics Engineering,
Lee Kong Chian Faculty of Engineering and Science,
Universiti Tunku Abdul Rahman,
in partial fulfillment of the requirements for the degree of
Master of Engineering Science
January 2018

ABSTRACT

STUDY ON ELECTROENCEPHALOGRAM SIGNALS FOR NORMAL AND DEPRESSIVE SYMPTOMS AMONG YOUNG ADULTS

Donica Kan Pei Xin

There is an unmet need for practical and reliable biomarkers for mood disorders such as depression. Electroencephalography (EEG) is a promising tool for biomarker development to guide the diagnosis and treatment of depression. The present study investigates the EEG power spectrum difference in nonclinical sample of euthymic and depressed young adults at resting state. We anticipated that depressed participants would have differences in the EEG power spectrum as compared to healthy control participants. A total of 125 participants without prior psychiatric history were recruited in this study. They were assessed with PHQ-9 and DASS-21 scores and 100 participants (n=50 normal, n=50 depressive) were eligible for the study. Each participant underwent 32 lead bipolar wet electrodes EEG and completed self-report measures to characterize their state of consciousness. The EEG signals in broad frequency band (delta, theta, low alpha, high alpha and beta) of both groups were compared in resting state with eyes-closed and eyes-opened

conditions. Besides, the acute effect on EEG changes by deep breathing activity and listening to seawaves music were investigated respectively in both group. The results in eyes-closed resting condition showed that the depressive group had significant decreased in high alpha power (10-12 Hz) at whole brain region and decreased beta power (12-30 Hz) at prefrontal, frontal and posterior regions. Deep breathing session revealed significant beta power changes at occipital region and post-seawaves music recorded significant difference among control and depressive group at high alpha power at the whole brain region. The data suggested that the high alpha power and the beta power during eyes-closed condition at resting state may serve as the biomarkers in differentiating the euthymic and depressive symptoms from EEG. Also, the difference in beta power changes in deep breathing session and high alpha power at post-seawaves music may be an alternating approach to ease in detecting depressive symptom.

ACKNOWLEDGEMENT

I would like to thank everyone who had contributed to the successful completion of this project. I would like to express my gratitude to my research supervisor, Dr. Lee Poh Foong for her invaluable advice, guidance and her enormous patience throughout the development of the research. Thanks to UTAR for providing me the scholarship to support my master study.

In addition, I would also like to express my gratitude to my loving parent and friends who had helped and given me encouragement to persuade my dream. The journey to complete the master study was not easy, but with their guidance and encouragement makes my journey full of motivation and joy. Besides that, I would like to thanks to my co-supervisor, Dr Kok Jin Kuan and external collaborator Dr. Phang Cheng Kar in assisting and given me valuable advise throughout the research. Also, I would like to thanks to friends and students who volunteered themselves to help and participate in my research experiment. Without their participation, it will not be a success in gaining the significant output of this project.

APPROVAL SHEET

This dissertation/thesis entitled "**STUDY ON ELECTROENCEPHALOGRAM SIGNALS FOR NORMAL AND DEPRESSIVE SYMPTOMS AMONG YOUNG ADULTS"** was prepared by DONICA KAN PEI XIN and submitted as partial fulfillment of the requirements for the degree of Master of Engineering Science at Universiti Tunku Abdul Rahman.

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SUBMISSION OF THESIS

It is hereby certified that **DONICA KAN PEI XIN** (ID No: ***13UEM08525***) has completed this thesis entitled "**Study on Electroencephalogram Signals for Normal and Depressive Symptoms among Young Adults**" under the supervision of Dr. Lee Poh Foong (Supervisor) from the Department of Biomedical and Mechatronics Engineering, Lee Kong Chian Faculty of Engineering and Science, and Dr. Kok Jin Kuan (Co-Supervisor) from the Department of Psychology and Counselling, Faculty of Arts and Social Science.

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(*Donica Kan Pei Xin*)

DECLARATION

I (DONICA KAN PEI XIN) hereby declare that the dissertation is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UTAR or other institutions.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS / ABBREVIATIONS

M	Mean
SD	Standard Deviation
t	t-test
p	Probability
Z	Wilcoxon signed rank test
U	Mann-Whitney U test

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Depressive disorder is a common illness that affects the body, mood and thoughts (World Health Organization, 2017). Depressive disorder affects not only adults and elderly but also young adults. According to World Health Organisation, suicide is the second leading causes of death in aged 15 to 29 years old (World Health Organization, 2017). Young adults aged between 18 to 29 years old are the emerging adults that experienced end of adolescent, where they started to learn to take responsibility but may still have attachment to parents or family (Arnett, 2014). This is the period where they start to make decision for themselves and be independent. This is the age of identity exploration, self-focus, instability, feeling in between and possibilities (Arnett, 2014). It is estimated that over 25 percent of young adults are affected by at least mild symptoms (Rushton, Forcier and Schectman, 2002). According to a few studies on prevalence of depression among university students, about 10% to 85% of them were suffering from depression (Dyrbye, Thomas and Shanafelt, 2006; Ibrahim *et al.*, 2013; Shamsuddin *et al.*, 2013). The young adults who lived below the poverty line were twice likely to have depressive

symptoms (Child Trends Databank, 2015). Besides that, depression in young adults and adolescent was reported to have strong relation to the family history of depression disorder (Miller, 2007). Depressed young adults may result in low motivation and output which turns their life into complicated with negative events such as deficits in academic, loss of friendships and dropping out of activities (Garland and Solomons, 2002).

If there is an efficient biomarker for early detection on depressive symptoms, it may help to prevent the sickness worsen. Meanwhile, depression is affecting 350 million people globally of all ages and is highlighted as the leading cause of disability according to World Health Organization (World Health Organization, 2017). However, people are commonly unaware of suffering from depression and those who aware may ashamed or afraid to seek for help and treatment. Early diagnosis and treatment of depressive symptoms could prevent it from deepen into it. Currently, clinical practices are using mental health screening measures or depressive symptoms rating scales for case finding and in monitoring outcomes (Lam *et al.*, 2016). The current classification of depressive disorders is based on the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-V) (American Psychiatric Association, 2013). However, high proportion of sufferers does not attend to health professional and receive no treatment. Depressive symptoms if leave unattended will lead to depression and eventually suicide. This might cause by the population is unaware about the early stage of depression or some may suffer from major depression.

In this study, the focus is on finding the pattern between normal and depressive symptom groups on young adults without prior diagnosed with depression. Electroencephalogram (EEG) is employed to detect the brainwaves change in presence of the depressive symptoms as it is able to measure the brain's spontaneous electrical activity acquired from the electrodes placed on the scalp. The recorded activity at each electrode presents the gross reading of electrical activity arising from numerous neurons in the cortical areas surrounding the electrode (Teplan, 2002). The rhythmic EEG spectrum from the electrical activity is categorized into different frequency range. These well-known frequency bands from low to high frequencies respectively are delta (δ), theta (θ), alpha (α) and beta (β) (Baskaran, Milev and McIntyre, 2012). Each frequency band has been identified to relate certain brain conditions through numerous research over the time. For instance, delta waves (<4 Hz) observed during reduce alertness and sleep (Knyazev *et al.*, 2011), theta waves (4-8 Hz) reflect a state of drowsiness (Sih and Tang, 2013) , alpha waves (8-12 Hz) accompany a relaxed state (Bazanova and Vernon, 2014), and beta waves (12-30 Hz) reflect an engaged or active brain (Fan *et al.*, 2007). EEG signals are either described in terms of absolute or relative power (Bronzino and Peterson, 2015). EEG has clear advantages over other proposed biomarkers as it is non-invasive, widely available, and relatively cost effective (Baskaran, Milev and McIntyre, 2012). EEG has been applied in detecting numerous brain diseases (Jagadeesan *et al.*, 2013), sleeping disorder pattern (Šušmáková, 2004) and epilepsy monitoring (Smith, 2005).

1.2 Aims and Objectives

The primary aim of the present study was to investigate the difference in delta, theta, alpha and beta bands of the EEG spectrum of whole brain region between the normal and depressive groups. A group of participants without prior notice of their own mental state were recruited in this study. Participants were then categorized into healthy control or depressive group according to two mental depression screening instruments: Patient Health Questionnaire-9 (PHQ-9) (Kroenke, Spitzer and Williams, 2001) and Depression Anxiety Stress Scale-21 (DASS-21) (Crawford and Henry, 2003). The EEG signals of eyes-closed and eyes-opened of both control and depressive groups at resting state were compared to identify the best condition giving obvious signal on depressive symptoms. The second aim of this project was to adopt two different activities which are listening to seawaves music and deep breathing activity to compare the changes of brainwaves between the control and depressive groups. The acute effect of brainwaves changes at the pre- and post- of the seawaves music listening and the pre- and post- of the deep breathing activity was evaluated respectively to find the EEG power difference between the control and depressive groups.

The specific objectives of this research work are as follows:

1) To investigate the EEG difference at whole brain region between control and depressive groups at resting state.
2) To evaluate the EEG change at whole brain region after a deep breathing activity on control and depressive groups.

3) To evaluate the EEG change at whole brain region after a seawaves music listening activity on control and depressive groups.

1.3 Overview

This dissertation consists of five chapters and is organized as follows:

Chapter 1 introduces the background of the study followed by presenting the research aims and objectives of the work.

Chapter 2 provides an overview on depression and the fundamentals of electroencephalogram (EEG). This chapter also summarizes the literature review on previous EEG study on depression, effect of deep breathing and effect of seawaves music listening.

Chapter 3 describes the methodology of the study. The details of the participant recruitment process, the procedure of EEG experiment and the analysis methods are explained in this chapter.

Chapter 4 presents the result and discussion of the EEG studies. The participant demographics followed by the EEG results for resting state, after deep breathing and after seawaves music listening were discussed respectively.

Chapter 5 draws the main conclusion from the study and proposes the suggestions for future work.

CHAPTER 2

LITERATURE REVIEW

2.1 Depression and depressive symptoms

Depression is a common mental disorder that negatively affect the feeling, thoughts, and behaviour of a person (World Health Organization, 2017) . The symptoms of depression vary depending on the severity of depression, which may include depressed mood, loss of interest or pleasure, change in appetite, insomnia, poor concentration, feeling worthless, low in energy and have suicidal thoughts (American Psychiatric Association, 2013). Depressive symptoms are categorized into four main symptoms: psychological symptoms, behavioural symptoms, functional symptoms and psychotic symptoms (American Psychiatric Association, 2013). The psychological symptom is depressive symptoms that relate to the mood or feeling of an individual. Depressed people feel sad, hopeless, tired, lack of energy during the day and have less initiative and strength. Besides that, depressed individual is having problem with concentration, memory and have difficulty in decision-making. Higher level of depression includes feeling of fear and having the thoughts of guiltiness and worthlessness. Conversely, behavioural symptoms

associated to the behaviour of a depressed person. Depressed individual begin to loss ability to have fun and loss of interest to the surrounding. Crying is one of the behavioural symptoms of depression. Individuals with serious depression will have physical agitation and have the tendency or thoughts of suicidal. In term of functional symptoms, depressed individual might have eating disorder, sleeping disorder, sexual disorder and physical symptoms such as diarrhoea or constipation. Lastly, the most severe depressive symptom is the psychotic symptoms. Only 20% of people with depression will have psychotic symptoms (Flint *et al.*, 2013). The person will have strange look to the reality and begin to have delusions and hallucinations. The content of delusion is based on their own personal shortcoming, failures guilt, death or penalty.

Depressive disorder is classified into mild, moderate and severe depending on the number and severity of symptoms. Mild depressive individual may have minor functioning impairment but severe depressive individual may significant interfere with his functioning (National Collaborating Centre for Mental Health, 2010). According to National Institute of Mental Health, there are few types of depression disorder, namely major depressive disorder, persistent depressive disorder and bipolar depression. Major depression disorder is a common but serious depression that happens once in a lifetime of a person that will affect the daily life of a person (Belmaker and Agam, 2008). Where else, persistent depressive disorder is another type of depression that last for more than 2 years (Melrose, 2017). Individual who have persistent depressive disorder may undergo periods with

major depression and certain period with less symptoms. Lastly, bipolar depression is a less common type of depression. Bipolar depression sufferer will experience cycling mood changes from extreme high to extreme low mood from time to time (McCormick, Murray and McNew, 2015). Besides that, there are certain depression that formed under special circumstances such as postpartum depression, psychotic depression and seasonal affective disorder (National Institute of Mental Health, 2011).

Depression is initiated by several factors or reasons. They are biochemical factor, biogenetic factor, psychosocial factor, psychological factor, and organic factor (American Psychiatric Association, 2013). Studies showed that the chemical imbalance in the brain such as serotonin, norepinephrine and dopamine is the source of major depression. In terms of biogenetic factor, children of parent with depression are three times higher in risk of suffering in depression. Furthermore, some individual felt depressed after experienced certain major life event such as death of family member, loss of jobs or childbirth too. Individual who had traumatic childhood experience was more likely to suffer in depression as they hope to block their painful feelings and thoughts. Lastly, certain intake of medication or drugs such as high blood pressure medication, alcohol, cocaine or amphetamine will cause the person to have depression symptoms (American Psychiatric Association, 2013).

2.1.1 Instrument for screening depression

Currently, depression screening tool or mental health screening tool is used in clinical practice to detect depression in individual. The current classification of depressive disorder is based on the Diagnostic and Statistical Manual of Mental Disorders, fifth Edition (DSM-V) (American Psychiatric Association, 2013). Depression screening measurement does not diagnose depression but act as an indicator of depressive symptoms within a given period. Shorter screening measure is used as a general screening for depression symptom for adult populations whereas longer screening measure is used for targeted adults patient or populations who are at high risk for depression (Sharp and Lipsky, 2002). Certain criteria have to be considered during the selection of a measurement. The criteria includes the characteristics of target population, psychometric properties of the measurement, duration needed to complete the measures, ease of use and the cost of obtaining the measures. Table 2.1 shows the details of several current depression screening tools used in the clinical practice (Kroenke, Spitzer and Williams, 2001). The result obtained from the depression screening measures is useful in providing the information for the primary health care for further monitoring and diagnosis. In this study, PHQ-9 and DASS-21 are selected as the instruments for depression screening to categorise the participants into two groups: normal and depressive groups.

Table 2.1: Current depression screening tools used in clinical practice

Measure	Symptoms Duration	Number of items	Time to complete (approximate minutes)	Estimated price
Patient Health Questionnaire-9 (PHQ-9)	Pass 2 weeks	9	Less than 5	Free
Beck Depression Inventory II (BDI II)	Pass 2 weeks	21	5 to 10	$191
Depression Anxiety Stress Scale-21 (DASS-21)	Pass 1 week	21	Less than 5	Free
Center for Epidemiological Studies Depression (CES-D)	Pass 1 week	20	5 to 10	Free
Zung Depression Rating Scale	Pass several days	20	5 to 10	Free

(Kroenke, Spitzer and Williams, 2001)

2.1.2 Patient Health Questionnaire (PHQ-9)

PHQ-9 has a high validity and reliability, it is commonly used in clinical settings (Mukhtar and Oei, 2011; Gelaye *et al.*, 2013). It consists of 9 questions that used for detecting and monitor depression for diverse populations and it is available in different languages (Huang *et al.*, 2006; Sherina, Arroll and Goodyear-Smith, 2012). The scores of PHQ-9 range from 0 to 27, as each item was scored from 0 (not at all) to 3 (nearly every day).

PHQ-9 scores of 5, 10, 15, and 20 represent mild, moderate, moderately severe, and severe depression, respectively (Kroenke, Spitzer and Williams, 2001). Participant who obtained a score of 10 or above was categorized into having depressive symptoms (Kroenke, Spitzer and Williams, 2001).

2.1.3 Depression Anxiety Stress Scale (DASS-21)

On the other hand, the DASS-21 consists of 21 questions related to the daily living, depression, anxiety, and stress of an individual. DASS-21 is widely used by clinicians in the United Kingdom and has high reliability and validity (Crawford and Henry, 2003). The depression scores of 10, 14, 21 and 28 represent normal, mild, moderate, severe and extremely severe respectively. While anxiety scores of 8, 10, 15, 20 and stress scores of 15, 19, 26 and 34 are categorized as normal, mild, moderate, severe, and extremely severe respectively. DASS-21 provides the maximum differentiation between depressive and anxiety symptoms which is useful for community and clinical individuals (Bottesi *et al.*, 2015). In this study, DASS 21 is used to determine if an individual is free from depression, anxiety and stress. The participants with depression scores of below 10; anxiety scores of below 8; and stress scores of below 14; are categorized as control group. Whereas, the participants with depression scores of above 10 (anxiety and stress scores may vary) are categorized into depressive group. In this study, the non-clinical diagnosed participants are categorized into either a normal or a depressive groups by PHQ-9 and DASS-21 scores which will be further explained in the methodology chapter.

2.2 Electroencephalogram (EEG)

The electrical activity of human brain is due to the current flow of the nerve cells. The nerve cell consists of dendrites and a cell body and an axon as shown in Figure 2.1. The function of the axon is to transmit information to different neurons. Dendrites are connected to the axon and receive the electrical impulse from other neuron cells. Each nerve of the human is connected to approximately 1000 of other nerve cells. The electrical impulses due to the impulse transmission is very small which is in microvoltage (μV) range and the frequency is less than 100 Hz (Sanei and Chambers, 2007). The electroencephalogram (EEG) measures the small electrical potential difference in between two locations on the scalp of human by amplifying the current along the internal resistors of amplifier (Schwilden, 2006). The brain's spontaneous electrical activity can be acquired from the electrodes placed on the scalp and the recorded EEG signals at each electrode presents the gross reading of electrical activity arising from numerous neurons in cortical areas surrounding the electrode (Teplan, 2002).

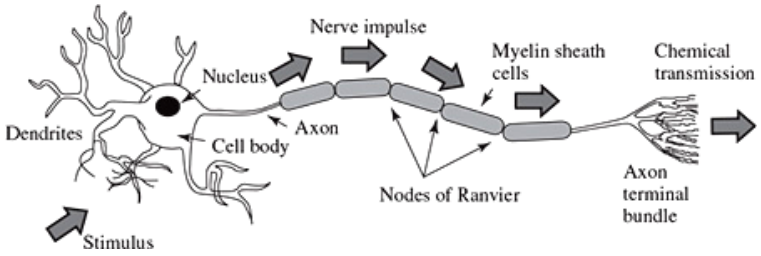

Figure 2.1: Structure of neurons (Sanei and Chambers, 2007)

2.2.1 International 10-20 System of EEG

The EEG can be recorded from electrodes arranged in particular pattern or montage. The common standard EEG arrangement system is the international 10-20 electrode placement system (Klem *et al.*, 1999). The electrodes are labelled according to the anatomical placement and laterality numbers (Teplan, 2002). The human brain is divided into few regions: prefrontal (Fp), frontal (F), central (C), temporal (T), parietal (P) and occipital (O) lobe. The laterality number is labelled according to the left (odd numbers) and right (even numbers) side of the head as shown in Figure 2.2 (Teplan, 2002).

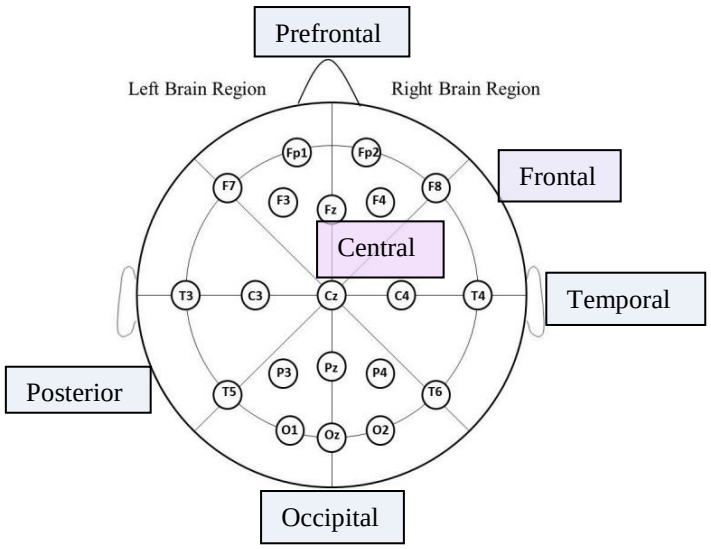

Figure 2.2: Topography of EEG electrode positions comply to the international 10-20 electrodes placement system (Teplan, 2002).

Different brain regions are relate to different functions of the brain. According to the study from Walker and colleagues (2007), the prefrontal region (Fp_1, Fp_2) is associated with logical and emotional attention. The mid-

frontal region (F_3, F_4) is functioning for the motor planning while lateral-frontal region (F_7, F_8) is functioning for verbal and emotional expression. The central region (C_3, C_4) is responsible for sensorimotor integration. The posterior region (P_3, P_4) works for cognitive processing or perception whereas the occipital region (O_1, O_2) is responsible for visual processing, Lastly, the lateral-temporal region (T_3, T_4) is involving in memory formation and storage and the posterior-temporal (T_5, T_6) is working for understanding (Walker, Kozlowski and Lawson, 2007).

2.2.2 Frequency band of EEG

The EEG signals are categorized based on their frequency power spectrum. There are four main EEG frequency bands: delta (δ), theta (θ), alpha (α) and beta (β) (Baskaran, Milev and McIntyre, 2012). The lowest frequency band is the delta waves, which its frequency band is lower than 4 Hz. It is the slowest waves with highest amplitude. The delta waves are dominant in infants and are observed in adults during reduced alertness and sleep (Knyazev, 2012). Besides that, a review reported that the delta frequency involves in cognitive processes and emotional process. The delta frequency was high at frontal, central and posterior regions during cognitive load (Güntekin and Başar, 2016).

Theta waves are slow waves ranged from 4 Hz to 8 Hz. This frequency band reflects a state of drowsiness (Sih and Tang, 2013). It is commonly see in young children and adults. Younger children have higher theta power but

reduce slowly along with increasing age (Sih and Tang, 2013). In addition, the theta waves are associated to cognitive process and theta power is high during variety task such as working memory, calculation and even musical imagining (Sih and Tang, 2013).

The alpha waves are EEG frequencies range from 8 Hz to 12 Hz. Alpha waves are appeared during relaxation state (Bazanova and Vernon, 2014). The alpha power is high during eyes-closed condition and reduced during eyes-opened or stress. The alpha power is associated with the visual processing of human brain (Barry *et al.*, 2007). In addition, the high alpha power during relaxation state could be interpreted as an index of neural inactivity, while the power suppression of alpha frequency is reflecting the active cognitive processing (Neuper and Pfurtscheller, 2001).

The beta waves are EEG frequency band from 12 Hz to 30 Hz. The beta activity is fast with low amplitude. The amplitude in beta waves is less than 30 μV. The beta band is reflecting an engaged or active brain (Fan *et al.*, 2007). Beta power is high during alert or anxious state. Furthermore, beta power is high during active activity such as sensorimotor behavior (Kilavik *et al.*, 2013), language processing (Weiss and Mueller, 2012) and memory (Weiss and Mueller, 2012). Table 2.2 presents the comparison of each EEG frequency band.

Table 2.2: The comparison of EEG brainwaves

Brainwaves	Frequency (Hz)	Mental Condition
Delta	1 - 4	Sleep, dreamless, non-rapid eye movement sleep
Theta	4 - 8	Light sleep, creativity and insight
Alpha	8 - 12	Calm, peaceful yet alert state
Beta	12 - 30	Thinking, focusing state Intensity or anxiety

(Sanei and Chambers, 2007)

2.3 EEG activity in depression

Prior research has also considered EEG measures in depressive disorders (Olbrich and Arns, 2013). Numerous studies have examined the differences in EEG frequency between normal and depressed participants. For instance, Fingelkurts et al., reported that depressed patients demonstrated greater alpha and less distributed delta activity compared to healthy controls (Fingelkurts *et al.,* 2006). The EEG experiment was conducted with two minutes of EEG recording in eyes-closed resting condition. Another study demonstrated an increase in EEG power in a broad range of parietal, occipital, posterior temporal and central areas in patients with new-onset depression (Grin-Yatsenko *et al.,* 2009). The EEG was recorded for three minutes with closed and eyes-opened resting conditions.

Conversely, work by Begic and colleagues demonstrated that depressed patients had increased delta, theta, and beta but decreased alpha power, specifically in the frontal regions (Begić *et al.*, 2011). The EEG acquisition was conducted in eyes-closed resting condition for 100 seconds. A recent study examined an internet addicted group of participants with depression and demonstrated increased relative theta but decreased relative alpha power for whole brain regions (Lee *et al.*, 2014). The EEG was recorded for a period of 10 minutes with 4 minutes of eyes-closed, followed by 2 minutes of eyes-opened and 4 minutes of eyes-closed.

Other studies focused on alpha power asymmetry (Gotlib, Ranganath and Rosenfeld, 1987; Debener *et al.*, 2000). Henriques and Davidson reported that depressed participants had less left sided activity in another words higher alpha activity in left hemisphere (Henriques and Davidson, 1991). In a recent study on classification of depressed participants using machine learning, depressed participants was found to have higher mean alpha power at left side of the brain (Hosseinifard, Moradi and Rostami, 2013). Depressed group was reported to have greater alpha asymmetry than the normal group (Gollan *et al.*, 2014). However, a contradictory findings from Cavalho and colleagues (2011) shows that there was no difference in EEG alpha frontal asymmetry between depressed, remitted and controls individuals (Carvalho, Moraes, Silveira, Ribeiro, Roberto A M Piedade, *et al.*, 2011).

EEG has also been used to predict treatment response (Bruder *et al.*, 2008) and understand associations between depression and other psychiatric co-morbidities (Tement, Pahor and Jaušovec, 2016). These heterogeneous findings have limited clinical utility. The discrepancies among these studies could be explained by methodological differences, lack of standardized measures, recruitment of participants at different stages of depression or simply the involvement of different pathophysiological pathways in depression (Olbrich and Arns, 2013).

2.4 The effect of music on human emotion

Music has the ability to influence directly to humans emotion and create pleasurable experiences (Menon and Levitin, 2005). It has the power of healing and promoting flexibility and creativity (Wigram, Pedersen and Bonde, 2002). In terms of neurobiology study, music is able to stimulate the brain area that is associated with reasoning and cognitive function (Fukui and Toyoshima, 2008). Music has been used in mental health service for decades, it was claimed to have ability in exerting therapeutic outcome (Singh Solanki, 2016). Music is economic and non-invasive, it is a highly acceptable invention tools for stress management (Thoma *et al.*, 2013). The therapeutic effect of music is utilised in music therapy. Music therapy is demonstrated effective in improving sleep quality (Chan, Chan and Mok, 2010) and enhancing cognitive functions (Im and Lee, 2014).

Numerous studies investigated the effect of music in depressive individuals. It was reported effective in management of cancer pain, acute pain and labor pain (Castillo-Pérez *et al.*, 2010). Castillo-Perez and colleagues found that music therapy was able to decrease depressive symptom more effectively than psychology therapy. The depressive group who undergo 8 weeks of classical and baroque music as music therapy showed less depressive symptoms than depressive group who went through psychology therapy for the same period (Castillo-Pérez *et al.*, 2010). They concluded that music is able to stimulate beneficial feelings, hence decreasing the frequency of

depressive symptoms and decrease the levels of depression (Castillo-Pérez *et al.*, 2010).

Another study investigated the effect of different type of music as music therapy with major depression disorder patient (Hsu and Lai, 2004). Different type of music included natural sound music, country music, baroque music, easy listening music, Taiwanese folk song and Chinese folk song were played to different depressive group for a period of 2 weeks daily. All depression groups were reported decreased in depressive symptoms after the 2 weeks of music therapy (Hsu and Lai, 2004). Another research on chronic non-malignant patient reported that participants had decreased in pain and decreased in depressive scores after 1 week of music session with orchestra, piano, jazz, harp and synthesizer music (Siedliecki and Good, 2006).

Furthermore, modest studies investigated the effect of music to EEG frequency band. Pavlygina and colleagues investigated the effect of music with different intensity to human brain. High intensity music, which was the rock music, increased the theta and low alpha over the whole brain region after one session of music (Pavlygina, Sakharov and Davydov, 2004). Conversely, the low intensity music, which was the classical music, increased the high alpha, beta and gamma power of whole brain region (Pavlygina, Sakharov and Davydov, 2004). Different intensity of music had different effect to EEG frequency band. In addition, rock music was found to decrease the relative right frontal activation (negative affect) of chronically depressed female adolescents during and after one music session (Field *et al.*, 1998). The

positive effect of one music session to depression group associated with EEG frequency band is noteworthy to be further investigated.

In this research, the brainwaves changes due to listening seawaves music is adopted to distinguish the difference in between normal and depression group. Seawaves music was used in some EEG studies as the control stimuli. Hisanobu and colleagues used seawaves music for audibly isolation and to maintain the consciousness of participants during a subtle energy experiment (Hisanobu, Uchida and Kuramoto, 1997). Furthermore, Koelsch and collegues used seawaves as a control stimuli in a music listening experiment on cortisol level and the participants claimed that the seawaves stimuli was relaxing and pleasant (Koelsch *et al.*, 2011). Seawaves music was claimed to affect the cognitive and emotion of human (Thoma *et al.*, 2013). Therefore, the difference in acute changes in brainwaves after listening to seawaves music between two groups could be analysed to identify depressive symptoms.

2.5 The effect of deep breathing to human

The rate of spontaneous breathing at rest for a healthy adults range from 9 to 24 breaths per minutes (Lehrer and Gevirtz, 2014). Deep breathing is comparable slow, deep and even breaths. The rate of deep breathing is approximately 10 breaths per minutes or slower (Lee and Campbell, 2009). Deep breathing is one of the mindfulness breathing in meditation. Individual has to breathe naturally and be mindful to each breath when it enters and leaves the body (Krygier *et al.*, 2013). According to Marksberry, deep breathing helps our body to relax and increased the well-being feeling (Marksberry, 2012). Mindfulness breathing meditation helps to divert attention away from self-discrepancies. The practice of mindfulness breathing helps to reduce negative mood and reduce rumination through distraction (Morrow and Nolen-Hoeksema, 1990). The benefit of mindfulness meditation practices was discovered and began to applied into the treatment management of stress, pain and anxiety-related conditions (Hofmann *et al.*, 2010).

Less EEG research on the effect of deep breathing but few studies investigated the effect of breathing meditation to human brain. Davidson and colleagues reported that the healthy participants had increased in left-sided anterior activation which is associated to positive emotion after eight weeks of intensive training in mindfulness meditation (Davidson *et al.*, 2003). The state effect of one single session of mindfulness practise on brain frequency band was investigated too. A group of previously depressed individuals went through a single session of breathing meditation practise found changes in

their alpha asymmetry towards stronger relative left prefrontal activation (Barnhofer *et al.*, 2010). Besides that, a person without meditation experience could benefit from mindfulness practice for the first time too. According to a study from Chan and colleagues, brief guided mindfulness relaxation practice showed a significant positive effect to affective state of brain. The young adults showed an increase in alpha left-sided activation and frontal midline theta power after one session of guided relaxation technique in which the alpha is associated with positive emotions and the theta is associated with internalized attention according to the study (Chan, Han and Cheung, 2008). In a recent study on recurrent and remitted depression females group, the subjects had a significant shift in alpha symmetry towards stronger relative right-frontal alpha activity after went through a session of guided mindfulness meditation (Keune *et al.*, 2013). These findings demonstrated that either a short program or a session of mindfulness breathing meditation is able to exert a positive effect to the human brain. Since the brainwaves in normal and depressive group are different, the present study hypotheses that the changes of brainwaves after deep breathing are different in both groups too. The difference in acute effect changes in deep breathing between both groups is compared to find the potential as a tool in distinguishing the depressive people from the normal group.

CHAPTER 3

METHODOLOGY

3.1 Demographic Data of Participants

A total of 125 undergraduates with an age range between 18 to 25 years old were recruited from University of Tunku Abdul Rahman. All participants have met the criteria of no prior notice of depression, no psychiatric disease history and no consumption of antidepressants. They were screened with depression self screening measures, Patient Health Questions-9 (PHQ-9) and Depression(D) Anxiety(A) Stress(S) Scale (S)-21 (DASS-21) to be categoried into either a healthy control group or a depressive groups. A total of 100 participants were eligible for the study as among the 125 participants recruited, 25 reported high stress without any depressive symptoms. Therefore, the 25 participants did not qualify for either depressive group or control group. Fifty healthy participants (Age: M = 22.28, SD = 1.45) and 50 participants (Age: M = 21.40, SD = 1.76) were selected to participate in this study. The study took place within the Kuala Lumpur campus and Kampar campus of University of Tunku Abdul Rahman.

The study protocol was reviewed and approved by the University of Tunku Abdul Rahman Scientific and Ethical Review Committee (SERC). All participants participated in the study on a voluntary basis and written informed consent (refer to Appendix B) were obtained before the study began. All participants were provided with detailed information regarding the background of the study and confidentiality.

3.2 Depression Screening Instruments

Participants were screened with Patient Health Questionnaire-9 (PHQ-9) (refer to Appendices C) and Depression, Anxiety, and Stress Scale-21 (DASS-21) (refer to Appendices D) for categorization into control and depressive groups. These 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). These two questionnaires are commonly used in the public domain and relatively easy to administer. The questionnaires were given to the participant before the starting of the EEG experiment. PHQ-9 was used to identify depressive symptoms while the DASS 21 was used to determine the control group was free from depression, anxiety and stress. The depressive group must meet the criteria of having scores of above 10 for both PHQ-9 and DASS-21 depression score respectively. The control group must meet the criteria of having PHQ-9 scores below 10 with DASS-21 depression scores below 10, anxiety score below 8 and stress score below 14 as showed in Figure 3.1.

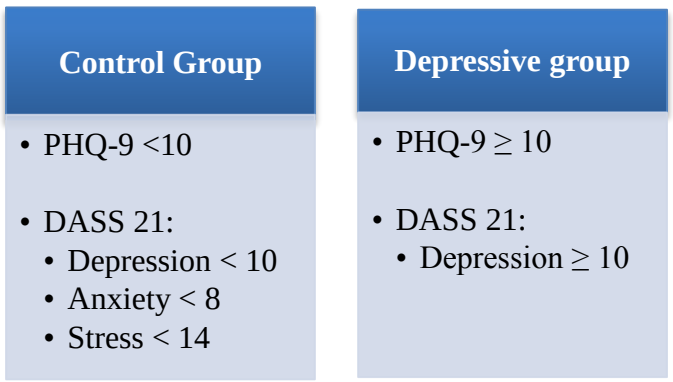

Figure 3.1: Criteria of participants for control group and depressive group

3.3 Procedure

Participants were given prior notice to clean their hair and not to apply styling products for experiment day. Upon arrival, participants were given an information sheet, signed the consent form and completing the screening questionnaires. The study was conducted with a conventional EEG registration with NCC Medical 32-channel bipolar electroencephalogram (EEG). The EEG was recorded at 32 scalp loci, comply with the international 10-20 electrodes placement system as referred to Figure 2.2 in literature review. The scalp of participants was first cleaned with skin preparation gel, and then the EEG cap was worn on the participants' head. Conductivity gel was injected using a blunted tip to fill in the hole in each electrode cup for reduction of contact impedance at the electrode-skin interface (Teplan, 2002). Each participant was seated comfortably in a control environment and guided by a facilitator to relax for two minutes before the start of the experiment.

3.3.1 EEG Recording Procedure

A flow chart of the study procedure in brief is depicted in Figure 3.2. In this study, the EEG recording experiment was divided into three sessions. The first session was EEG brainwaves measurement on eyes-closed then eyes-opened at resting state conditions for 2 minutes each, respectively as the baseline measurement. This baseline session was to determine the difference in EEG power between control and depressive groups under resting condition. Besides that, the difference in EEG power in between eyes-closed and eyes-opened was also investigated. The eyes-opened resting state EEG power was used as the baseline reading for the subsequent EEG study.

The second session of experiment continued with listening to seawaves music with eyes-opened condition for 5 minutes. This session was to investigate the acute effect of brainwaves changes before and after listening to seawaves music. The seawaves music was purely natural sound recorded from the splashing of sea water to the beach. Listening to seawaves music affects the cognitive and emotion of human (Thoma *et al.*, 2013). The seawaves music was presented to the participants through headphone. The EEG was recorded after the music session ended at eyes-opened resting condition for 2 minutes as post-seawaves music. The EEG power change in between pre-seawaves music (baseline eyes-opened resting condition) and post-seawaves music was evaluated.

The last session was the deep breathing activity with eyes-opened condition for 2 minutes.. This session was to investigate the acute effect of brainwaves changes before and after deep breathing under normal circumstances. The deep breathing activity began with guided instruction by the facilitator with a rate of 10 breaths/min for 1 minute (Lee and Campbell, 2009) then continued with deep breathing without guidance for 1 minute where the participant self-count for 10 cycles of deep breathing with similar breathing rate. The participant was briefed to breathe naturally and be mindful to each breath. During guided deep breath, the participants breathed in and out followed the instruction by the facilitator. Participants were guided to breathe in and out deeply through nose with mouth closed, inhaled slowly until they felt the diaphragm was filled with air and exhaled slowly to empty the air in the diaphragm (McConnell, 2011). The EEG was recorded at resting state after the deep breathing session ended as post-deep breathing. The EEG power changes in between pre-deep breathing (baseline eyes-opened resting condition) and post-deep breathing was evaluated.

In addition, the pulse rate of participants was measured throughout the experiment with pulse oximeter. A finger pulse oximeter was clipped on the participant left middle finger. The pulse rate of the participant was recorded and the mean pulse rate in bpm of each experiment was obtained. The mean pulse rate of both control and depressive group was compared based on each experiment. Furthermore, a simple self-reported assessment (refer to Appendix E) was filled in by the participants after each session ended to record their current state of mind whether they were in day dreaming, sleepy, relaxing or

other mental state during each experiment session. The result of self-reported measurement was used to further verify the consciousness of participants during EEG recording with the EEG data collected afterwards.

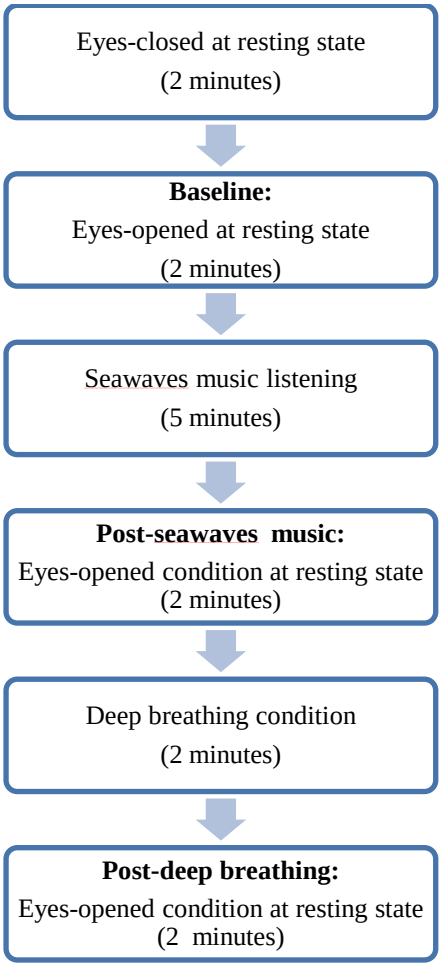

Figure 3.2: EEG experiment protocol

3.3.2 EEG Data Acquisition and Analysis

The EEG signals were digitized at 128 samples per seconds. The EEG signals was filtered by a band-pass filter at 0.5 Hz to 40 Hz, and a notch filter at 50 Hz to eliminate the low frequency by power line. The EEG records were inspected visually and areas contaminated by artefacts such as extreme values and abnormal trend were rejected. Fast Fourier Transform (FFT) were performed on EEG data to determine the EEG power spectrum of each channel (Cooley and Tukey, 1965). The power spectrum is computed by

$$P(f) = R_e^2[X(f)] + I_m^2[X(f)]$$

Where *X(f)* is the Fourier transform of the EEG signal (Bronzino and Peterson, 2015). Power in μV^2 was determined for standard frequency bands: delta (1-4 Hz), theta (4-8 Hz), low alpha (8-10 Hz), high alpha (10-12 Hz) and beta (12-30 Hz) (Babiloni et al., 2009). The monitored regions as shown in Table 3.2 were prefrontal (Fp_1, Fp_2), mid-frontal (F_3, F_4), lateral-frontal (F_7, F_8), central (C_3, C_4), posterior (P_3, P_4), occipital (O_1, O_2), lateral-temporal (T_3, T_4), and posterior-temporal (T_5, T_6). The FFT data was retrieved from the NCC Medical EEG software and then computed in MATLAB version program to obtain the median power of the total 50 participants for each control and depressive group on each frequency band. The median power ($k\mu V^2$) of each frequency band is presented in bar charts to compare their difference in between control and depressive groups.

Table 3.1: The power spectrum selected in this study

Frequency Band	Power
Delta	1 – 4 Hz
Theta	4 – 8 Hz
Low Alpha	8 – 10 Hz
High Alpha	10 – 12 Hz
Beta	12 – 30 Hz

Table 3.2: The monitored brain regions in this study

Brain Region	Electrodes Monitored
Prefrontal	Fp_1, Fp_2
Mid-frontal	F_3, F_4
Lateral-frontal	F_7, F_8
Central	C_3, C_4
Posterior	P_3, P_4
Occipital	O_1, O_2
Posterior-temporal	T_3, T_4
Lateral-temporal	T_5, T_6

3.3.3 Statistical Analyses

Statistical Package for the Social Science, ver. 11.5. (SPSS) was used for statistic analysis (SPSS Inc., Chicago, IL, USA). Parametric analysis method was used in analysing normally distributed data (Rosner, 2011). Independent T-Test was conducted to compare the mean score difference of PHQ-9 and DASS-21 between the control and depressive groups. Besides that, the pulse rate difference between the control and depressive groups was

compared with Independent T-Test. Also, the pulse rate of both control and depressive groups was analyzed with paired sample t-test to study the differences between eyes-closed and eyes-opened conditions, pre- and post-deep breathing, and pre- and post-seawaves music listening. Besides that, non-parametric analysis including Mann-Whitney U test (comparing two independent conditions) and Wilcoxon signed rank test (comparing two related conditions) were used to analyses the EEG frequency data Non-parametric method was used for the comparison of EEG data which was not normally distributed data (Rosner, 2011). Mann-Whitney U Test was used to compare the EEG power between the control and depressive groups. Wilcoxon signed rank test was conducted to evaluate the differences in EEG power for the conditions, between eyes-closed and eyes-opened conditions, pre- and post-deep breathing and pre- and post-seawaves music for both groups.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Analysis of the participant demographic data

A total of 100 undergraduates were recruited into the experiment. 50 participants were categorized into control group and 50 participants into depressive group. The control group comprises of 33 males (66%, 33 out of 50 participants in control group) and 17 females (34%) with mean age of 22.8. A total of 29 males (58%) and 21 females (42%) with mean age of 21.4 were recruited into depressive group. Table 4.1 shows the mean score and standard deviation of PHQ-9 and DASS-21 for both depressive and control groups. The depressive group had higher mean scores of above 10 for PHQ-9 and depression score of DASS-21 and was found significant higher in terms of independent t-test.

Table 4.1: Comparison of mean PHQ-9 scores and DASS-21 scores between depressive and control group before intervention.

Variables	*Depressive*		*Control*			
	M	SD	M	SD	*t(98)*	*p*
PHQ-9	11.54	5.28	4.08	2.37	9.112	<0.001
Depression	18.6	8.59	3.96	2.44	11.589	<0.001
Anxiety	14.24	9.62	6.84	5.76	4.668	<0.001
Stress	18.6	9.06	8.4	5.19	6.905	<0.001

Note: M=Mean. SD=Standard deviation. PHQ-9=Patient Health Questionnaire-9. Depression=Depression of Depression Anxiety Stress Scale-21. Anxiety=Anxiety of Depression Anxiety Stress Scale-21. Stress=Stress of Depression Anxiety Stress Scale-21.

4.2 EEG study and comparison on the eyes-closed and eyes-opened conditions at resting state for control group as baseline for depressive symptoms

The focus of this study is to compare the EEG findings of eyes-closed and eyes-opened condition at resting stage for verified euthymic participants. The mean scores for the Patient Health Question-9 (PHQ-9) in this study and Depression Anxiety Stress Scale-21 (DASS-21) is presented clearly in Table 4.1 above.

4.2.1 Self-reported measures on the state of mind and pulse rate measures during EEG recording of eyes-closed and eyes-opened condition

Participants were requested to fill in the self-reported measures on the state of mind during each experiment session. The purpose of the self-reported measures was to further verify the participants' mind states with the EEG data collected afterwards. Referring to Figure 4.1, majority of the participants were in relaxing state during both closed and eyes-opened condition as they were briefed to calm and relax themselves during the EEG recording. Control group achieved the highest percentage of relaxing state during eyes-opened condition (70%). There were participants who day dreamed (26% during eyes-closed and 32% during eyes-opened) and felt sleepy (28% during eyes-closed and 20% during eyes-opened) during the experiment. Minority of the participants selected "others" explained that they were having random thinking and couldn't relax during the EEG recording.

Besides that, the pulse rate of the participants was measured throughout the experiment. The pulse rate of control group in Figure 4.2 was served as the baseline reading for the following studies in this project. Paired t-test analysis was conducted to find the difference in pulse rate in between eyes-closed and eyes-opened condition of control group, the analysis reported there that was no significant difference ($t(49)=-0.225$, $p=0.823$) in between both conditions.

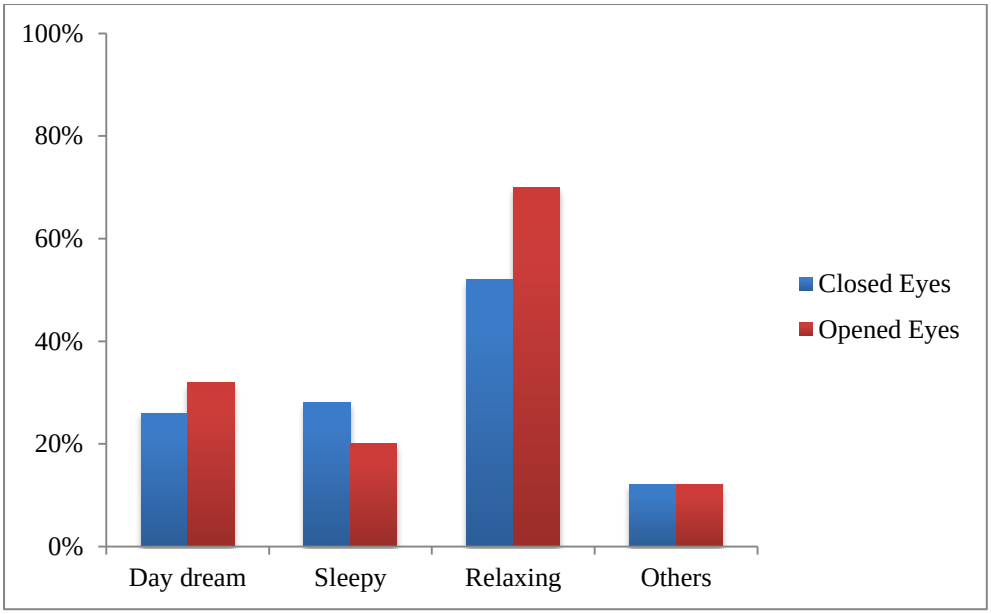

Figure 4.1: Comparison of self-reported measures result for eyes-closed and eyes-opened condition based on the mind states of control group during the EEG measurement

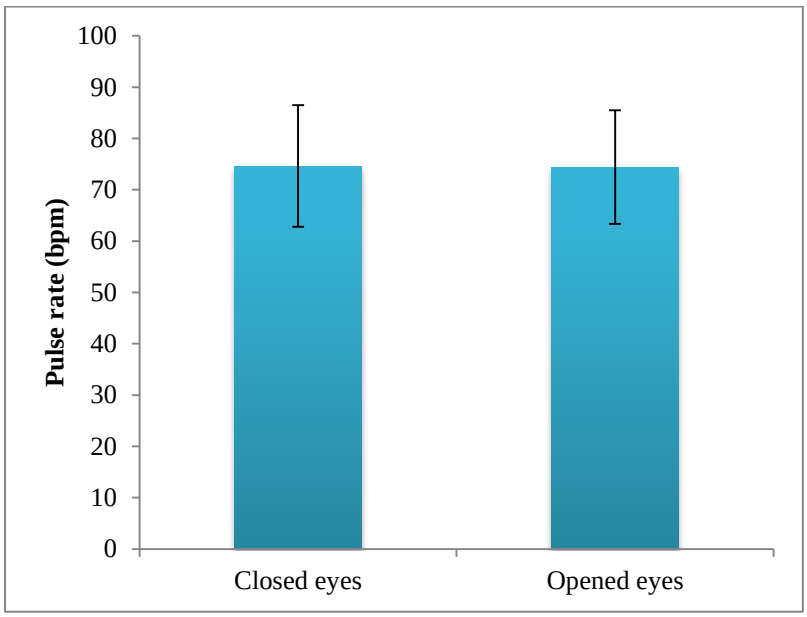

Figure 4.2: Comparison of pulse rate between eyes-closed and eyes-opened condition of control group

4.2.2 Comparison of EEG power bands (0-30 Hz) during eyes-closed and eyes-opened conditions at resting state for control group

4.2.2.1 Delta power (1-4 Hz)

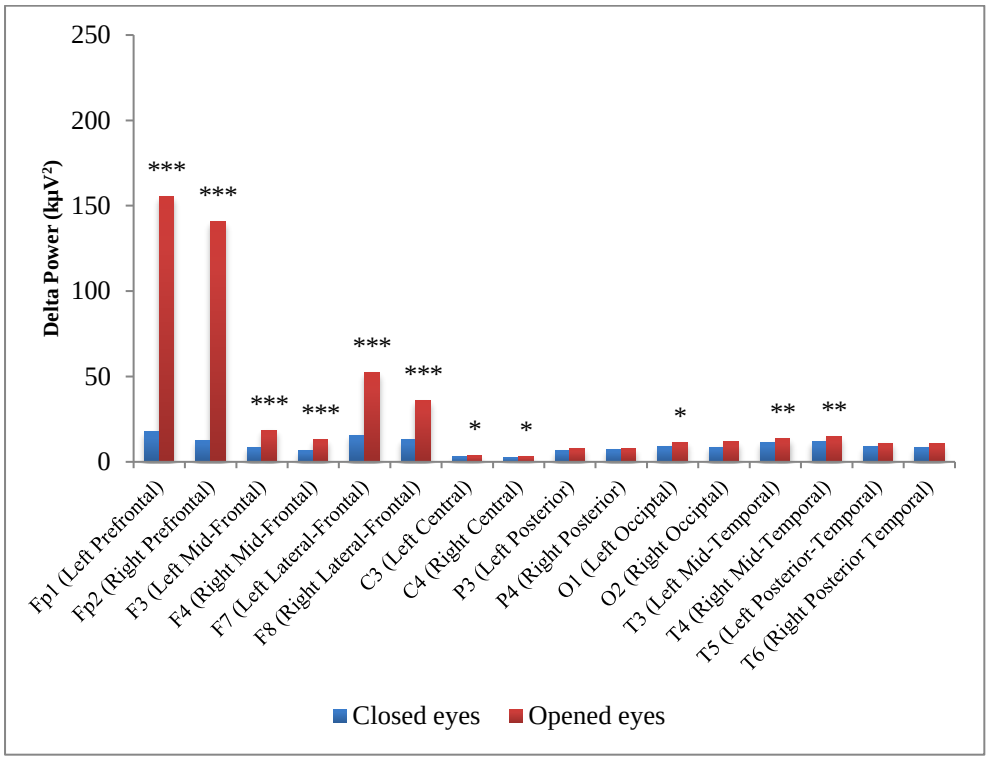

Figure 4.3: Median absolute delta power of eyes-closed and eyes-opened condition at resting state (*=p<0.05, **=p<0.01, ***=p<0.001: Wilcoxon signed rank test showed level of significant difference comparing eyes-closed and eyes-opened condition at each brain region

Figure 4.3 shows the median delta power from the signal acquisition for both eyes-closed and eyes-opened condition at resting stage of each brain region inclusive left and right brain. From Figure 4.3, delta power band displayed a profound reading at prefrontal (Fp1, Fp2) at eyes-opened

condition. The same outcome is observed at frontal region (from F3 to F8) where the median delta power for eyes-opened condition was higher compared to eyes-closed condition. For other brain region, the EEG power band reading for both conditions obtained no significant different.

The number of asterisk mark in Figure 4.3 shows significant level of differences between opened and eyes-closed condition based on statistical analysis with Wilcoxon signed rank test. The delta power was found significantly lower during eyes-closed compared to eyes-opened at left prefrontal Fp1 ($Z = -6.086$, $p < 0.001$), right prefrontal Fp2 ($Z = -5.792$, $p < 0.001$) and left mid-frontal F3 ($Z = -4.751$, $p < 0.001$), right mid-frontal F4 ($Z = -4.851$, $p < 0.001$), left lateral frontal F7 ($Z = -5.652$, $p < 0.001$) and right lateral frontal F8 ($Z = -5.488$, $p < 0.001$), left central C3 ($Z = -2.226$, $p = 0.026$), left occipital O1 ($Z = -2.331$, $p = 0.020$), and left mid-temporal T3 ($Z = -2.819$, $p = 0.005$), and right mid-temporal T4 ($Z = -2.751$, $p = 0.006$).

Detail statistical analysis on showing the significant amplitude for left and right brain region is tabulated in Table 4.2. Region of the brain which showed significant differences in power acquisition for left and right part is at prefrontal, mid-frontal, lateral-frontal and central eyes-opened condition. Meanwhile, other brain regions showed no significant differences between left and right region of the brain. On the other hand, for the same variable comparison, eyes-closed condition reported significant different for delta power at prefrontal, mid-frontal, lateral frontal, centre and posterior, as

compared to eyes-opened condition, posterior is the only part of the brain that showed significant increase in close eyes condition.

Table 4.2: *Z* and *p* values of Wilcoxon signed-rank test comparing the delta power between left and right brain region during eyes-opened and eyes-closed condition at resting state.

Brain Region	Eyes-opened		Eyes-closed	
	Z	*p*	*Z*	*p*
Prefrontal (Fp2-Fp1)	-4.600	<0.001***	-2.795	0.005**
Mid-frontal (F4-F3)	-3.528	<0.001***	-2.308	0.021*
Lateral-frontal (F8-F7)	-2.196	0.028 *	-2.974	0.002**
Centre (C4-C3)	-3.871	<0.001***	-4.296	<0.001***
Occipital (O2-O1)	-0.285	0.776	-0.103	0.918
Posterior (P4-P3)	-1.899	0.058	-2.53	0.011**
Mid-temporal (T4-T3)	-0.656	0.512	-0.224	0.823
Posterior-temporal (T6-T5)	-0.692	0.489	-0.124	0.901

Note: *=p<0.05, **=p<0.01, ***=p<0.001: Wilcoxon signed rank test showed level of significant difference comparing left and right brain region.

In this study, delta power increased profoundly at prefrontal, frontal and central areas during eyes-opened condition where p<0.001 as compared to eyes-closed condition. This might due to the fact that delta frequency was always appeared to be related to cortical plasticity in wakefulness and sleep, the delta power increased during deep sleep (Assenza *et al.*, 2013). Güntekin et. al. reported that the delta frequency involves cognitive processes and

emotional process at frontal, central and posterior during cognitive load, which this result is supporting our finding as shown above (Güntekin and Başar, 2016). From the same research group but earlier study also indicated delta frequency at frontal-central-posterior as well as occipital might be affected by emotional process (Güntekin and Başar, 2014). Besides, delta frequency band was essential in giving information on disease. Generally, the reduction in delta frequency was recommended as electrophysiological marker for cognitive dysfunction for Alzheimer's disease, Mild Cognitive Impairment (MCI), bipolar disorder, schizophrenia and alcoholism (Güntekin and Başar, 2016). For higher or increased in delta frequency band, research found that the female participants produced higher delta responses in comparison to male participants during visual stimulation (Güntekin and Başar, 2007; Klados *et al.*, 2009).

A noteworthy result from Figure 4.3, delta power at prefrontal cortex was reported much higher during eyes opened condition compare to eyes closed condition which previous reports indicated that the outcome might due to the eye blinking movement (Fisch and Spehlmann, 2000). Evident was found showing that the prefrontal (Fp1, Fp2) cortex region recorded the largest potential changes was due to the eye blink (lateral movement) which the EEG were placed directly above the eyes (Fisch and Spehlmann, 2000). According to Fisch and Spehlmann (2000), a blinking movement, the cornea which act as positive pole move closer to the prefrontal (Fp1, Fp2) electrodes producing a symmetric downward deflection. Conversely, during downward eye movement the positive pole (cornea) of the globe moves away from prefrontal

electrodes producing an upward deflection (Fisch and Spehlmann, 2000). Therefore, the amplitude of these peaks was significant higher compared to the rhythmatic brain activity. For similar situation, the eye blinking frequency was dominant at 3 Hz which was reported at delta frequency (Manoilov, 2006). Consequently, the delta power of eyes-opened conditions at prefrontal cortex was higher than the eyes-closed condition.

4.2.2.2 Theta power (4-8 Hz)

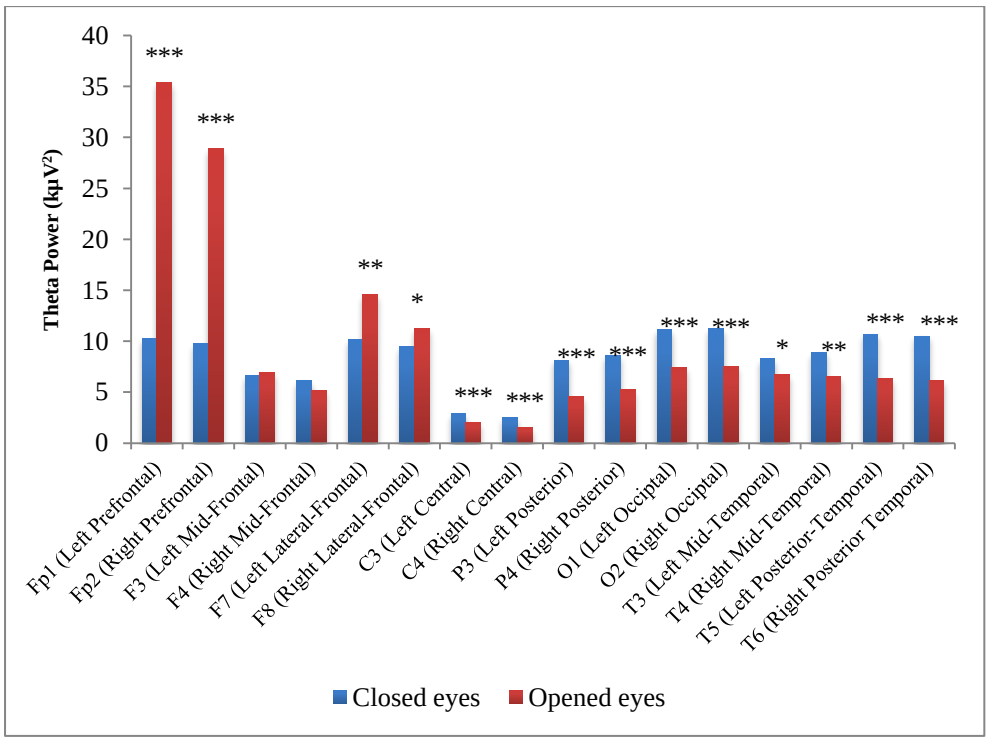

Figure 4.4: Median absolute theta power of eyes-closed and eyes-opened condition at resting state (*=p<0.05, **=p<0.01, ***=p<0.001: Wilcoxon signed rank test showed level of significant difference comparing eyes-closed and eyes-opened condition at each brain region

Theta frequency right after delta frequency is presented in Figure 4.4. In eyes-opened condition, theta power is noteworthy high at both left and right of prefrontal area (Fp1, Fp2) compared to eyes-closed condition. Besides that, the brain region of central (C3, C4), posterior (P3, P4), occipital (O1, O2) and temporal (T3, T4, T5, T6) are observed to be having a higher theta power during eyes-closed condition than eyes-opened condition.

On the other hand, the statistical analysis for theta power band shows a significant decreased at left prefrontal Fp1($Z=-5.324$, $p<0.001$), right prefrontal Fp2($Z=-5.097$, $p<0.001$), left lateral frontal F7($Z=-2.939$, $p=0.003$) and right lateral F8 ($Z=-1.998$, $p=0.046$) but increased at left central C3($Z=-3.738$, $p<0.001$), right central C4($Z=-4.427$, $p<0.001$) , left posterior P3($Z=-4.885$, $p<0.001$), right posterior P4 ($Z=4.755$, $p<0.001$), left occipital O1 ($Z=-4.335$, $p<0.001$), right occipital O2 ($Z=-3.691$, $p<0.001$), left mid-temporal T3 ($Z=-2.356$, $p=0.018$), right mid-temporal T4($Z=-2.781$, $p=0.005$), left posterior temporal T5 ($Z=-4.596$, $p<0.001$) and right posterior temporal T6 ($Z=-4.129$, $p<0.001$) for eyes-closed compared to eyes-opened. Whereas in terms of comparing between left and right region, both eyes-opened and eyes-closed condition had significant difference at prefrontal, mid-frontal, lateral frontal and centre with eyes-opened had additional significant difference at posterior temporal region as shown in Table 4.3.

Table 4.3: Z **and *p* values of Wilcoxon signed-rank test comparing the theta power between left and right brain region during eyes-opened and eyes-closed condition at resting state.**

Brain Region	Eyes-opened		Eyes-closed	
	Z	*p*	*Z*	*p*
Prefrontal (Fp2-Fp1)	-4.307	<0.001***	-3.766	<0.001***
Mid-frontal (F4-F3)	-4.335	0.0001***	-3.235	0.001***
Lateral-frontal (F8-F7)	-3.423	0.001***	-3.443	0.001***
Centre (C4-C3)	-5.568	<0.001***	-3.844	0.001***
Occipital (O2-O1)	-1.697	0.090	-1.212	0.225
Posterior (P4-P3)	-0.119	0.905	-0.352	0.724
Mid-temporal (T4-T3)	-1.318	0.187	-0.969	0.333
Posterior-temporal (T6-T5)	-2.023	0.043*	-1.883	0.060

Note: *=p<0.05, **=p<0.01, ***=p<0.001: Wilcoxon signed rank test showed level of significant difference comparing left and right brain region.

Studies reported that theta power increases over frontal and central region during cognitive process and during variety tasks such as working memory, calculation and even musical imagining (Sasaki *et al.*, 1996). Theta power during resting condition in this study showed a drastically increased at the prefrontal and lateral frontal areas but decreased at central, posterior, occipital and temporal area during eyes-opened condition at resting state. This result was consistent with the findings from Barry and colleagues who reported on globally reduction of the theta activity during eyes-opened condition, suggested that this situation was associated with stimulus

processing especially at the posterior regions and accompanied by an increased theta power in frontal hemisphere regions for adults (Barry *et al.*, 2007). On the other hand, some group of researcher reported that theta power during resting or sleeping state decreases with age (Somsen *et al.*, 1997; Yordanova and Kolev, 1997, 1998). Older children might have lower theta power than younger children as a sign of brain maturation (Liu, Woltering and Lewis, 2014). The participants in this study were the grown up group aged between 18 to 25 years old which were able to produce a normal adult theta power. Consequently, the result of this study which significant was reported same as the findings from Barry and colleagues where theta power reduced during eyes-opened condition at central, posterior, occipital and temporal area as compared to eyes-closed condition (Barry *et al.*, 2007). Theta activity is known to be affected by emotion processing (Aftanas *et al.*, 2001) and is associated with neuropsychiatric disorders such as depression (Aftanas *et al.*, 2001; Pizzagalli, Oakes and Davidson, 2003; Mulert *et al.*, 2007). Again, the euthymic participant's brainwaves in this study would give a clear baseline before proceed to other future study.

4.2.2.3 Alpha power (8-14 Hz)

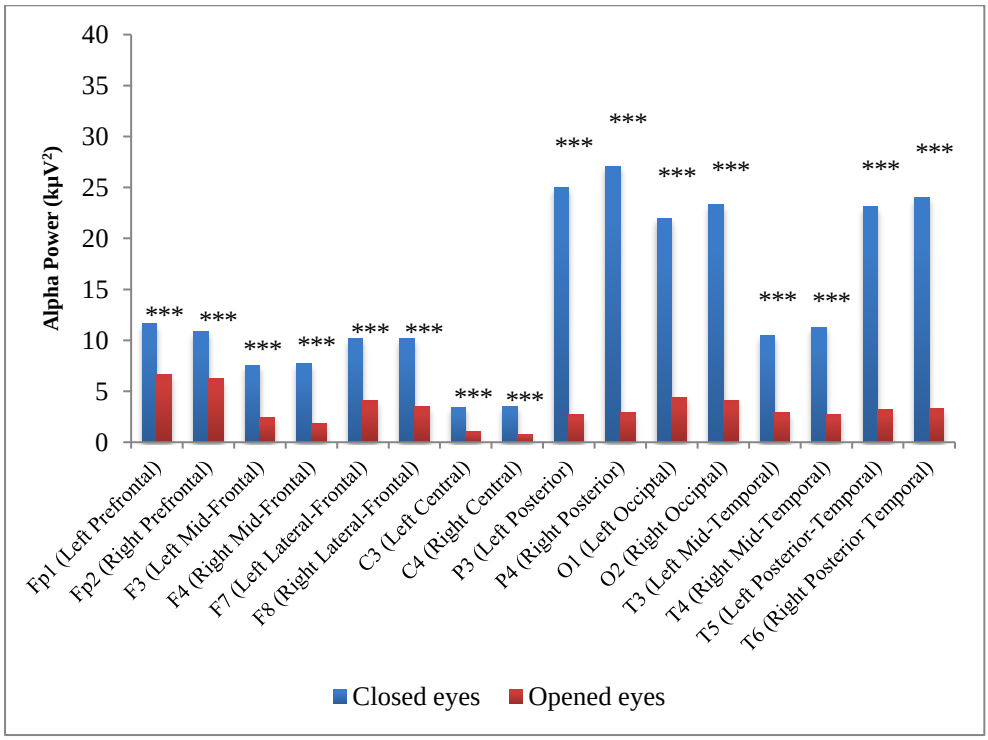

Figure 4.5: Median absolute low alpha power of eyes-closed and eyes-opened condition at resting state (*=p<0.05, **=p<0.01, ***=p<0.001: Wilcoxon signed rank test showed level of significant difference comparing eyes-closed and eyes-opened condition at each brain region)

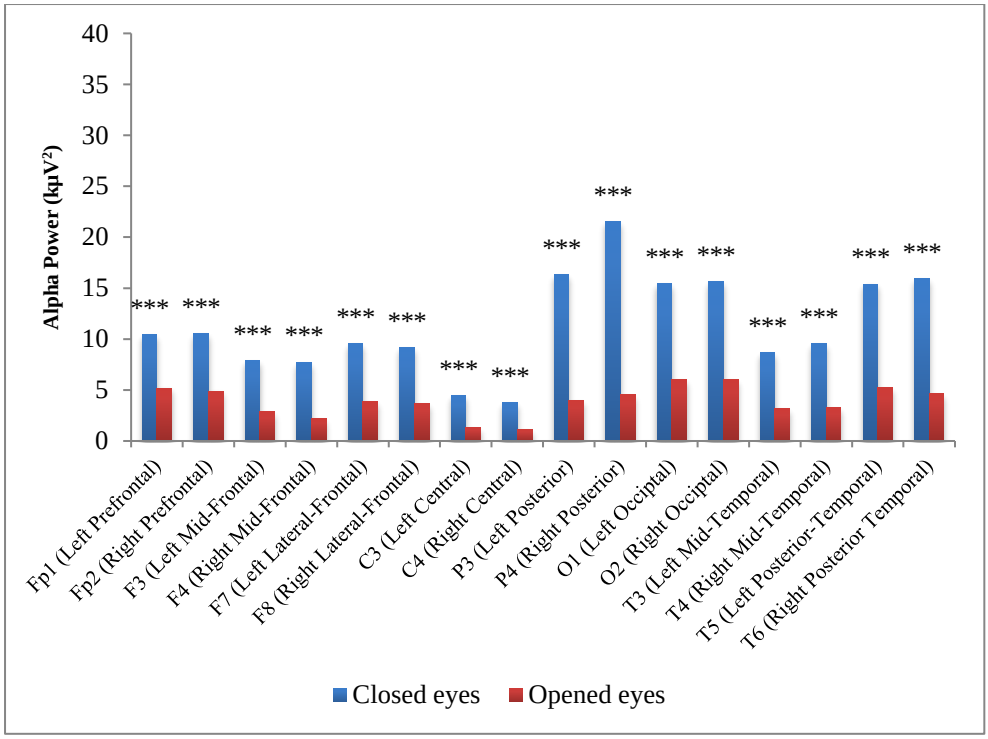

Figure 4.6: Median absolute high alpha power of eyes-closed and eyes-opened condition at resting state (*=p<0.05, **=p<0.01, ***=p<0.001: Wilcoxon signed rank test showed level of significant difference comparing eyes-closed and eyes-opened condition at each brain region

Figure 4.5 and Figure 4.6 shows a significant outcome on the difference in low alpha power and high alpha power in between eyes-closed and eyes-opened condition, respectively. Alpha frequency increased for entire brain regions for eyes-closed condition as compared to eyes-opened condition at resting state. This obvious difference was not shown in delta and theta frequency. Wilcoxon signed rank test reported low alpha power significantat left prefrontal Fp1 (Z= -3.567, p <0.001), right prefrontal Fp2 (Z=-3.746, p<0.001), left mid-frontal F3 (Z=-5.198, p<0.001), right mid-frontal F4 (Z=-5.725, p<0.001), left lateral frontal F7 (Z= -4.869, p<0.001), right lateral

frontal F8 (Z=-5.446, p<0.001), left central C3 (Z=-5.845, p<0.001), right central C4 (Z=-5.952, p<0.001), left posterior P3 (Z=-6.009, p<0.001), right posterior P4 (Z=-5.932, p<0.001), left occipital O1 (Z=-5.961, p<0.001), right occipital O2 (Z= -5.735, p<0.001), left mid-temporal T3(Z=-5.821, p<0.001), right mid-temporal T4 (Z=-5.407, p<0.001), left posterior temporal T5 (Z=-5.961, p<0.001) and right posterior temporal T6 (Z=-5.456, p<0.001).

Also, high alpha power reported significant at left prefrontal Fp1 (Z= -5.435, p <0.001), right prefrontal Fp2 (Z=-5.665, p<0.001), left mid-frontal F3 (Z=-5.898, p<0.001), right mid-frontal F4 (Z=-6.154, p<0.001), left lateral frontal F7 (Z= -6.005, p<0.001), right lateral frontal F8 (Z=-6.106, p<0.001), left central C3 (Z=-6.154, p<0.001), right central C4 (Z=-6.155, p<0.001), left posterior P3 (Z=-6.144, p<0.001), right posterior P4 (Z=-6.154, p<0.001), left occipital O1 (Z=-6.120, p<0.001), right occipital O2 (Z= -5.739, p<0.001), left mid-temporal T3(Z=-6.135, p<0.001), right mid-temporal T4 (Z=-6.154, p<0.001), left posterior temporal T5 (Z=-6.063, p<0.001) and right posterior temporal T6 (Z=-5.783, p<0.001).

Referring to Table 4.4, low alpha power had similar significant difference region between left and right brain region for both eyes-opened and eyes-closed condition. There are at prefrontal, mid-frontal, lateral frontal and central region. However, high alpha power in Table 4.5 had displayed significant different between left and right region at prefrontal, mid-frontal and centre for eyes-opened condition and mid-frontal, centre and posterior for eyes-closed condition. High alpha power at eyes-opened condition did not

have significant different between left and right brain region at prefrontal like eyes-closed condition but had additional difference at posterior region.

Table 4.4: Z **and *p* values of Wilcoxon signed-rank test comparing the low alpha power between left and right brain region during eyes-opened and eyes-closed condition at resting state.**

Brain Region	Eyes-opened		Eyes-closed	
	Z	*p*	*Z*	*p*
Prefrontal (Fp2-Fp1)	-3.397	0.001***	-2.965	0.003***
Mid-frontal (F4-F3)	-4.077	<0.001***	-2.288	0.022*
Lateral-frontal (F8-F7)	-3.041	0.002**	-2.021	0.043*
Centre (C4-C3)	-3.736	<0.001***	-4.021	<0.001***
Occipital (O2-O1)	-1.319	0.187	-0.159	0.874
Posterior (P4-P3)	-0.328	0.743	-0.145	0.885
Mid-temporal (T4-T3)	-0.401	0.689	-0.313	0.754
Posterior-temporal (T6-T5)	-1.208	0.227	-0.428	0.669

Note: *=p<0.05, **=p<0.01, ***=p<0.001: Wilcoxon signed rank test showed level of significant difference comparing left and right brain region.

Table 4.5: Z **and *p* values of Wilcoxon signed-rank test comparing the high alpha power between left and right brain region during eyes-opened and eyes-closed condition at resting state.**

Brain Region	Eyes-opened		Eyes-closed	
	Z	*p*	*Z*	*p*
Prefrontal (Fp2-Fp1)	-2.115	0.034*	-0.97	0.332
Mid-frontal (F4-F3)	-3.307	<0.001***	-2.705	0.007**
Lateral-frontal (F8-F7)	-1.185	0.236	-1.179	0.238
Centre (C4-C3)	-2.498	0.012*	-3.582	<0.001***
Occipital (O2-O1)	-0.836	0.403	-1.688	0.091
Posterior (P4-P3)	-1.14	0.254	-2.014	0.044*
Mid-temporal (T4-T3)	-0.898	0.369	-1.135	0.256
Posterior-temporal (T6-T5)	-0.542	0.588	-0.512	0.608

Note: *=p<0.05, **=p<0.01, ***=p<0.001: Wilcoxon signed rank test showed level of significant difference comparing left and right brain region.

Alpha frequency in this study showed higher power at all channels during eyes-closed condition which was consistent with the previous study recorded alpha power was dominant in normal individuals during eyes-closed resting condition. This outcome was further supported by another study reported that alpha activity will be suppressed by visual stimulation (Barry *et al.*, 2007). Eyes-opened condition activated the visual stimulation, consequently the alpha power was reduced. Alpha power resynchronization with visual input was also reported to be generally reflected on the functional innervations of visual system, hence activating the entire cortex (Başar and

Schürmann, 1999). This alpha band widespread reduction from eyes-closed to eyes-opened conditions was also found also in children aged between 8 to 12 years old (Barry *et al.*, 2009). Neuper and Pfurtscheller reported that alpha power in the resting state may be interpreted as an index of neural inactivity, while power suppression reflects active cognitive processing (Neuper and Pfurtscheller, 2001). Result in this study further contributes to the outcome on alpha power increased during eyes-closed condition at resting state.

4.2.2.4 Beta power (12-30 Hz)

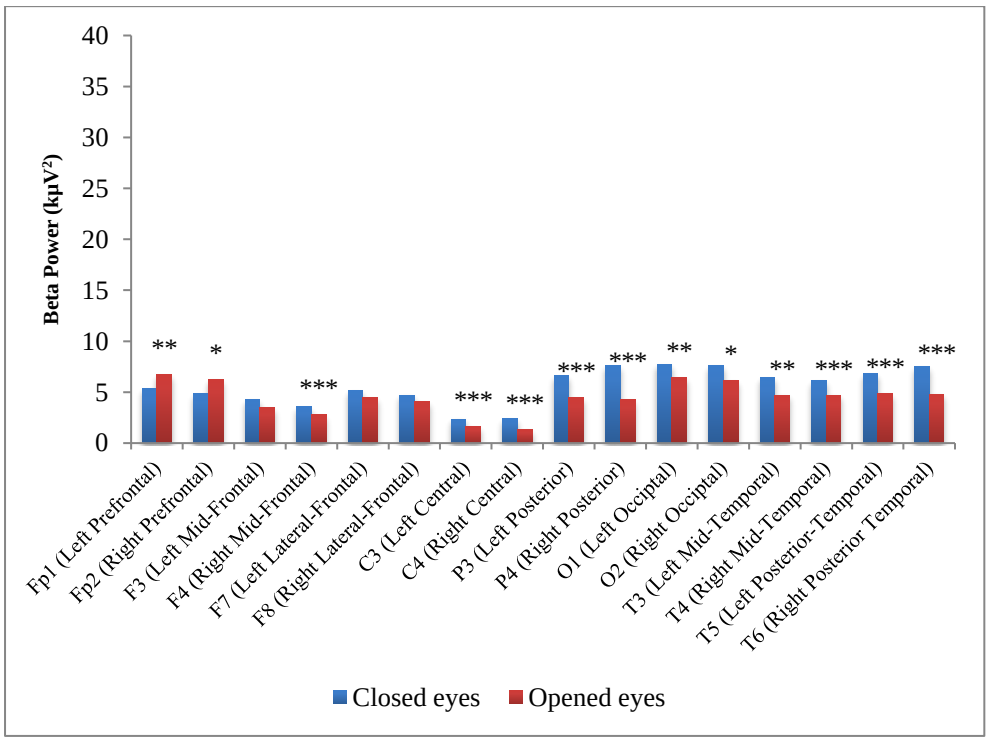

Figure 4.7: Median absolute beta power of eyes-closed and eyes-opened resting conditions(*=p<0.05, **=p<0.01, ***=p<0.001: Wilcoxon signed rank test showed level of significant difference comparing eyes-closed and eyes-opened condition at each brain region

Beta power obtained the lowest reading among all other frequency power in average for both eyes-closed and eyes-opened condition. From the entire view of histogram in Figure 4.7, both the highest and the lowest beta power occurred during eyes-opened condition where the highest power is at Fp1, 6.7 $k\mu V^2$ and lowest beta power is at C3 and C4 which below 2 $k\mu V^2$. Moving on to statistically analysis, beta power has significant decreased for eyes-closed condition at left prefrontal Fp1 ($Z=-2.703$, $p=0.007$) and right prefrontal Fp2 ($Z=-2.052$, $p=0.040$). Also, beta power significantly increased at right mid-frontal F4($Z=-4.418$, $p<0.001$), left central C3 ($Z=-4.879$, $p<0.001$), right central C4 ($Z=-5.663$, $p<0.001$), left posterior P3 ($Z=-5.268$, $p<0.001$), right posterior P4 ($Z=-5.213$, $p<0.001$), left occipital O1 ($Z=-2.699$, $p=0.007$), right occipital O2 ($Z=-2.549$, $p=0.011$), left mid-temporal T3 ($Z=-3.084$, $p=0.002$), right mid-temporal T4 ($Z=-3.964$, $p<0.001$), left posterior-temporal T5 ($Z=-4.606$, $p<0.001$) and right posterior temporal T6 ($Z=-4.512$, $p<0.001$). Besides that, the comparison of beta power between left and right region had less significant region compared to other frequency power. Beta power of eyes-opened condition only recorded significant difference between left and right region at mid-frontal and lateral-frontal and eyes-closed condition recorded significant at mid-frontal and posterior-temporal region. The similar significant difference between eyes-closed and eyes-opened condition comparing left and right brain region is at mid-frontal region only. Whereas, all other regions displayed non-significant difference.

Table 4.6: Z **and *p* values of Wilcoxon signed-rank test comparing beta power between left and right brain region during eyes-opened and eyes-closed condition at resting state.**

Brain Region	Eyes-opened		Eyes-closed	
	Z	*p*	*Z*	*p*
Prefrontal (Fp2-Fp1)	-1.726	0.084	-0.48	0.631
Mid-frontal (F4-F3)	-4.49	<0.001***	-3.502	<0.001***
Lateral-frontal (F8-F7)	-2.877	0.004**	-1.105	0.269
Centre (C4-C3)	-1.679	0.093	-0.486	0.627
Occipital (O2-O1)	-1.518	0.129	-1.222	0.222
Posterior (P4-P3)	-0.035	0.972	-0.477	0.633
Mid-temporal (T4-T3)	-1.149	0.250	-0.266	0.791
Posterior-temporal (T6-T5)	-1.339	0.181	-2.348	0.019*

Note: *=p<0.05, **=p<0.01, ***=p<0.001: Wilcoxon signed rank test showed level of significant difference comparing left and right brain region.

Beta power was relatively low during resting conditions may due to non-activation of process where beta-band activity is related to attention (Fan *et al.*, 2007), sensorimotor behaviour (Kilavik *et al.*, 2013), language processing (Weiss and Mueller, 2012) and memory (Hanslmayr, Staudigl and Fellner, 2012). The shift of beta power from posterior to prefrontal was observed from eyes-closed to eyes-opened condition, which is displayed in Figure 4.4. The shifting of beta power was compatible with previous research which proposed that the beta shifting topography reflects an increase in

activation relating to higher order processing and integration of visual input (Barry *et al.*, 2007).

4.2.3 Summary of EEG power comparison on the eyes-closed and eyes-opened condition at resting state for control group.

From the results above, prefrontal area (Fp1, Fp2) were observed to be having a higher brain activity power at delta, theta and beta frequency during eyes-opened condition except alpha power which increased profoundly during eyes-closed condition. During eyes-closed condition, posterior (P3, P4) and occipital (O1, O2) were observed to obtain a higher power at theta, alpha and beta frequency compared to eyes-opened condition. Also, central (C3, C4) were always having the lowest EEG power among all other channels, which is below 5.5 $k\mu V^2$. In general, prefrontal area obtained a higher delta, theta and beta power during eyes-opened compared to closed eye condition, may due to the activation of cognitive process with the related activation of visual system, where prefrontal cortex was associated with executive and cognitive functions (Gerhand, 1999). In contrast, alpha power is higher at prefrontal area during eyes-closed, which the alpha power is dominant with suppression of visual system. Posterior and occipital lobe is having higher theta, alpha and beta power during eyes-closed, where central lobe is always having the lowest EEG power. In term of comparison in between left and right brain region, both eyes-closed and eyes-opened condition recorded same significant difference at delta, theta and alpha 1 power at prefrontal (Fp2-Fp1), mid-frontal (F4-F3), lateral-frontal (F8-F7) and central (C4-C3) regions. This finding from this

session was important as eyes-closed and eyes-opened condition are often used as baseline conditions in EEG studies. From the result obtained, the significant difference in EEG power across whole brain region between both conditions suggested that these two conditions do not provide the similar outcome and hence must be take note in experiment design. Eyes-opened condition was suitable to be used as baseline condition for experiment that involve visual stimuli and eyes-closed condition was recommended for studies that do not use eyes-opened condition in their task.

4.3 EEG study and comparison on the eyes-closed and eyes-opened at resting state for control group versus depressive group

Previous subchapter reported the differences in EEG power between eyes-closed and eyes-opened solely for euthymic participants which the result may serve as a baseline. In this session, presenting here is the EEG power differences on depressive and non-depressive group which is the core aim of the research. For this study, the fixed parameter was focused on eyes-closed and eyes-opened at resting condition to find out the profound different brainwaves power on participants with depressive symptom and non-depressive. The EEG signals of eyes-closed condition and eyes-opened condition of both control and depressive group are compared to identify the best condition giving obvious signal on depressive symptoms. The participants were categorized into depressive group justified through Patient Heath Questionnaire-9 (PHQ-9) and Depression Anxiety Stress Score-21 (DASS-21). The scores of PHQ-9 and DASS-21 can be viewed in Table 4.1. Questionnaires were used as it is served as gold standard in clinical diagnosis at the moment, hence we still used this method to scope the participants on depressive and verifying the participants' condition with EEG. The control group had to meet the criteria which obtain PHQ-9 score of less than 10 and DASS-21 depression score of below 14, anxiety scores of below 10 and stress scores of below 19. Conversely, participants with score above 10 in PHQ-9 and depression score above 10 in DASS-21were categorized into depressive group.

4.3.1 Self-report measures on the state of mind during EEG recording of eyes-closed and eyes-opened for control and depressive group

Self-report measures from the participants is shown in Figure 4.8 for both control and depressive group during eyes-closed and eyes-opened conditions at resting state. The purpose of this step was to verify the brainwaves changes during EEG experiment. For close eyes condition, the self-measures result indicated approximately half of the control group participants (52%) felt relax during EEG recording section, but solely 26% of the participants in the depressive group felt relax for the same experiment. For eyes-opened condition, 70% of participants in control group reported feeling relaxed but contradictory, only 24% from depressive group felt relaxed during EEG section. In summary, control group had higher number of participants in relaxing state during both eyes-opened and eyes-closed condition compared to depressive group. Depressive group generally tend to day dream (42%) during eyes-opened condition and suffered more from drowsiness (sleepy) (32%) for eyes-closed condition. State of mind category under others obtained the lower scores for both group in both opened and eyes-closed conditions. Participants who selected others indicated that they were having random thoughts during the EEG recordings.

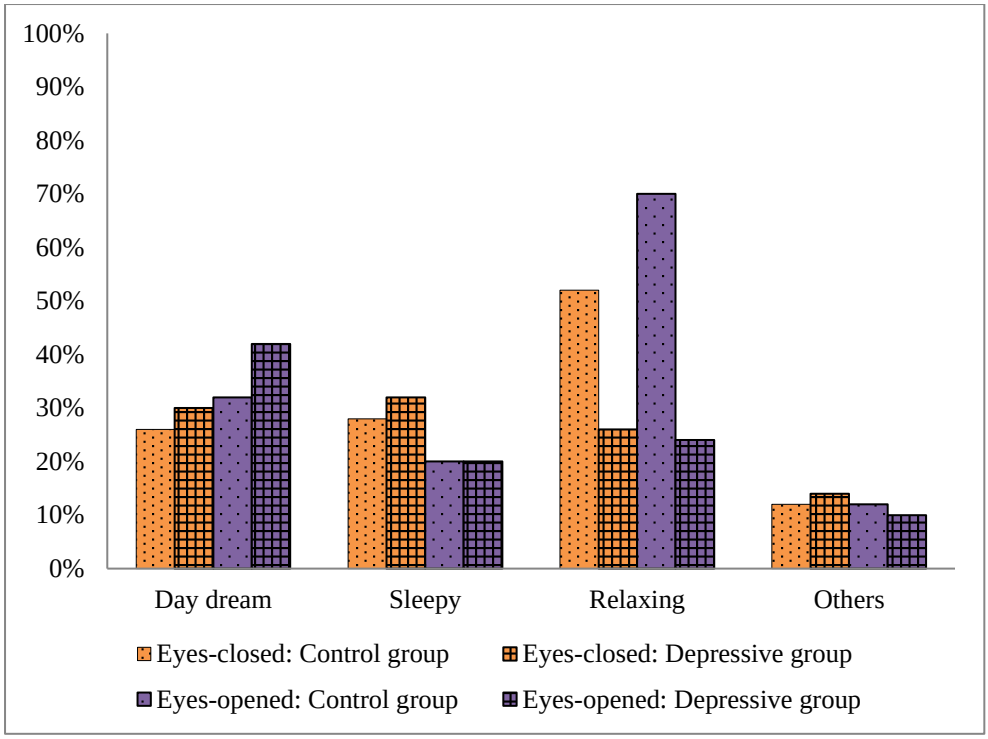

Figure 4.8: Comparison of self-report measures result based on the mind states between control and depressive group during eyes-opened and eyes-closed condition.

4.3.2 Pulse rate analysis comparison between control group and depressive group for eyes-closed and eyes-opened resting condition

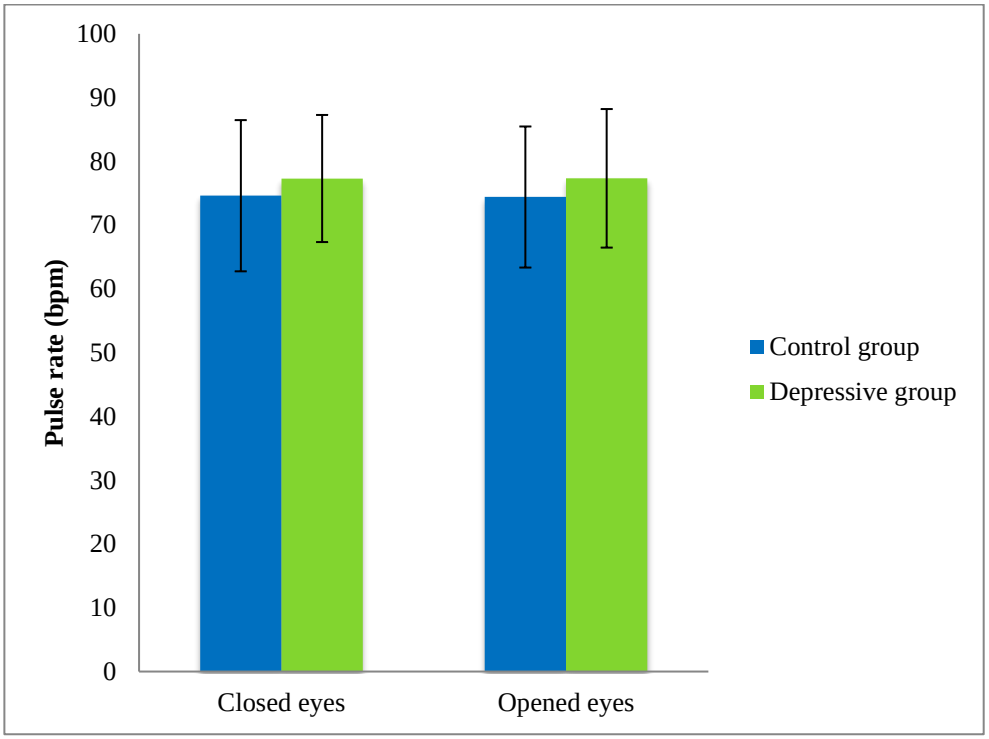

Figure 4.9: Comparison of pulse rate between control and depressive group during eyes-closed and eyes-opened condition

There is assumption that the person suffered from depressive symptom would have higher pulse rate. Here, we included the pulse rate measurement to further verify the differences of the biological parameter of depressive and non-depressive groups besides brainwaves. The pulse rate of the participants was recorded throughout the EEG experiment. Result shows in Figure 4.9 indicated that the mean pulse rate of control group for both eyes-closed and eyes-opened condition was approximately 74 bpm, while depressive group had

slightly increased in pulse rate compared with control group, 77 bpm. However, there is no significant difference in independent T-test comparing pulse rate between depressive and control group for eyes-closed ($t(98)=1.185$, $p=0.239$) and eyes-opened ($t(98)=1.275$, $p=0.206$) condition. On the other hand, there was no significant difference in paired t-test analysis differentiating eyes-closed and eyes-opened condition for control group ($t(49)=-0.225$, $p=0.823$) and depressive group ($t(49)=0.087$, $p=0.931$) respectively. Research less reported on pulse rate correlates to depressive symptoms but there were few studies related major depression to a decrement in heart rate variability (HRV) (Agelink *et al.*, 2002; Borrione *et al.*, 2017; Chen *et al.*, 2017). Pulse rate is the average heart rate beats per minutes whereas heart rate variability (HRV) is the variation in time interval between one heart beat and the next heart beat. Therefore, high pulse rate produces low HRV and vice versa (Hart, 2013). However, this study showed no significant in pulse rate in between normal and depressive group, this may due to the participants are suffered from depressive symptom and non-clinical diagnose depression and some of them not even noticed that they were under depressive category until this experiment.

4.3.3 Comparison on eyes-closed and eyes-opened condition at resting state between control and depressive groups for EEG power bands (0-30Hz)

4.3.3.1 Delta Power (1-4 Hz)

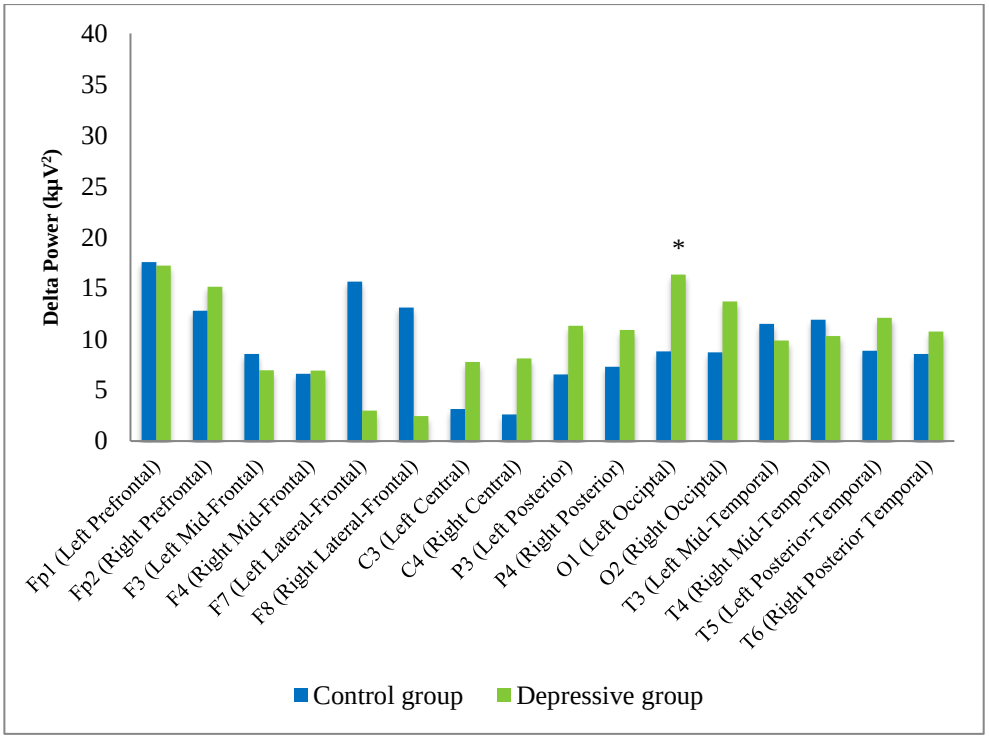

Figure 4.10: Median absolute delta power of control and depressive group during eyes-closed condition at resting state(*=p<0.05, **=p<0.01, ***=p<0.001: Mann-Whitney U test showed level of significant difference comparing control and depressive group at each brain region)

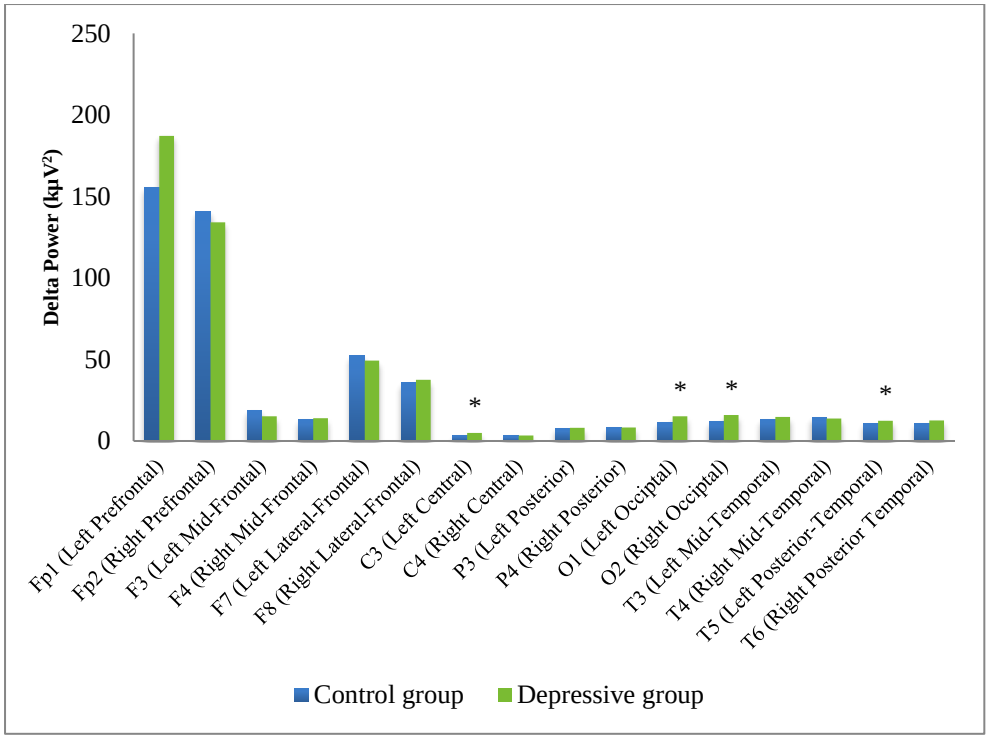

Figure 4.11: Median absolute delta power of control and depressive group during eyes-opened condition.(*=p<0.05, **=p<0.01, ***=p<0.001: Mann-Whitney U test showed level of significant difference comparing control and depressive group at each brain region)

Figure 4.10 and Figure 4.11 shows the delta power band of control and depressive group for eyes-closed and eyes-opened conditions. Eyes-closed condition displayed higher delta power amplitude acquisition in depressive group at central (C3, C4), posterior (P3, P4), occipital (O1, O2) and posterior-temporal (T5, T6) areas of the brain. On the other hand, eyes-opened condition displayed higher delta power amplitude acquisition in depressive group at central (C3, C4), occipital (O1, O2) and posterior temporal (T5, T6) only. Besides that, in eyes-closed condition, lateral frontal (F7, F8) region was observed to have profound higher theta power in control group than depressive

group but not in eyes-opened condition. Furthermore, the delta power of both control group and depressive group during eyes-opened condition was profound high at prefrontal (Fp1, Fp2) and lateral frontal (F7, F8) area which were similar to the result in previous section discussed in chapter 4.2. The high amplitude in delta power was caused by the eye-blinking movement effect (Fisch & Spehlmann, 2000).

However, according to Mann-Whitney U test, delta power in eyes-closed condition reported significant only at left occipital region, O1($U=925$, $p=0.025$) in between control and depressive group. On the other hand, the eyes-opened condition reported significant different in between control and depressive group at left central C3 ($U=928.5$, $p=0.027$), left occipital O1 ($U=905.5$, $p=0.018$) and right occipital O2, ($U=905.5$, $p=0.018$), and left temporal T5 ($U=911.5$, $p=0.04$).

Depressive group in this investigation shows greater delta power at central, posterior and occipital region for eyes-closed condition. This result was similar to a bipolar disorder study where patients were reported to have greater power in delta activity compared to healthy controls (El-Badri *et al.*, 2001). Also, an MEG studied by Chen and colleagues reported increased delta oscillation synchronization in bipolar disorder patients (Chen *et al.*, 2008). Besides that, as mentioned in chapter 4.2 earlier on difference of delta power in eyes-closed and eyes-opened condition, delta power was related to sleepiness waves (Assenza *et al.*, 2013) and associated to cognitive and emotional process (Güntekin and Başar, 2016). Güntekin reported that the

delta power at frontal, central and posterior increased with increased cognitive loads (Güntekin and Başar, 2016). Also, the delta power at occipital region was reported increased with the processing on the perception of face and facial expression (Güntekin and Başar, 2014). This findings was further supported by numerous studies where the depressed patients were reported to show decreased sensitivity toward happy faces (Joormann and Gotlib, 2006) and induced greater sensitivity on sad faces (Gilboa-Schechtman, Erhard-Weiss and Jeczemien, 2002).

In this study, the EEG signal was recorded in resting conditions that do not involve cognitive processing of human. However, the depressive group displayed higher delta power at the central, posterior and occipital regions than control group. This indicated that the depressive group was engaged in cognitive or emotional processing during the EEG recording. Depressive people may find difficulty in calming and relaxing themselves. Studies reported that emotional disturbance is the core causation for depressive symptomatology which will lead to cognitive disturbance (Roiser, Elliott and Sahakian, 2012). Depressed people was prone to suffer from distorted affective processing which in nature will have difficulty in decision making and anhedonia (Roiser, Elliott and Sahakian, 2012). Prior study also reported that depression is a disorder of impaired emotional regulation and was reported to have difficulties in cognitive control (Joormann and Gotlib, 2010). The lateral-frontal (F7, F8) region of depressive group was observed to be profound lower during eyes-closed condition. The function of left lateral-frontal, F7 is for verbal expression and right lateral-frontal, F8 is for emotional

expression and both left and right lateral frontal were related to mood regulation (Walker, Kozlowski and Lawson, 2007). The emotional regulation in depressive people may have suppressed the delta power of depressive group especially during eyes-closed condition. The increase in delta powers at central, posterior and occipital region maybe a potential indicator in detecting depressive symptoms. However, the less significant difference found in statistical analysis for both eyes-closed and eyes-opened condition requires further verification in future work.

4.3.3.2 Theta Power (4-8 Hz)

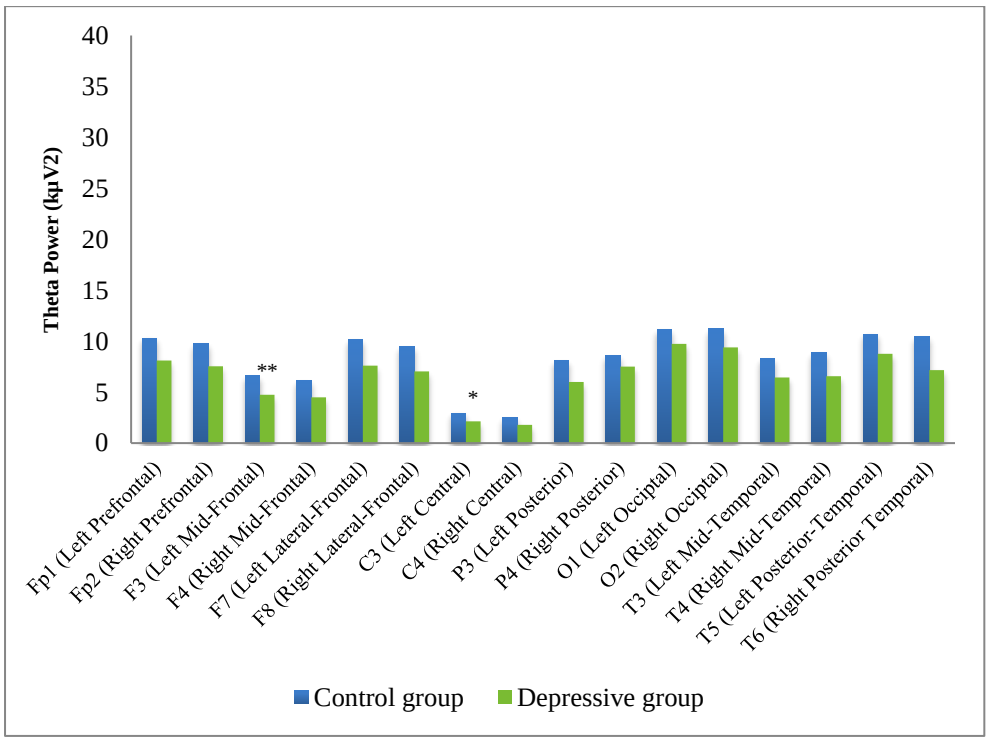

Figure 4.12: Median absolute theta power of control and depressive group during eyes-closed condition(*=p<0.05, **=p<0.01, ***=p<0.001: Mann-Whitney U test showed level of significant difference comparing control and depressive group at each brain region)

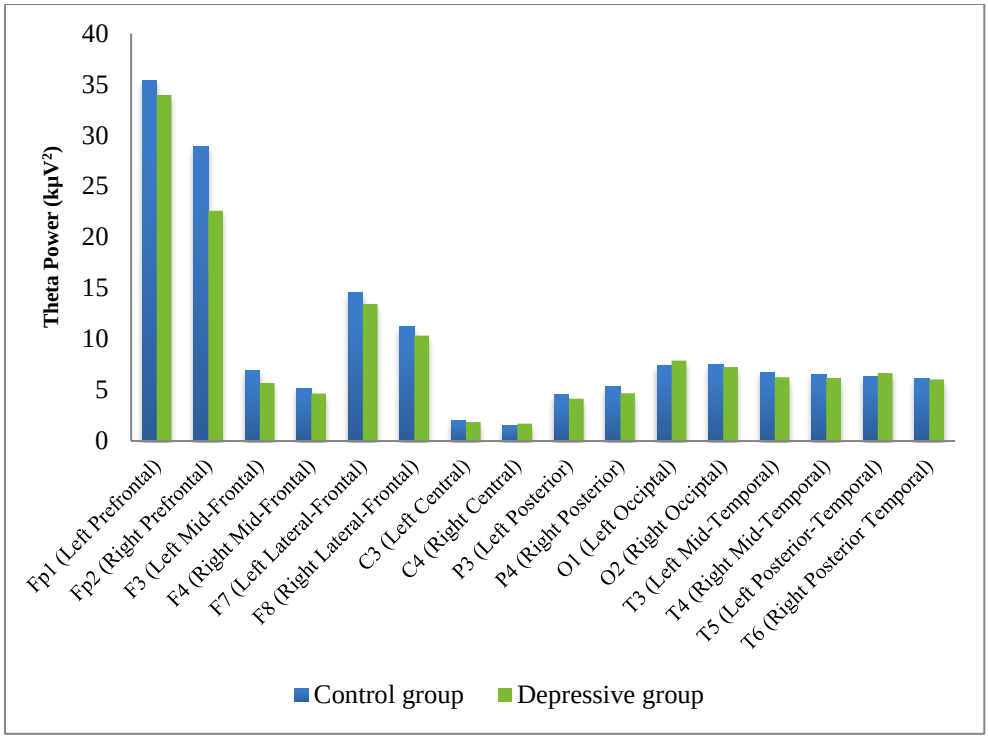

Figure 4.13: Median absolute theta power of control and depressive group during eyes-opened condition(*=p<0.05, **=p<0.01, ***=p<0.001: Mann-Whitney U test showed level of significant difference comparing control and depressive group at each brain region)

Figure 4.12 shows higher power acquisition for control group during eyes-closed condition in entire brain regions regardless left or right part of the brain as compared to depressive group. However, statistical analysis shows no obvious different for the same comparison except location at left frontal F3 (U=850.5, p=0.006) and left central C3 (U=939.5, p=0.032) region. Referring to Figure 4.13, the theta power during eyes-opened condition shows no profound changes in between control and depressive group and Mann-Whitney U test statistically analysis reported no significant different in between them. Besides that, by comparing Figure 4.12 with Figure 4.13, a

noteworthy result was the theta power at prefrontal (Fp1, Fp2) and lateral-frontal (F7, F8) during eyes-opened condition were higher than eyes-closed condition.

The study outcome was found to be in line with Barry's study which reported that the theta power was associated with stimulus processing where they indicated that the theta power increased at the hemisphere region and reduced at other region during eyes-opened condition (Barry *et al.*, 2007). Theta power of the depressive group in eyes-closed condition was overall slightly lower than control group as theta activity was affected by emotional processing according to a study by Aftanas and colleagues (Aftanas *et al.*, 2001). Previous study also reported that theta power was associated with depression and was used to study the response to antidepressant medication (Pizzagalli, Oakes and Davidson, 2003; Mulert *et al.*, 2007; Korb *et al.*, 2009). The theta power was lower in depressive group during eyes-closed condition. Control and depressive group could be differentiated clearly through the power acquisition as shown in Figure 4.12 but statistically was only shown significant at two locations which are at left mid frontal F3 and left central C3. The changes of the theta power band were trivial which may not be a feasible frequency band as biomarker in detecting depressive symptoms.

4.3.3.3 Alpha Power (8-12 Hz)

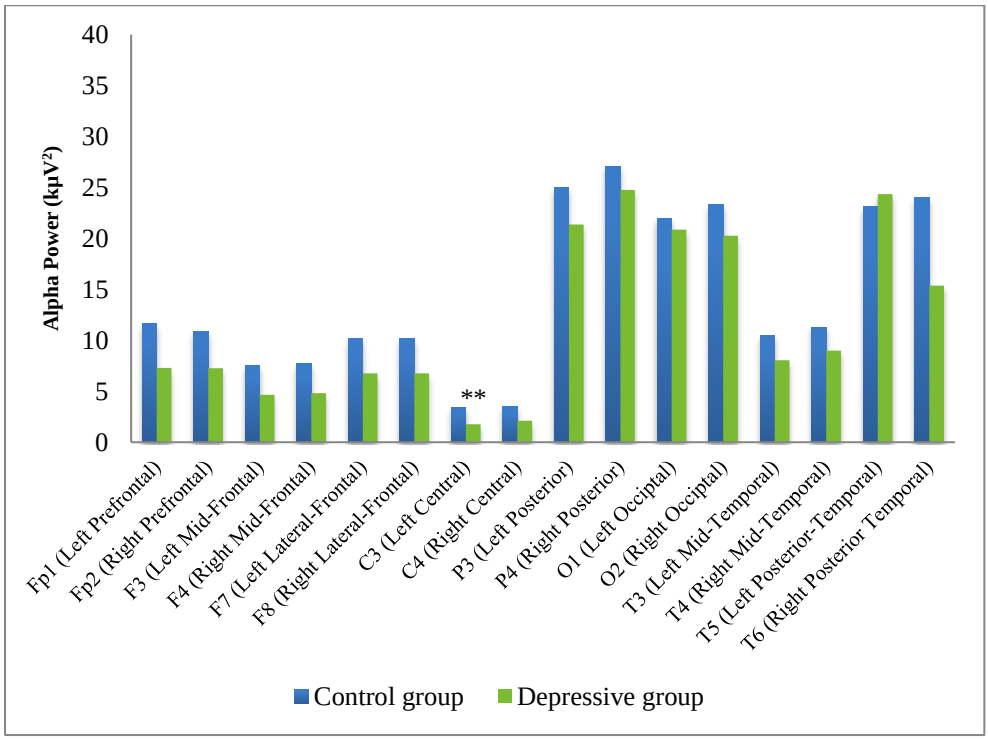

Figure 4.14: Median absolute low alpha power of control and depressive group during eyes-closed condition(*=p<0.05, **=p<0.01, ***=p<0.001: Mann-Whitney U test showed level of significant difference comparing control and depressive group at each brain region)

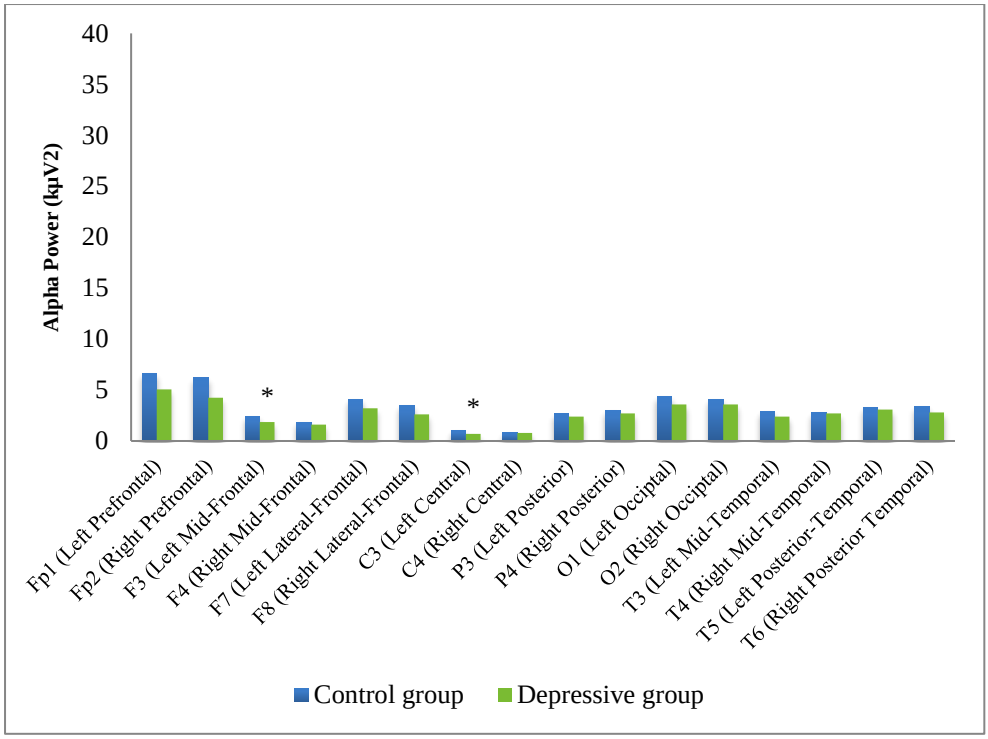

Figure 4.15: Median absolute low alpha power of control and depressive group during eyes-opened condition(*=p<0.05, **=p<0.01, ***=p<0.001: Mann-Whitney U test showed level of significant difference comparing control and depressive group at each brain region)

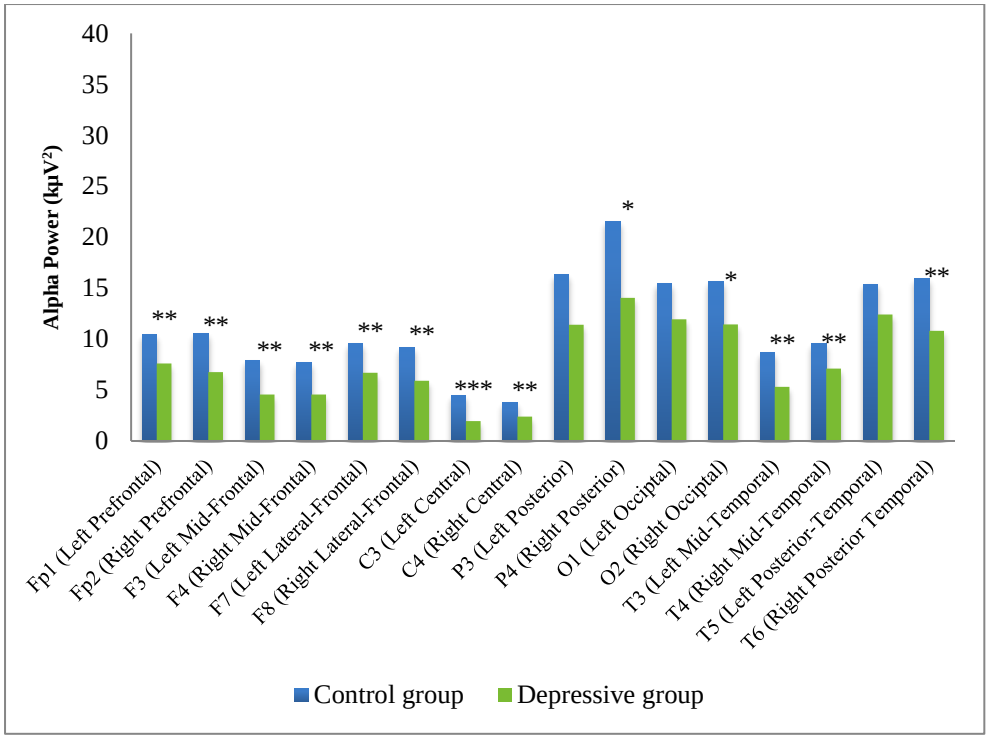

Figure 4.16: Median absolute high alpha power of control and depressive group during eyes-closed condition(*=p<0.05, **=p<0.01, ***=p<0.001: Mann-Whitney U test showed level of significant difference comparing control and depressive group at each brain region)

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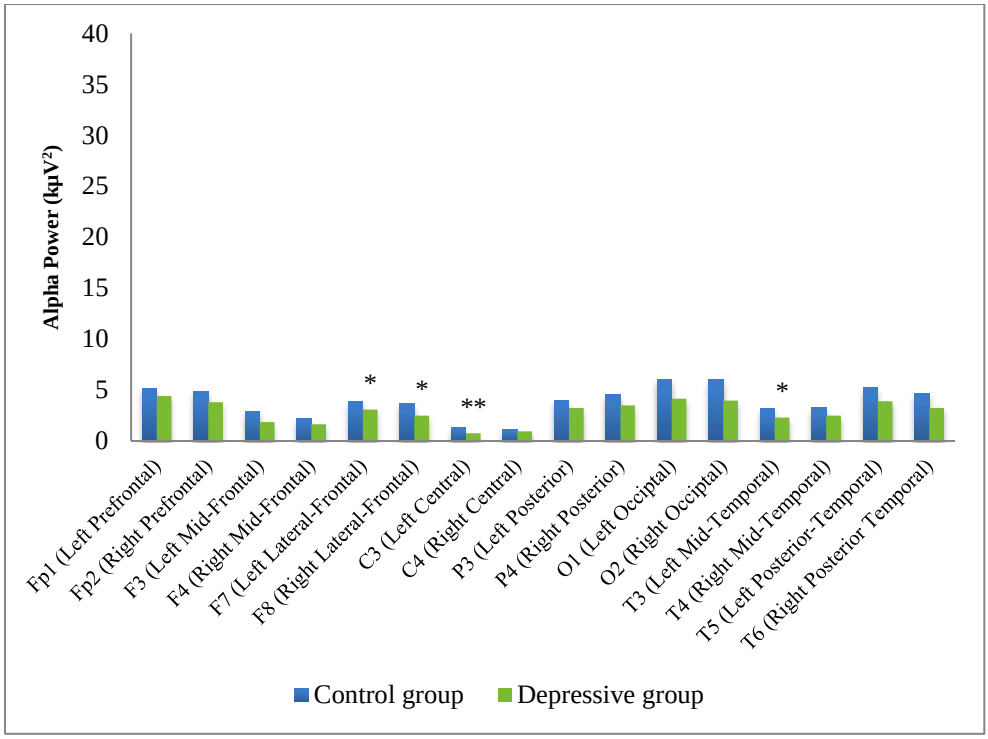

Figure 4.17: Median absolute high alpha power of control and depressive group during eyes-opened condition(*=p<0.05, **=p<0.01, ***=p<0.001: Mann-Whitney U test showed level of significant difference comparing control and depressive group at each brain region)

Alpha power (8-10 Hz) was generally reported to be dominated during eyes-closed condition resting condition (Barry *et al.*, 2007). The alpha power was separated into low alpha (8-10 Hz) and high alpha (10-12 Hz) to compare the significant difference in between control and depressive group respectively. Figure 4.14 and Figure 4.15 displayed the low alpha power in eyes-closed and eyes-opened condition, respectively. Low alpha power of depressive group was observed to be lower than control group for both eyes-closed and eyes-opened conditions at whole brain regions. By comparing Figure 4.14 with Figure 4.15, the alpha power in eyes-closed condition was observed to be

higher than eyes-opened condition regardless control or depressive group. In terms of statistical analysis, low alpha power was reported significant different between control and depressive group at left central C3 (U=847.5, p=0.006) only for eyes-closed condition according to Mann-Whitney U test. Conversely for eyes-opened condition, it was reported significant different at left mid-frontal F3 (U=925, p=0.025) and left central C3 (U=906, p=0.017) region.

On the other hand, Figure 4.16 and Figure 4.17 displayed the high alpha power acquisition for eyes-closed and eyes-opened condition respectively. Referring to both figures, depressive group was observed to obtain lower high alpha power than control group at entire brain region. For eyes-closed condition, the Mann Whitney U test reported significant different between control and depressive group at left prefrontal Fp1 (U=866.5, p=0.008), right prefrontal Fp2 (U=858, p=0.007, left mid-frontal F3 (U=842, p=0.005), right mid-frontal F4 (U=857.5, p=0.007), left lateral frontal F7 (U=847, p=0.004), right lateral frontal F8 (U=847, p=0.005), left central C3 (U=661.5, P<0.001), right central C4 (U=952, p=0.004), right posterior P4 (U=923, p=0.024), right occipital O2 (U=935.5, p=0.03), left mid-temporal T3 (U=903.5, p=0.002), right mid-temporal T4 (U=878.5, p=0.01) and right posterior temporal T6 (U=863, p=0.008). However, high alpha power at eyes-opened condition recorded less number of significant difference brain areas. The depressive group was significant lower than control group at left central C3 (U=809, p=0.002), left lateral frontal F7 (U=964.5, p=0.049), right lateral frontal F8 (U=938, p=0.03) and left mid-temporal T3 (U=931, p=0.028). High

alpha power band during eyes-closed condition indicated a more convincing brainwaves region in differentiating the control and depressive groups.

This result was consistent with the recent study reported global decreased in alpha synchronization in bipolar depression patients compared to normal participants with greatest decreased at right fronto-central and centro-parietal connections (Kim *et al.*, 2013). Recent study reported that there were no differences in EEG power between bipolar depression with unipolar depression (Tas *et al.*, 2015). Besides that, there were studies found in line with this report presenting decreased alpha waves in depressed group compared to control group at whole brain region (Price *et al.*, 2008; Kan and Lee, 2015). Moreover, Pozzi et. al. stated that the depressed patient obtained lower relative alpha power in right posterior region compare to non-depressed patients (Pozzi *et al.*, 1995).

4.3.3.4 Beta Power (12-30 Hz)

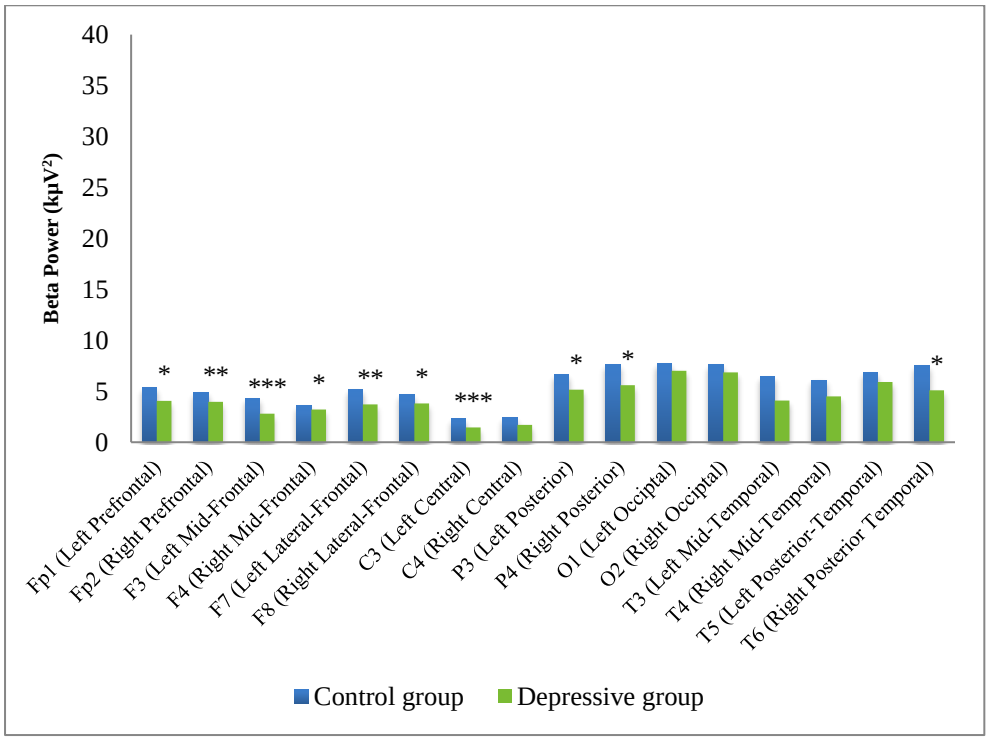

Figure 4.18: Median absolute beta power of control and depressive group during eyes-closed condition.(*=p<0.05, **=p<0.01, ***=p<0.001: Mann-Whitney U test showed level of significant difference comparing control and depressive group at each brain region)

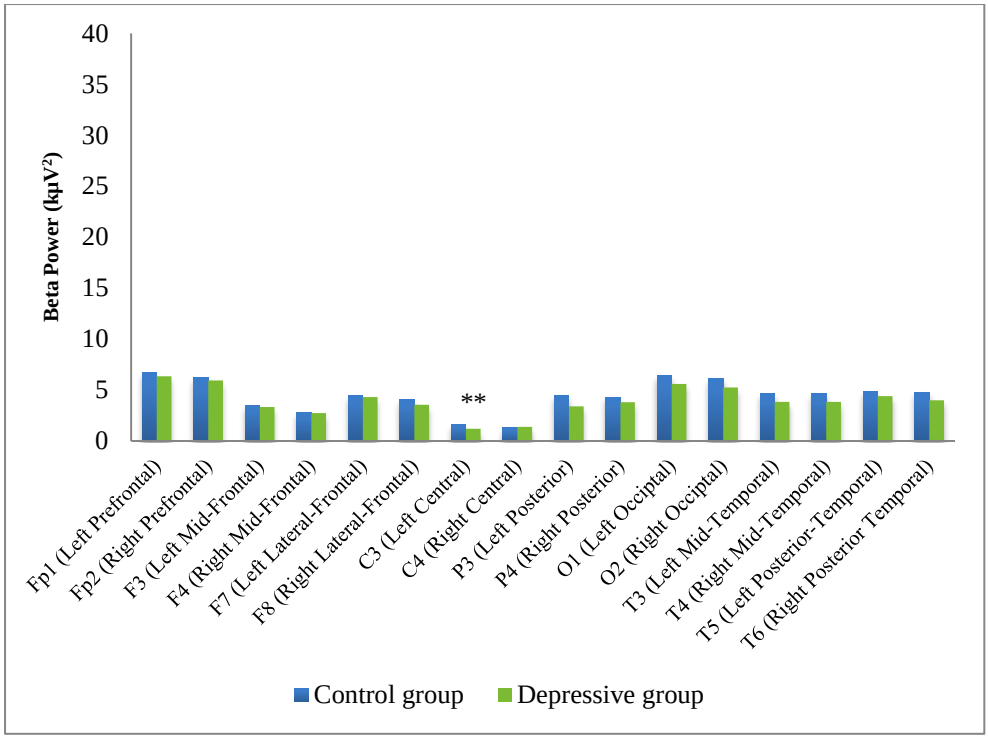

Figure 4.19: Median absolute beta power of control and depressive group during eyes-opened condition(*=p<0.05, **=p<0.01, ***=p<0.001: Mann-Whitney U test showed level of significant difference comparing control and depressive group at each brain region)

The beta power for both control and depressive group were observed to be relatively low as compared to other frequency band, shown in Figure 4.18 and Figure 4.19. The great finding was that the amplitudes of the power acquisition for depressive group for both eyes-opened and close eyes conditions were significantly lower for whole brain region. Mann-Whitney U test showed significant different in eyes-closed condition at left prefrontal Fp1 (U=891.5, p=0.013), right prefrontal Fp2 (U=868.5, p=0.009), left mid-frontal F3 (U=762.5, p=0.001), right mid-frontal F4 (U=9455.5, p=0.036), left lateral frontal F7 (U=831, p=0.004), right lateral frontal F8 (U=892.5,

p=0.014), left central C3 (U=671.5, p<0.001), left posterior P3 (U=949.5, p=0.038), right posterior P4 (U=952.5, p=0.04) and right posterior-temporal T6 (U=1065, p=0.018). Eyes-opened condition itself showed significant different at left central C3 (U=908, p= 0.0018) only.

Beta power is reported to be higher in amplitudes for observing functions on attention paying (Fan *et al.*, 2007), sensorimotor behavior (Kilavik *et al.*, 2013), language processing (Weiss and Mueller, 2012) and memory (Hanslmayr, Staudigl and Fellner, 2012). The resting state condition during this experiment produced relatively low beta power for both closed and eyes-opened condition as compared to other frequency region. Our result was contradicted to findings of prior studies where Yatsenko *et. al.* reported increased in beta power in patients of early stages in depression (Grin-Yatsenko *et al.*, 2009). Studies by Begic and colleagues also found increased of beta power at parietal and occipital region in depression group compare to healthy controls (Begić *et al.*, 2011). However, our argument point here is that the targeted group was shown depressive symptom and was far from diagnosed as depression state. Consequently, this finding may imply a new trend on showing the beta region is potential in identifying depressive symptom.

4.3.4 Summary of EEG power comparison on control and depressive groups for both eyes-closed and eyes-opened condition at resting state

This session reported the difference in EEG frequency bands for healthy control and depressive groups of whole brain region for both eyes-closed and eyes-opened conditions. The significant input for this study was the eyes-closed condition reported the most occurrences differentiating the control and depressive group. The noteworthy result in of the obvious decreased in high alpha power band for depressive group as compared to control group at eyes-closed condition for whole brain region. Beta power band had shown the similar outcome which the depressive group decreased in power acquisition although the amplitude shown is low compared with other frequency band but the trend is obvious to address the different between both groups. Both alpha and beta in this study reports a promising power bands in differentiating brainwaves of those with depressive symptoms and non-depressed. Alpha and beta band during eyes-closed condition was proposed to be the suitable parameter in identify the depressive symptoms between normal and depressive group.

4.4 EEG study and comparison on the pre-deep breathing and post-deep breathing for control group versus depressive group

Previous chapter studied on the difference in EEG frequency between control and depressive group during resting state. In this session, the EEG frequency changes was further investigate to study the acute effect of deep breathing to brainwaves of control and depressive group. This technique involves focusing on taking slow, deep, and even breaths. According to Greenberg (2002), increase of breathing awareness increased the calmness of an individual and increase the attention to their internal and external stressors (Greenberg, 2002). The alpha and beta power should increase after the deep breathing session. This session of experiment was done under eyes-opened condition to evaluate the effect of deep breathing during normal circumstances. The EEG power after deep breathing (post-deep breathing) was compared to the baseline EEG power (pre-deep breathing). The comparison of EEG power in between control and depressive group for pre and post-deep breathing maybe an approach in detecting depressive symptoms. The methods of deep breathing was described in chapter 3 in details.

4.4.1 Self report measures on the state of mind during pre-deep breathing and post-deep breathing

This session was to investigate the acute effect of deep breathing activity to control and depressive group. By referring to Figure 4.20, more participants from depressive group reported that they were relaxing after deep

breathing, where the percentage of relaxing increase from 24% during pre-deep breathing recording to 60% during post- deep breathing. Conversely, the percentage of relaxing of control group decreased from 70% during pre-deep breathing to 47% only after deep breathing. Both depressive and control group reported decrease in drowsiness (sleepy) from 20% during pre-deep breathing recording to 10% and 11%, respectively after deep breathing condition. Depressive participants were calmer after breathing activity but not control group.

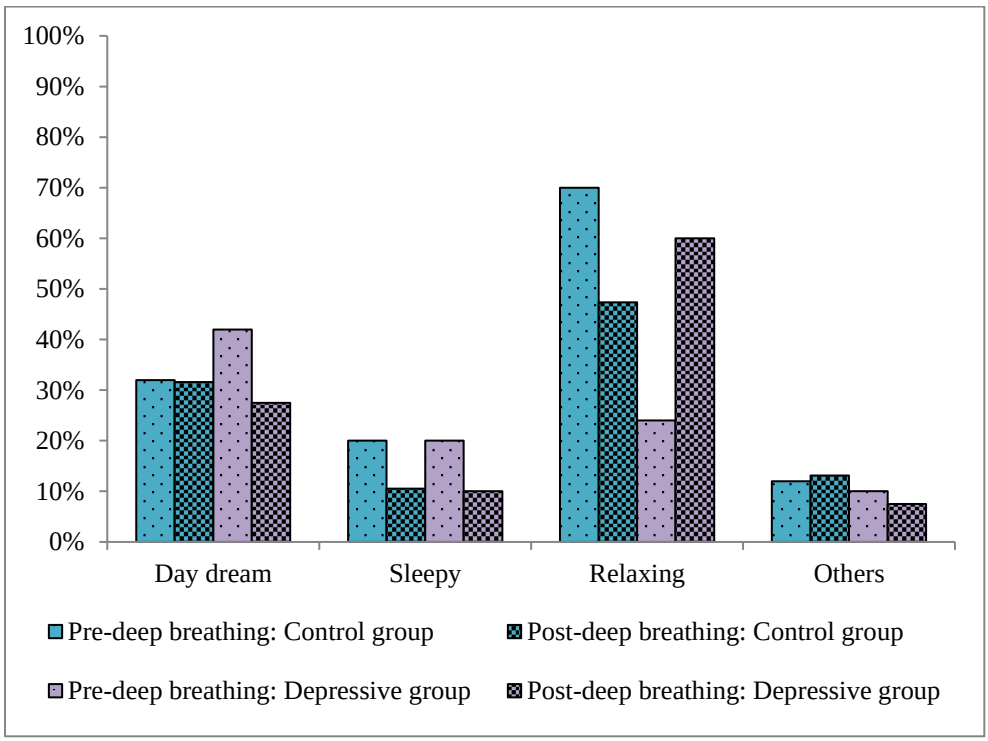

Figure 4.20: Comparison of self-report measures result based on the mind states during the EEG measurement of pre-deep breathing and post-deep breathing with eyes-opened condition

4.4.2 Pulse rate analysis comparison between pre-deep breathing and post-deep breathing condition for control and depressive group

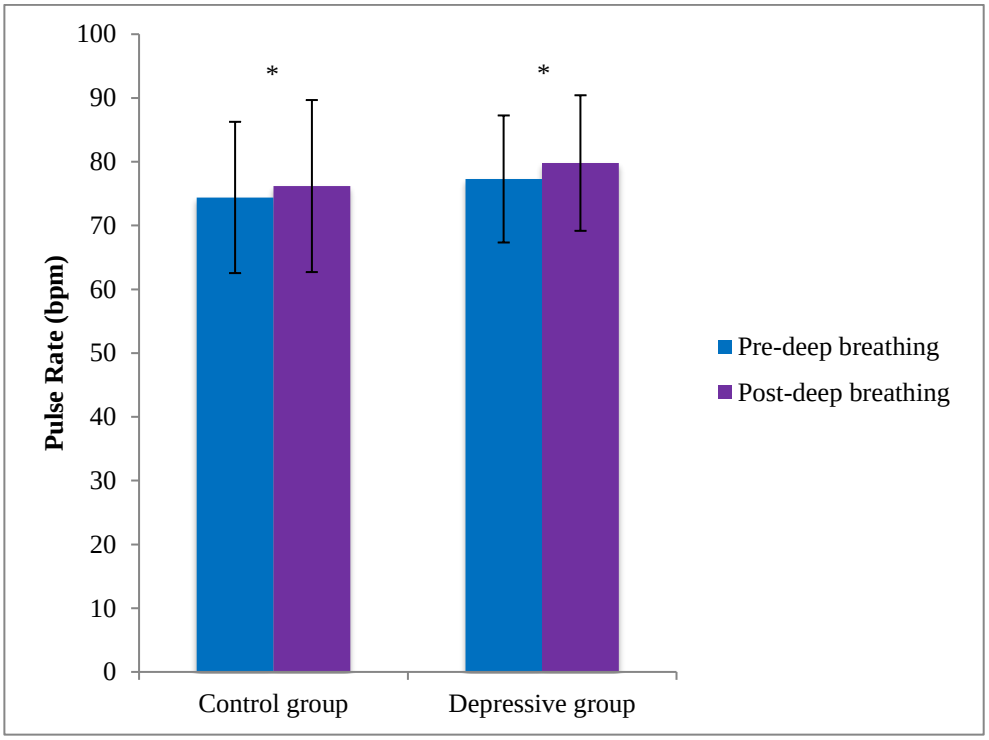

Figure 4.21: Comparison of pulse rate between pre and post deep breathing for control and depressive group (*=p<0.05, **=p<0.01, ***=p<0.001: Paired t-test showed level of significant difference between pre-deep breathing and post-deep breathing)

The pulse rate of participants was taken throughout the experiment to observe the changes of pulse rate before and after deep breathing. Overall the pulse rate of depressive group was higher than control group as showed in Figure 4.21. However, independent T-test showed no significant difference comparing control and depressive group for pre-deep breathing ($t(98)=1.274$, $p=0.206$) and post-deep breathing ($t(98)=1.345$, $p=0.182$), respectively. On the

other hand, the pulse rate of control group increased after deep breathing with paired t-test showed significant difference of t(49)=-2.267, p=0.03). Also, depressive group reported increased in pulse rate after deep breathing with statistical significant difference of t(49)=-2.249, p=0.03. This finding concluded that the deep breathing increased the pulse rate of both control and depressive group. Studies reported that the heart rate was related to breathing or respiratory rate and blood pressure (Pitzalis *et al.*, 1998). The breathing rate was always relate to heart rate variability (HRV) where prior study reported decreased of breathing rate was associated with greater HRV (Lin, Tai and Fan, 2014). The breathing rate of spontaneous breathing at rest for healthy adults is approximately 9 – 24 breaths per minute (Lehrer and Gevirtz, 2014). In this study, the breathing rate of deep breathing was approximately 10 breaths per minute. From this study, deep breathing increased the pulse rates of participants regardless the participants were from control or depressive group. Prior study reported that the variation of breathing rate did not give significant differ in mean pulse rate unless the breathing rates in comparison had big difference where that prior study reported significant reduced in heart rate at a slow breathing rate at 4 breaths per minute compared to breathing rate of 14 breaths per minute (Song and Lehrer, 2003). The pulse rate of participants during deep breathing was higher than spontaneous breathing. The spontaneous breathing rates for pre-deep breathing of 50 participants in each group maybe slower than the rates of instructed deep breathing. This result required further study in details with measurement of spontaneous breathing rate of participants at before experiment at resting state.

4.4.3 Comparison on pre-deep breathing and post-deep breathing between control and depressive groups for EEG power bands (0-30Hz)

4.4.3.1 Delta Power (1-4 Hz)

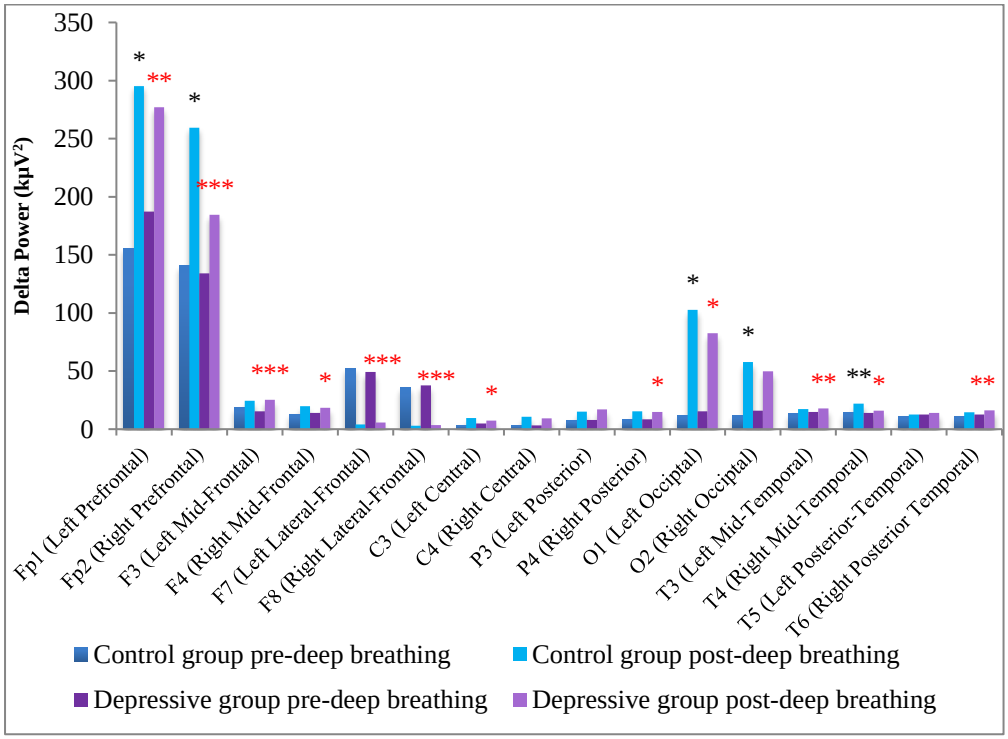

Figure 4.22: Median absolute delta power of pre and post deep breathing for control and depressive group (*=p<0.05, **=p<0.01, ***=p<0.001:Wilcoxon signed-rank test showed level of significant difference between pre-deep breathing and post-deep breathing)

Figure 4.22 presented the comparison of pre and post deep breathing for control group (in blue) and depressive group (in purple). The black asterisk (*) in the Figure showed that the control group was having significant different in between pre and post-deep breathing whereas the red asterisk (*) was referring to the significant difference of depressive group. Referred to the

control group in Figure 4.21, the delta power increased at all brain regions after deep breathing activity. The Wilcoxon signed-rank test reported control group elicit statistical different at left prefrontal Fp_1 (Z=-2.382, p= 0.017), right prefrontal Fp_2 (Z= -2.494, p=0.013), left occipital O1 (Z=-2.526, p=0.012), right occipital O2 (Z=-2.157, p=0.031), and right mid-temporal T4 (Z=-2.626, p=0.009).

Conversely, depressive group had increased delta power at all region except lateral frontal (F7, F8) after deep breathing. Wilcoxon signed rank-test reported significant increase of delta power in depressive group at left prefrontal Fp1 (Z=-2.822, p=0.005), right prefrontal Fp2 (Z=-3.290, p=0.001), left mid-frontal F3 (Z=3.934, p<0.001), right mid-frontal F4 (Z=-2.117, p=0.034), left central C3 (p=-2.054, p=0.040), right posterior P4 (Z=-1.074, p=0.011), left occipital O1(Z=-1.975, p=0.048), left mid-temporal T3 (Z=-3.146, p=0.002), right mid-temporal T4 (Z=-2.421, p=0.015) and right posterior-temporal T6 (Z=-2.698, p=0.007) with significant decreased at left lateral-frontal F7 (Z=-3.731, p=<0.001) and right lateral-frontal F8 (Z=-3.539, p<0.001). The control and depressive group had similar significant increase of delta power at prefrontal (Fp1, Fp2), left occipital O1 and right mid-temporal T4 after breathing activity. The delta power of control and depressive group decreased at lateral frontal (F7, F8). Man Whitney U test was conducted to evaluate the significant difference between control and depressive group at post-deep breathing, the analysis reported no significant in between both group at whole brain region.

Increase of delta power was correlated to increase in cognitive loads. Delta power was reported to be involved in cognitive processes such as attention, perception, signal detection and decision making (Güntekin and Başar, 2016). The noteworthy result from both control and depressive group is delta power significantly increased at prefrontal (Fp1, Fp2) and occipital (O1, O2) after deep breathing may indicate that deep breathing may have helps in inducing cognitive load at prefrontal area. According to Goldman-Rakic, the prefrontal cortex is the area connecting frontal lobe and a central component in the network of brain regions supporting cognitive control (Sawaguchi and Goldman-Rakic, 1991). Also, prefrontal area was the main cortex of performing executive functions (Funahashi and Andreau, 2013). From the result, the breathing activity may activate the cognitive load or executive function of control and depressive group by increasing the delta power at prefrontal area. Besides that, the increase of delta power at occipital region was reported to be related to perception of face and facial expression process (Güntekin and Başar, 2016) The finding from this study was consistent with the Guntekin study, therefore deep breathing may help to activate the perception process with the increase of occipital delta power.

The decrease of delta power at frontal F7 and F8 was noticed in both control and depressive group. Frontal F7 and F8 were related to mood regulation besides functioned for verbal and emotional expression respectively (Walker, Kozlowski and Lawson, 2007). Depression is a disorder of impaired emotional regulation and was reported to have difficulties in cognitive control (Joormann and Gotlib, 2010). The suppression of delta power of both group at

lateral-frontal F7 and F8 indicated that the deep breathing activity may regulated the mood of both group after deep breathing. Lastly, the breathing activity showed less significant difference in control group but more in depressive group, this may indicate that the delta power of depressive group impacted more from deep breathing.

4.4.3.2 Theta Power (4-8 Hz)

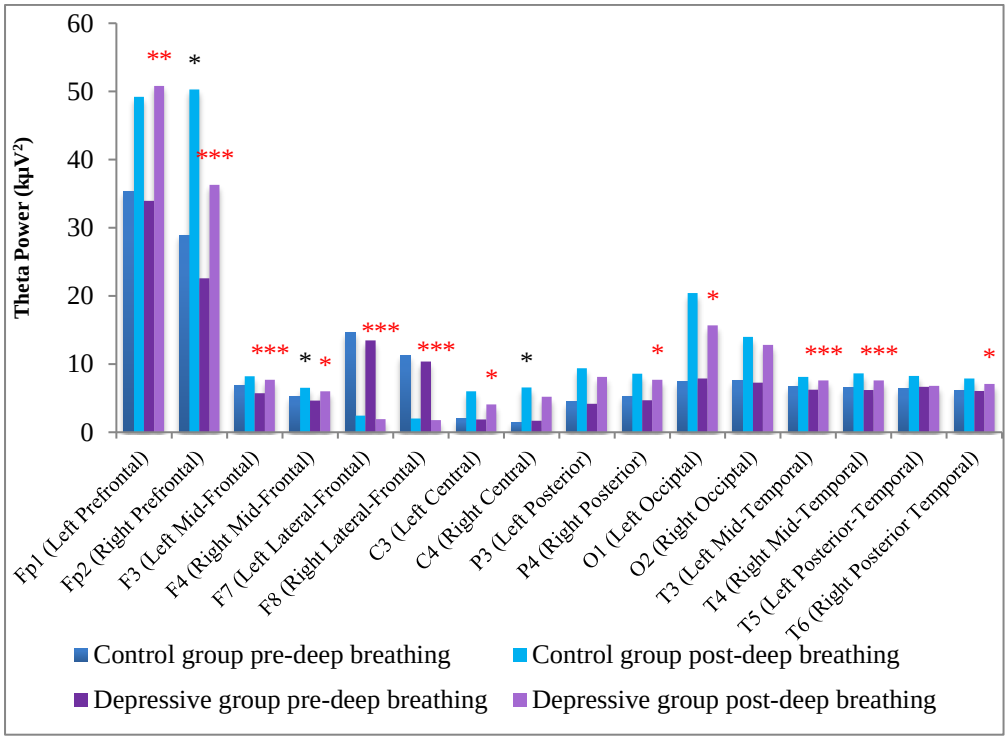

Figure 4.23: Median absolute theta power of pre and post deep breathing for control and depressive group (*=p<0.05, **=p<0.01, ***=p<0.001:Wilcoxon signed-rank test showed level of significant difference between pre-deep breathing and post-deep breathing)

Similar to delta power, the theta power of both control and depressive group in Figure 4.23 was observed to be increased at all brain region and decreased at lateral frontal (F7, F8) after deep breathing. Control group was statistical significant at right prefrontal Fp2 (Z=-1.613, p=0.026), right mid-frontal F4 (Z=-2.195, p=0.028) and right central C4 (Z=-2.071, p=0.038) only. Whereas depressive group recorded significant increase of theta power at left prefrontal Fp1 (Z=-2.90, p=0.004), right prefrontal Fp2 (Z=-3.764, p<0.001), left mid-frontal F3 (Z=4.112, p<0.001), right mid-frontal F4 (Z=-2.123, p=0.034), left central C3 (p=-1.994, p=0.046), right posterior P4 (Z=-2.489, p=0.013), left occipital O1(Z=-2.388, p=0.017), left mid-temporal T3 (Z=-3.401, p<0.001), right mid-temporal T4 (Z=-3.304, p=0.001) and right posterior-temporal T6 (Z=-2.207, p=0.027) with significant decreased at lateral-frontal F7 (Z=-3.742, p<0.001) and F8 (Z=-4.383, P<0.001). Theta power of control and depressive group was having similar significant different between pre and post breathing activity at right prefrontal Fp2 and right mid-frontal F4. The theta power at prefrontal (Fp1, Fp2) region increased profoundly at post-deep breathing for both control and depressive group. The control group had less significant difference in theta power than depressive group comparing pre and post deep breathing. Conversely, according to Mann-Whitney U test, there was no significant difference in between control and depressive group at whole brain region.

Prior study reported that the theta power increased over frontal and central region during cognitive process and during variety task such as working memory, calculation and even musical imagining (Sasaki *et al.*, 1996).

The increase of theta power at post-deep breathing at prefrontal and central in this study indicated that deep breathing helps in increase cognitive load. The deep breathing activity impacted more on depressive group as the number of regions had significant changes in theta power was higher than number of regions in control group. However, similar to delta power, the theta power of both control and depressive group was also suppressed at lateral-frontal F7 and F8 significantly. Although the main function of left lateral-frontal F7 is verbal expression and right lateral-frontal F8 is emotional expression but both lateral-frontal F7 and F8 was functioning for mood regulation (Walker, Kozlowski and Lawson, 2007). The emotional regulation had suppressed the theta power after deep breathing activity. The suppression of theta power was the effect of deep breathing activity.

4.4.3.3 Alpha Power (8-12 Hz)

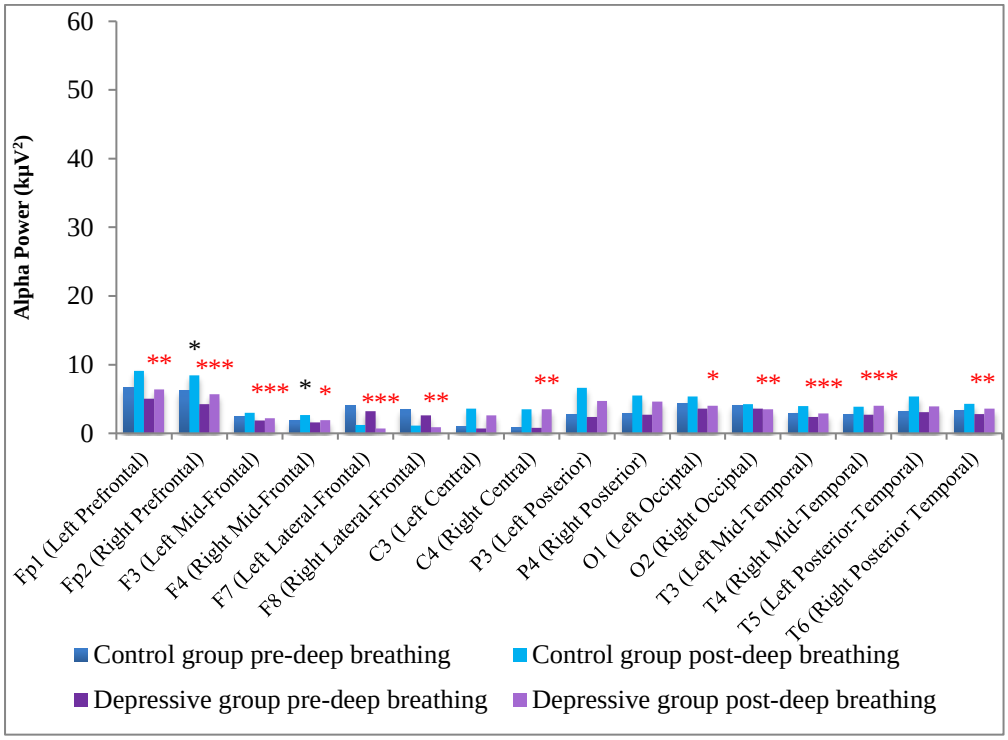

Figure 4.24: Median absolute low alpha power of pre and post deep breathing for control and depressive group (*=p<0.05, **=p<0.01, ***=p<0.001:Wilcoxon signed-rank test showed level of significant difference between pre-deep breathing and post-deep breathing)

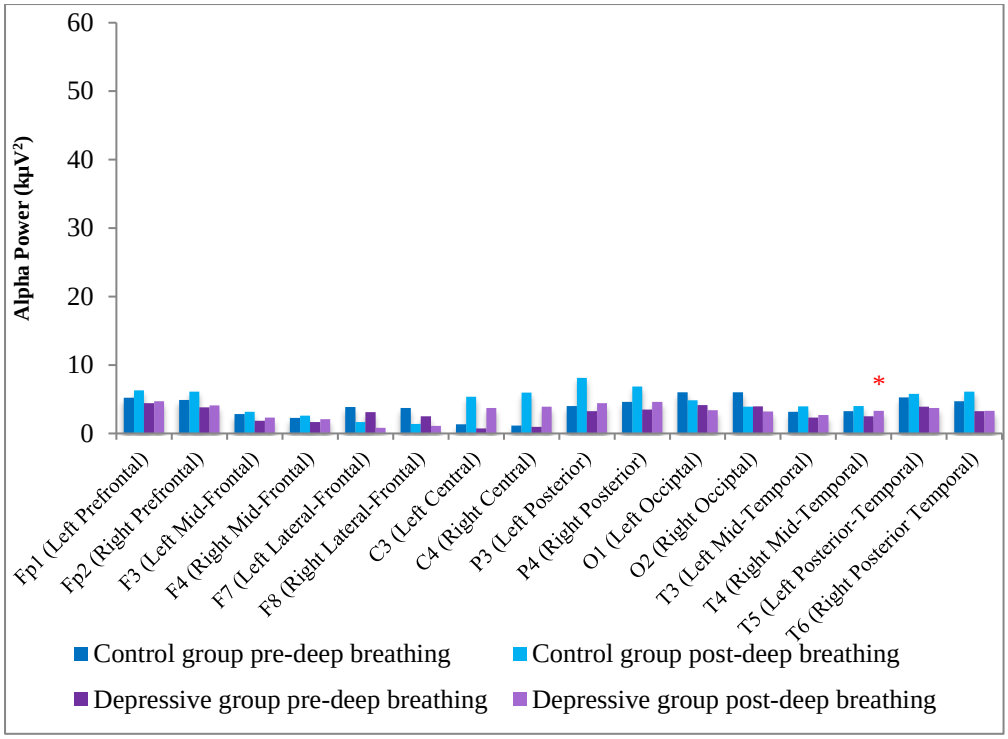

Figure 4.25: Median absolute high alpha power of pre and post deep breathing for control and depressive group (*=p<0.05, **=p<0.01, ***=p<0.001:Wilcoxon signed-rank test showed level of significant difference between pre-deep breathing and post-deep breathing)

The low alpha power of control group was observed to increase after deep breathing at all region except lateral frontal (F7, F8) according to Figure 4.24. However, Wilcoxon signed rank test only reported significant different at right prefrontal Fp2 (Z=-2.357, p=0.018) and right mid-frontal F4 (Z=-1.970, p=0.049). Depressive group had overall increased low alpha power at post-deep breathing with significant at left prefrontal Fp1 (Z=-2.989, p=0.003), right prefrontal Fp2 (Z=-3.678, p<0.001), left mid-frontal F3 (Z=-3.520, p<0.001), right mid-frontal F4 (Z=-2.165, p=0.030), right central C4 (p=-2.664, p=0.008), right occipital O2 (Z=-2.446, p=0.014), left mid-temporal T3

(Z=-3.038, p=0.002), right mid-temporal T4 (Z=-3.860, p<0.001) and right posterior-temporal T6 (Z=-2.723, p=0.006) but decreased at left lateral-frontal F7 (Z=-3.939, p=<0.001), right lateral-frontal F8 (Z=-4.397, p<0.001) and left occipital O1(Z=-2.586, p=0.010). Low alpha power of left central C3 and right central C4 after deep breathing for depressive group was also observed to be higher than the alpha 1 power of pre and post-deep breathing. On the other hand, high alpha power by referring to Figure 4.25 was having similar result of low alpha power in Figure 4.24. The high alpha power of control group was observed to be overall increased after deep breathing but Wilcoxon statistical analysis reported no significant difference. Conversely, high alpha power of the depressive group at post-deep breathing was observed to increase at central (C3, C4), posterior (P3, P4) and mid-temporal (T3, T4) with significant increased at right temporal T4 (Z=-2.428, p=0.015) only and decreased at lateral-frontal (F7, F8), occipital (O1, O2) and left posterior-temporal T5 without significant difference. Low alpha power had shown more significant result than the high alpha power. On the other hand, in terms of comparing control and depressive group at post-deep breathing, Mann Whitney U test reported low alpha had significant at left central, C3 (U=648, p=0.011). Meanwhile, high alpha had significant different at more region: right prefrontal Fp2 (U=679.5, p=0.024), left mid-frontal F3 (U=653.5, p=0.013), left lateral-frontal F7(U=632, p=0.008), right lateral-frontal F8 (U=694, p=0.033), left central C3 (U=607.5, p=0.004), left occipital O1 (U=690, p=0.03), right occipital O2 (U=673.5, p=0.021), left lateral-temporal T3 (U=680.5, p=0.025), left posterior-temporal T5 (U=687, p=0.028), and right posterior temporal T6 (U=626.5, p=0.007). By referring to post-deep-

breathing only, low alpha was a potential frequency band in differentiating control and depressive group.

Alpha power was well known to be increased during resting state and dominant during eyes-closed condition (Berger, 1993). The increasing of low alpha power at post-deep breathing reported that both the control and depressive group felt more relaxed after deep breathing. Prior study reported that the increased in breath awareness could increase the capacity to remain calm and help individuals to respond more adaptively to internal and external stressors (Greenberg, 2002). This finding was consistent with the interview result where greater number of participants in depressive group reported more relax after deep breathing, denotes in Figure 4.20. A noteworthy result on alpha power was the increase of left central C3 and right central C4 after breathing activity of control and depressive group. According to Walker and colleagues, besides functioning as sensorimotor integration, left central C3 was involved in alerting responses and right central C4 was involved in calming (Walker, Kozlowski and Lawson, 2007). The breathing activity helps both control and depressive group in relaxing with increasing alpha power. As a conclusion, deep breathing activity helps in calming and had higher impact on depressive group as depressive group reported more significant difference in alpha power between pre and post-deep breathing especially in low alpha power.

4.4.3.4 Beta Power (12-30 Hz)

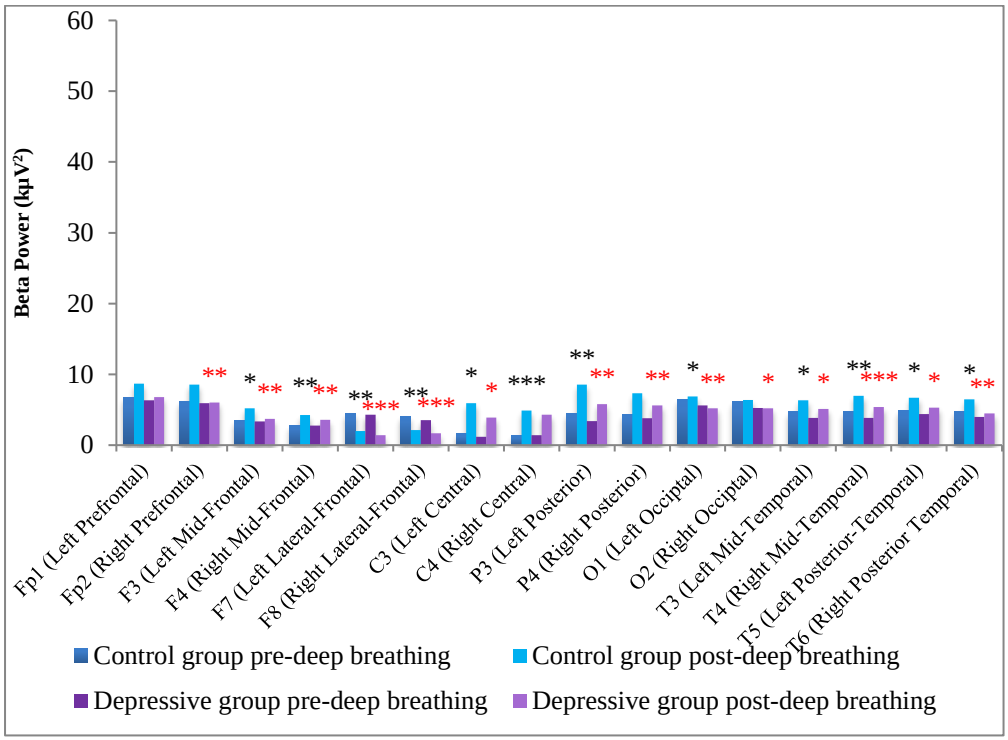

Figure 4.26: Median absolute beta power of pre and post deep breathing for control and depressive group (*=p<0.05, **=p<0.01, ***=p<0.001:Wilcoxon signed-rank test showed level of significant difference between pre-deep breathing and post-deep breathing)

Referring to Figure 4.26, the control group recorded increase in beta power at post-deep breathing at whole brain region except lateral frontal region with statistically significant at left mid-frontal F3 (Z=-2.157, p=0.031), right mid-frontal F4 (Z=-2.720, p=0.007), left lateral-frontal F7(Z=-2.696, p=0.007), right lateral-frontal F8 (Z=-3.020, p=0.003), left central C3 (Z=-2.314, p=0.021), right central C4(Z=-3.308, p=0.001), left posterior P3 (Z=-2.626, p=0.009), left occipital O1 (Z=-2.019, p=0.043), left mid-temporal T3 (Z=-2.395, p=0.017), right mid-temporal T4 (Z=-2.676, p=0.007), left

posterior-temporal T5 (Z=-2.332, p=0.020) and right posterior temporal T6 (Z=-2.074, p=0.038). On the other hand, the beta power of depressive group increased significantly at right prefrontal Fp2 (Z=-2.077, p=0.038), left mid-frontal F3 (Z=-2.766, p=0.006), right mid-frontal F4 (Z=-2.654, p=0.008), right posterior P4 (Z=-2.902, p=0.004), left mid-temporal T3 (Z=-2.895, p=0.04), right mid-temporal T4 (Z=-3.949, p<0.001), left posterior-temporal T5 (Z=-2.428, p=0.015), right posterior-temporal T6 (Z=-2.826, p=0.005) and decreased significantly at left lateral-frontal F7 (Z=-3.928, p<0.001), right lateral-frontal F8 (Z=-4.390, p<0.001), left central C3 (Z=-2.228, p=0.026), left occipital O1(Z=-2.947, p=0.003) and right occipital O2 (Z=-2.385, p=0.017). The noteworthy result in beta power was the depressive group had decreased beta power at post-deep breathing at occipital region (O1, O2). The Mann-Whitney U test reported that the post deep-breathing had significant difference in between control and depressive group at right prefrontal Fp2 (U=701.5, p=0.039), left mid-frontal F3 (U=639, p=0.009), left lateral-frontal F7 (U=648, p=0.012), left central C3 (U=658.5, p=0.015), left posterior P3 (U=646, p=0.011), left occipital O1 (U=646, p=0.011), left posterior-temporal T5 (U=637, p=0.009), and right posterior-temporal T6 (U=627, p=0.007).

Beta power was reported high during active functions (Fan *et al.*, 2007). Therefore, the increase of beta power indicated that breathing activity helps in improving attention level and alert state especially in control group. In addition, beta power at lateral-frontal (F7, F8) and occipital (O1, O2) of depressive group was found decreased after deep breathing. The power at lateral-frontal F7 and F8 were suppressed in all frequency band including beta

power after deep breathing. According to Jormann and Gotlib, depression is an impaired of emotional regulation and the frontal part of F7 and F8 were related to mood regulation (Joormann and Gotlib, 2010). The suppression of all power band at this area may be due to this ineffective emotion regulation. The decrease of beta power at occipital region in depressive group was a distinctive result compared to other frequency band. Occipital region was functioning for visual processing and pattern recognition including colour, movement and edge perception (Joormann and Gotlib, 2010). On the other hand, the beta power of both pre and post deep breathing of depressive group were observed to be lower than the control group. This finding was consistent with the earlier finding in differentiating control and depressive group during resting state condition where beta power of depressive group was reported lower than the control group. This finding is potentially to be a new trend in detecting depressive symptoms. The decreased of beta power at both lateral-frontal (F7, F8) and occipital (O1, O2) could be further investigated in detail for its potential to be a biomaker in detecting the difference in between control and depressive group.

On the other hand, central (C3, C4) region of control and depressive group had significant increased in beta power after deep breathing. Central C3 and C4 were functioned as sensorimotor and in alertness (C3), calming (C4) response (Joormann and Gotlib, 2010). Therefore, assumption is made that the increased of beta power may indicate the alertness of control and depressive group increased gradually by deep breathing. In a nutshell, finding in this

report shows that the deep breathing helps both control and depressive group to increase alertness.

4.4.4 Summary of EEG power comparison on pre-deep breathing and post-deep breathing for control and depressive groups

From this findings, the short duration of deep breathing even just 10 sets each of guided and without guided deep breathing by the instructor had created obvious effect on both control and depressive group through brainwaves changes at all frequency band from delta, theta, low alpha, high alpha to beta power. The delta, theta and alpha power of depressive people reported more significant difference than control group in post-deep breathing. On the other hand, both control and depressive group had significant increased beta power after deep breathing indicated that the deep breathing helps in increase alertness and attention level for all people as beta power was high during observing function such as attention paying (Fan *et al.*, 2007). The central (C3, C4) region of both control and depressive group had profound increase in all frequency range inclusive delta, theta, low alpha, high alpha and beta power at post-deep breathing. Central region is relates to alert and calm response (Joormann and Gotlib, 2010), deep breathing may helps in increasing the alertness and calmness of participants. Besides that, all frequency power at lateral-frontal region (F7, F8) were suppressed at post-deep breathing for both control and depressive group. Deep breathing activity may regulated the mood of the listener regardless the person is depressive or not. Besides that, the noteworthy result was the suppression of beta power at occipital region (O1,

O2) of depressive group at post-deep breathing. This finding maybe a new biomarker in detecting depressive symptoms.

4.5 EEG study and comparison on the pre-seawaves music and post-seawaves music for control group versus depressive group

This session investigate the acute effect to brainwaves changes after listening to seawaves music. Seawaves music was generally claimed to help people in relaxing (Thoma *et al.*, 2013). The alpha power of individuals should increase after the music listening session. In this session, the EEG power after listen to seawaves music (post-seawaves music) was compared to the baseline EEG power (pre-seawaves music). The difference in EEG frequency changes between control and depressive group after listening to seawaves music maybe an approach in detecting depressive symptoms.

4.5.1 Self report measures on the state of mind during seawaves music

This session is to study the acute effect of natural seawaves music both control and depressive group in differentiating depressive symptoms. According to Figure 4.27, the control group found increased in sleepiness after listening to seawaves music but depressive group found increased in relaxing mode. The current state of mind during listening to music was also interviewed to obtain the opinion of participants as shown in Figure 4.28. Both control and depressive group recorded only half of participants were focusing

on the music played. The remaining participants tend to day dream or felt sleepy during music playing.

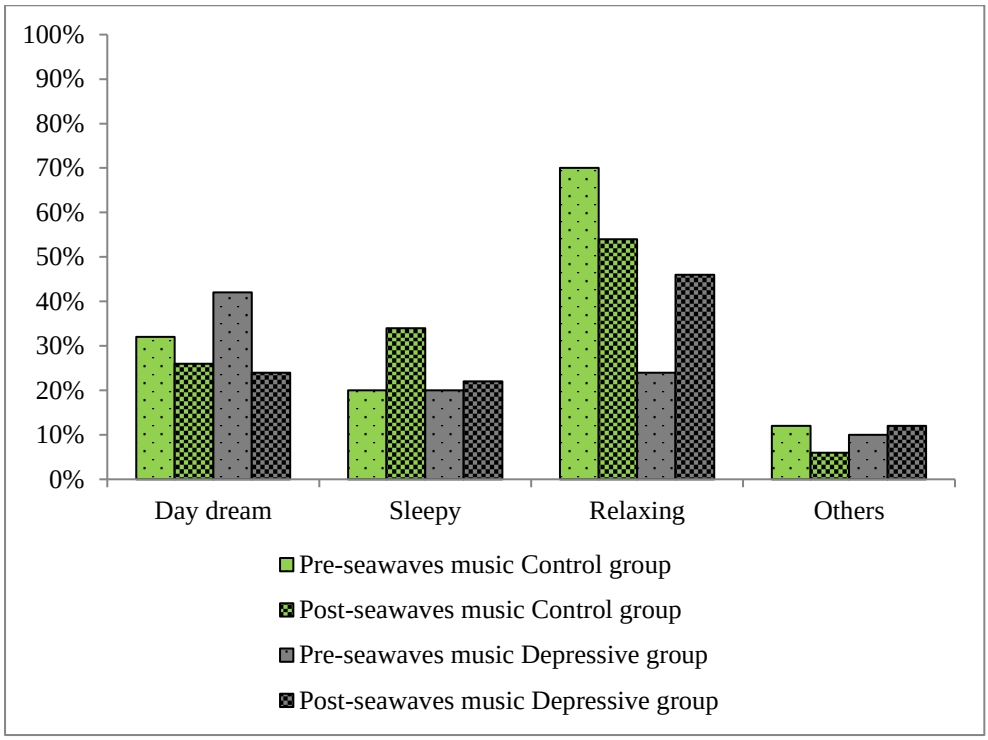

Figure 4.27: Comparison of self-report measures result based on the mind states during the EEG measurement of pre-seawaves music and post-seawaves music with eyes-opened condition

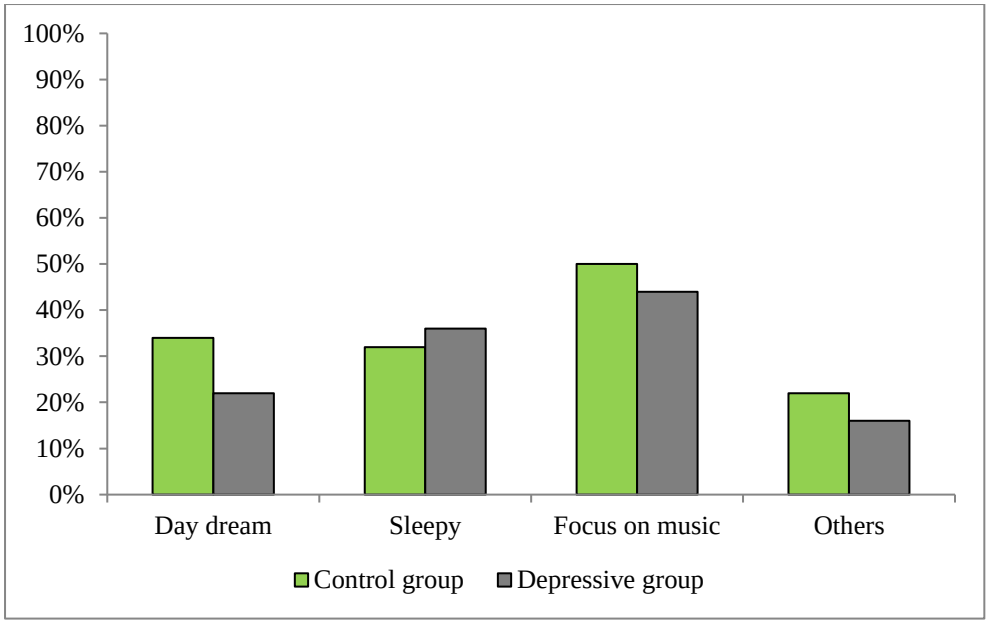

Figure 4.28: Comparison of self-report measures result based on the mind states during listening to seawaves music.

4.5.2 Pulse rate analysis comparison between pre-seawaves music and post-seawaves music condition for control and depressive group

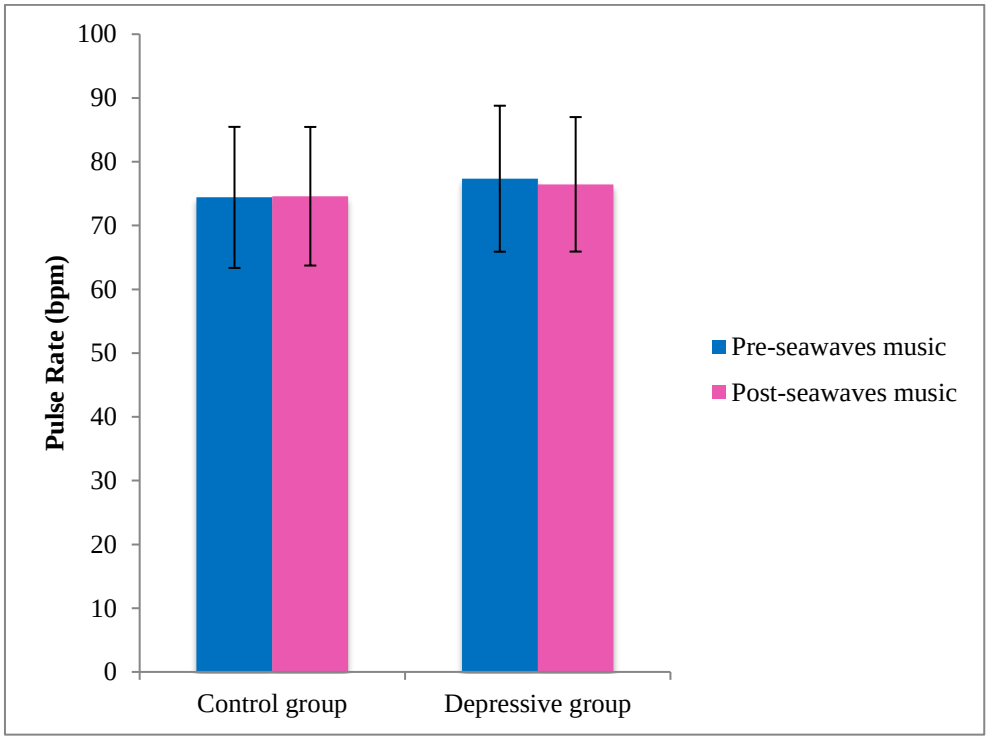

Figure 4.29: Comparison of pulse rate between pre and post-seawaves music for control and depressive group.

The pulse rate of participants was taken to compare the changes of pulse rate for pre and post-seawaves music for both control and depressive group.Paired T-test reported no statistical difference between pre-seawaves music and post seawaves music for both control group ($t(49)=-1.124$, $p=0.267$) and depressive group ($t(49)=-0.697$, $p=0.489$). On the other hand, comparison between control and depressive group using independent t-test also report no significant difference in pre-seawaves music ($t(98)=1.275$, $p=0.206$) and post-seawaves music ($t(98)=1.032$, $p=0.305$), respectively. The pulse rate outcome

from depressed and non-depressed participants was reported no significant changes by listening to seawaves music.

4.5.3 Comparison on pre-seawaves music and post-seawaves music between control and depressive groups for EEG power bands (0-30Hz)

4.5.3.1 Delta Power (1-4 Hz)

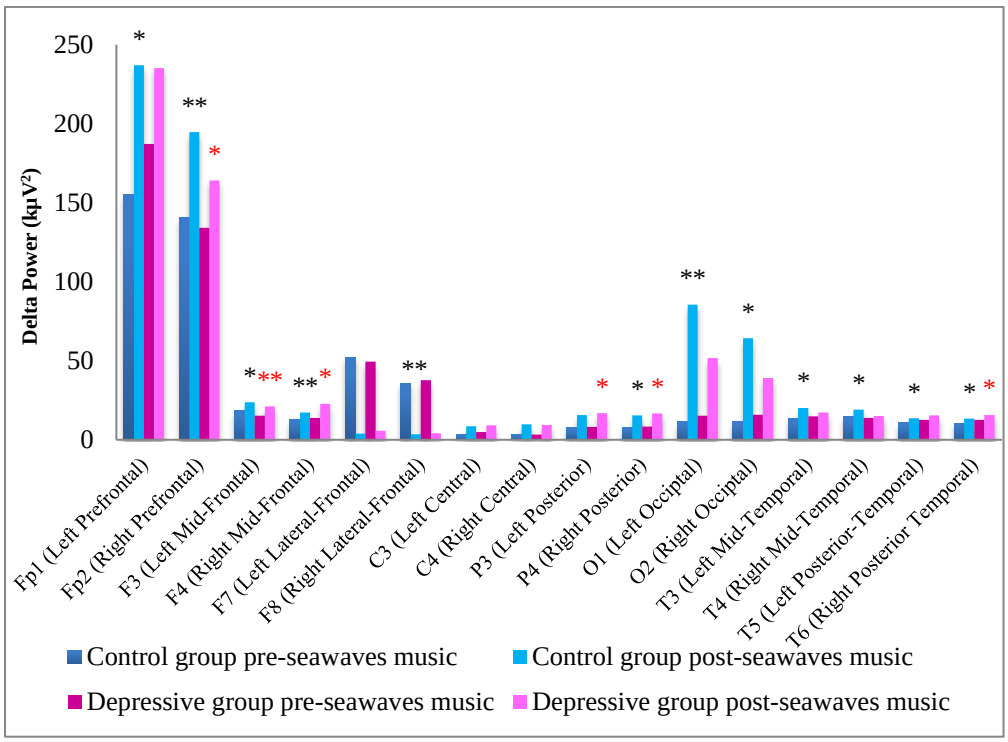

Figure 4.30: Median absolute delta power of pre and post-seawaves music for control and depressive group (*=p<0.05, **=p<0.01, ***=p<0.001:Wilcoxon signed-rank test showed level of significant difference between pre-seawaves and post-seawaves music)

According to Figure 4.30, the delta power of control and depressive group increased at prefrontal (Fp1, Fp2), mid-frontal (F3, F4), posterior (P3, P4), occipital (O1, O2), mid-temporal (T3, T4) and posterior temporal (T5, T6) after seawavesmusic but decrease at lateral frontal (F7, F8). Wilcoxon signed rank test showed that the control group was having significant increased at left prefrontal Fp1 (Z=-2.322, p=0.020), right prefrontal Fp2 (Z=-2.833, p=0.005), left mid-frontal F3 (Z=-2.577, p=0.010), right mid-frontal F4 (Z=-2.77555, p=0.006), right posterior P4 (Z=-2.375, p=0.018), left occipital O1 (Z=-3.283, p=0.001), right occipital O2 (Z=-2.442, p=0.015), left mid-temporal T3 (Z=-2.336, p=0.019), right mid-temporal T4 (Z=-2.278, p=0.038), left posterior-temporal T5 (Z=-2.278, p=0.023), right posterior-temporal T6 (Z=-2.188, p=0.029) with decrease at both left and right mid-frontal with significant at right mid-frontal F8 (Z=-2.742, p=0.006).The depressive group only had significant different at right prefrontal Fp2 (Z=-2.119, p=0.034), left lateral-frontal F3 (Z=-2.862, p=0.004), right mid-frontal F4 (Z=-1.984, p=0.047), left mid-posterior P3 (Z=-2.174, p=0.030), right posterior P4(Z=-2.472, p=0.013) and right posterior-temporal T6 (Z=-2.013, p=0.044). The depressive group had less significant difference between pre and post seawaves music than control group as the occipital and temporal region of depressive were not significantly different. The Man-Whitney analysis test was also conducted to compare the delta power of after seawaves music between control and depressive group,it was reported significant difference at left lateral-frontal F7 (U=869, p=0.009), right lateral-frontal F8 (U=911, p=0.019) and left central C3 (U=963, p=0.048).

Both control and depressive group showed the same changes in increased and decreased in amplitude for pre and post listening to seawaves music at delta power for different brain region. For control group, it shows significant increased at prefrontal, lateral frontal, occipital, and temporal after listening to seawaves music. From the prior study, delta power was found increased with rock music according to Pavlygina and colleagues where they claimed that different type of musics composition affecting different frequency bands of the brain region (Pavlygina, Sakharov and Davydov, 2004). Conversely, the increase of delta power in our findings was found contradicting with a prior study on acute patient that reported decreased in delta power especially at parietal and occipital regions when listening to music compared to resting condition (Morgan *et al.*, 2010).

From Figure 4.30, the delta power of both control and depressive group at lateral frontal F7 and F8 was suppressed at post-seawaves music. The delta power at post-seawaves music was lowered then pre-seawaves music. The function of the lateral frontal area, F7 and F8 was related to mood regulation according to a study by Walker (Walker, Kozlowski and Lawson, 2007). Hence, the suppression of delta power at lateral frontal may reflects that the seawaves music regulate the mood of both control and depressive group.

4.5.3.2 Theta Power (4-8 Hz)

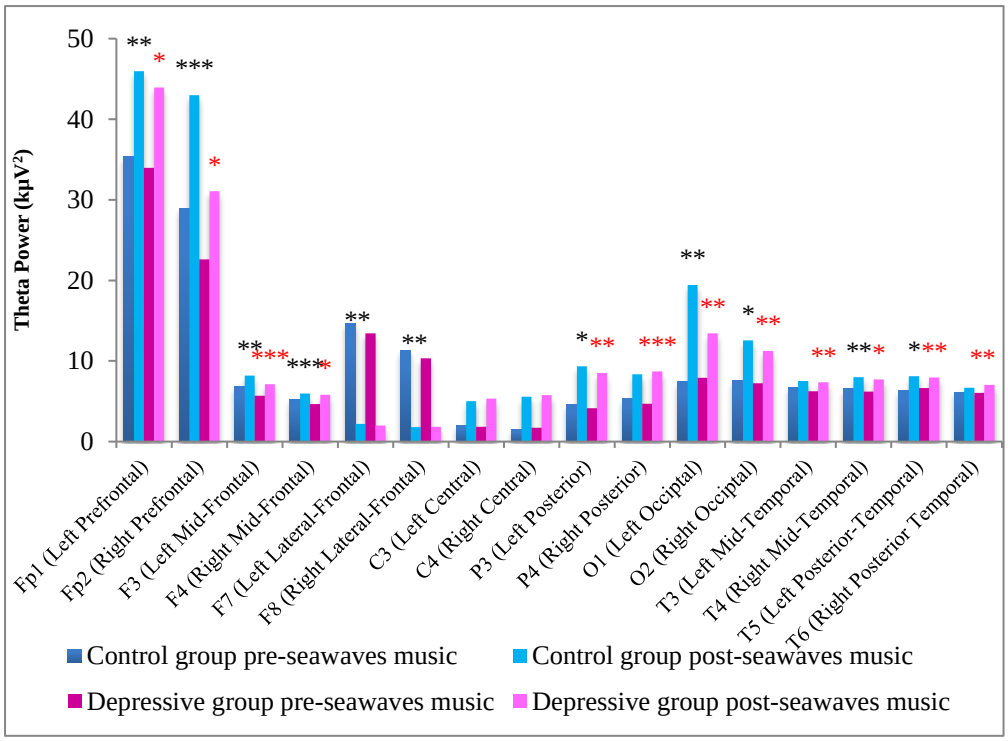

Figure 4.31: Median absolute theta power of pre and post-seawaves music for control and depressive group (*=p<0.05, **=p<0.01, ***=p<0.001:Wilcoxon signed-rank test showed level of significant difference between pre-seawaves and post-seawaves music)

Similar to delta power, theta power increased at all region except decreased at lateral-frontal (F7, F8). According to Wilcoxon signed-rank test, the control group had significant increased theta power at left prefrontal Fp1 (Z=-2.785, p=0.005), right prefrontal Fp2 (Z=-3.382, p=0.001), left mid-frontal F3 (Z=-2.940, p=0.003), right mid-frontal F4 (Z=-3.401, p=0.001), left posterior P3 (Z=-2.093, P=0.036), left occipital O1 (Z=-2.896, p=0.004), right occipital O2 (Z=-2.055, p=0.040),right mid-temporal T4 (Z=-2.565, p=0.010), left posterior temporal T5 (Z=-2.510, p=0.012) and significant decreased theta

power at left lateral-frontal F7 (Z=-2.565, p=0.010) and right lateral-frontal F8 (Z=-3.054, p=0.002) after seawaves music. Whereas depressive group had significant increased theta power at left prefrontal Fp1 (Z=-2.322, p=0.012), right prefrontal Fp2 (Z=-2.515, p=0.012), left mid-frontal F3 (Z=-2.534, p<0.001), right mid-frontal F4 (Z=-2.534, p=0.011), left posterior P3 (Z=-3.020, p=0.003), right posterior P4 (Z=-3.503, p<0.001), left occipital O1 (Z=-2.578, p=0.010), right occipital O2 (Z=-2.781, p=0.005), left mid-temporal T3 (Z=-2.914, p=0.004), right mid-temporal T4 (Z=-2.322, p=0.020), left posterior-temporal T5 (Z=-3.159, p=0.020)and right posterior-temporal T6 (Z=-3.051, p=0.002). Both control and depressive group had significant difference at left prefrontal Fp1, right prefrontal Fp2, left mid-frontal F3, right mid-frontal F4, right lateral-frontal F8, left posterior P3, left occipital O1, right occipital O2, right mid-temporal T4 and right posterior temporal T5. Mann Whitney test reported no significant difference of theta power between control and depressive group after seawaves music.

In this research, the seawaves music helped to increase the theta power of both control and depressive group at brain region of prefrontal, mid-frontal, posterior, occipital and temporal. This is supported from a report indicated that total theta power was increased significantly during listening to music in normal participants suggesting music listening might involving interhemispheric transmission of information in the fronto temporal areas (Yuan *et al.*, 2000). Type of intensity of music composition influenced the EEG spectrum, listening to classical music which was the low and moderate intensity music reported increased theta power at whole brain region together

with beta power (Pavlygina, Sakharov and Davydov, 2004). Also, pleasant music or happy music was found to increase theta power at frontal midline region according to Sammeler and colleagues (Sammler *et al.*, 2007). The authors claimed that the increase of theta power at frontal midline reflects the emotional processing in close interaction with attentional functions (Sammler *et al.*, 2007). The mid-frontal F3 and F4 in this experiment increased significantly in both control and depressive group at post-seawaves music might reflect that the seawaves music was a pleasant music in elevating the emotion of people. The theta power at lateral-frontal F7 and F8 of both control and depressive group were found decreased after listening to seawaves music. Seawaves music regulates the mood of both control and depressive group as lateral-frontal F7 and F8 was functioning on mood regulation (Walker, Kozlowski and Lawson, 2007).

4.5.3.3 Alpha Power (8-12 Hz)

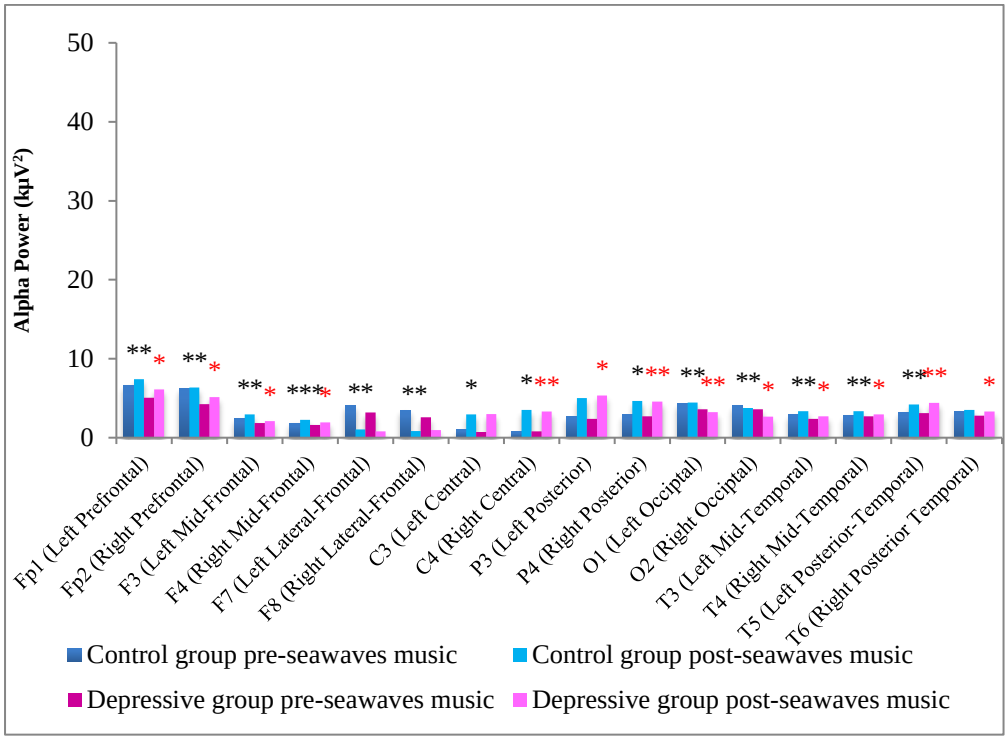

Figure 4.32: Median absolute low alpha power of pre and post-seawaves music for control and depressive group (*=p<0.05, **=p<0.01, ***=p<0.001:Wilcoxon signed-rank test showed level of significant difference between pre-seawaves and post-seawaves music)

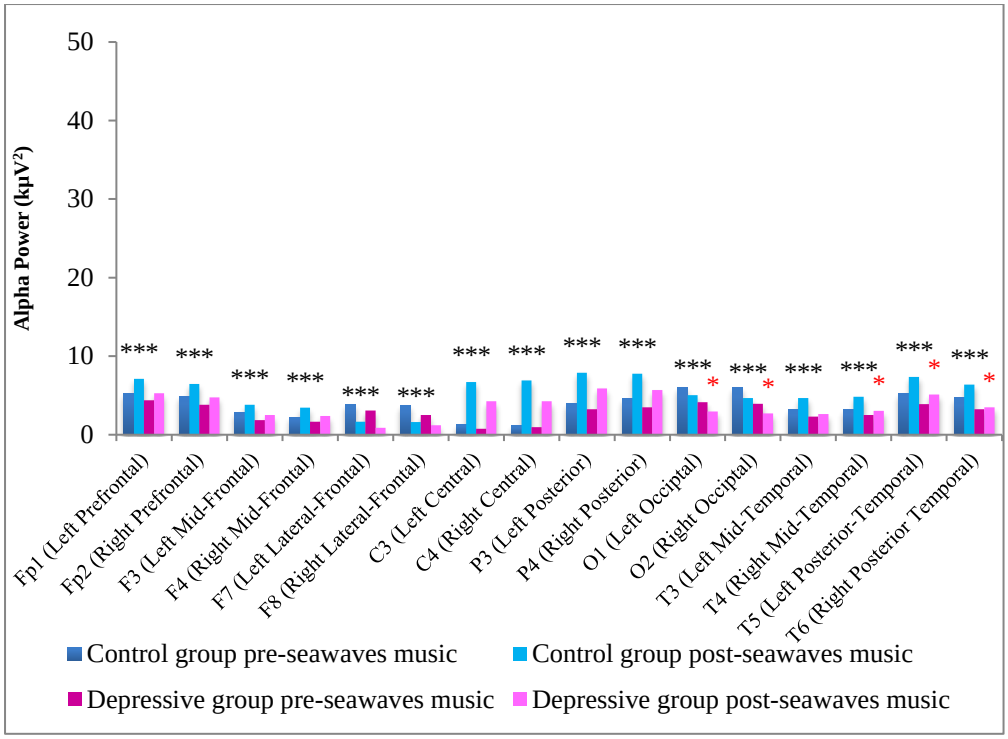

Figure 4.33: Median absolute high alpha power of pre and post-seawaves music for control and depressive group (*=p<0.05, **=p<0.01, ***=p<0.001:Wilcoxon signed-rank test showed level of significant difference between pre-seawaves and post-seawaves music)

The control group had significant increased low alpha power after seawaves music at left prefrontal Fp1 (Z=-2.855, p=0.004), right prefrontal Fp2 (Z=-3.225, p=0.001), left mid-frontal F3 (Z=-3.032, p=0.002), right mid-frontal F4 (Z=-3.415, p=0.001), left central C3 (Z=-2.313, p=0.021), right central C4 (Z=-2.352, p=0.019), right posterior P4 (Z=-2.065, p=0.039), left occipital O1 (Z=-2.592, p=0.010), left mid-temporal T3 (Z=-2.746, p=0.006), right mid-temporal T4 (p=-2.681, p=0.007) and left posterior-temporal T5 (Z=-2.567, p=0.010) but had significant decreased at left lateral-frontal F7 (Z=-3.109, p=0.002), right lateral-frontal F8 (Z=-3.110, p=0.002) and right

occipital O2 (Z=-2.334, p=0.020). The depressive group reported significant increased at left prefrontal Fp1 (Z=-2.084, p=0.037), right prefrontal Fp2 (Z=-2.438, p=0.015), left mid-frontal F3 (Z=-2.312, p=0.021), right mid-frontal F4 (Z=-1.997, p=0.046), right central C4 (Z=-2.693, p=0.021), left posterior P3 (Z=-2.308, p=0.021), right posterior P4 (Z=-2.729, p=0.006), left occipital O1 (Z=-2.776, p=0.005), left mid-temporal T3 (Z=-2.033, p=0.042), right mid-temporal T4 (Z=-2.364, p=0.018), left posterior-temporal T5 (Z=-3.079, p=0.002) and right posterior-temporal T6 (Z=-2.557, p=0.011) with significant decreased at left occipital O1 (Z=-2.776, p=0.005) and right occipital O2 (Z=-2.184, p=0.029). Both control and depressive group had same significant difference at prefrontal (Fp1, Fp2), mid-frontal (F3, F4), right central C4, right posterior P4, occipital (O1, O2), mid-temporal (T3, T4) and left posterior temporal T5. According to Mann Whitney test that comparing the control and depressive group at post seawaves music, the low alpha reported significant different at left lateral-frontal F3 (U=922, p=0.024), left lateral-frontal F7 (U=823, p=0.003), right lateral-frontal F8 (U=895.5, p=0.014) and left central C3 (U=959, p=0.044).

According to Figure 4.33, the control group of high alpha power had significant increased after seawaves music at left prefrontal Fp1 (Z=-3.408. p=0.001), right prefrontal Fp2 (Z=-3.673, p<0.001), left mid-frontal F3 (Z=-3.724, p<0.001) , right mid-frontal F4 (Z=-3.678, p<0.001), left central C3 (Z=-3.633, p<0.001), right central C4 (Z=-4.027, p<0.001), left posterior P3 (Z=-4.557, p<0.001), right posterior P4 (Z=-4.054, p<0.001), left mid-temporal T3 (Z=-4.253, p<0.001), right mid-temporal T4 (Z=-4.074, p<0.001),

left posterior-temporal T5 (Z=-4.671, p<0.001) and right posterior-temporal T6 (Z=-3.944, p<0.001) with significant decreased at left lateral-frontal F7 (Z=-3.944, p<0.001), right lateral-frontal F8 (Z=-3.708, p<0.001), left occipital O1 (Z=-4.611, p<0.001) and right occipital O2 (Z=-4.137, p<0.001). Depressive group had similar result as control group but only significant increasing high alpha power at right mid-temporal T4 (Z=-2.524, p=0.012), left posterior-temporal T5 (Z=-2.467, p=0.014), right posterior temporal T6 (Z=-2.071, p=0.038) and decreasing high alpha power at left occipital O1 (Z=-2.204, p=0.028) and right occipital O2 (Z=-2.144, p=0.032). The control group was observed to be having higher high alpha power than depressive group for both pre and post-seawaves music. Meanwhile according to Mann-Whitney U test, the high alpha of post-seawaves music reported significant different between control and depressive group at all region except right central C4 with left prefrontal Fp1 (U=903.5, p=0.017), right prefrontal Fp2 (U=857, p=0.007), left mid-frontal F3 (U=815, p=0.003), right mid-frontal F4 (U=914, p=0.019), left lateral-frontal F7 (U=748.5, p=0.001), right lateral-frontal F8 (U=788.5, p=0.001), left central C3 (U=703.5, p<0.001), left posterior P3 (U=834.5, p=0.004), right posterior P4 (U=871, p=0.009), left occipital O1 (U=904.5, p=0.017), right occipital O2 (U=888, p=0.013), left mid-temporal T3 (U=805, p=0.002), right mid-temporal T4 (U=871, p=0.009), left posterior-temporal T5 (U=880.5, p=0.011), right posterior temporal T6 (U=800.5, p=0.002). The control and depressive group could be differentiated from post-seawaves music.

Relaxation was associated to music according to study by Yuan and colleagues (Yuan *et al.*, 2000). The acute effect of seawaves music may help to increase the calmness of the participants as low alpha power at most brain region increased after listening to the music. Besides that, alpha power was reported to be related to aspect of music processing and increased with music perception (Schaefer, Vlek and Desain, 2011). The alpha power of healthy control was also reported to increase with musical complexity during music listening but not in schizophrenia patients, this finding by Gunther and colleagues was interpreted to reflect the cerebral 'hyperactivation' in this patient group (Günther *et al.*, 1991). The high alpha power in this experiment was found significantly increased at control group but also not found significant changes in depressive group. The low alpha and high alpha power of both control and depressive group had decreased at lateral-frontal F7 and F8 similar to other frequency power result. However, this finding was contradictory with a study by Iwaki and colleagues where high alpha power at frontal area was reported increased after stimulating music with increasing frontal interhemispheric coherence values (F7-F8) of high alpha band (Iwaki, Hayashi and Hori, 1997).

In addition, the low alpha and high alpha power of depressive group decreased at left occipital O1 and right occipital O2 at post-seawaves music. Another noteworthy difference between control and depressive group was the low alpha power at left occipital O1 of depressive group decreased at post-seawaves music whereas control group's low alpha power increased at post-seawaves music. Occipital region was mainly functioning on visual processing

and pattern recognition (Walker, Kozlowski and Lawson, 2007), the depressive group by nature had lower alpha power at occipital region then control group referred to early session. Similar to the result from post-breathing activity, the high alpha power of depressive group was suppressed after seawaves music. By comparing low alpha with high alpha, the effect of seawaves music at high alpha can be used to distinguish between depressive and control group. From the findings, control group had significant changes ($p<0.001$) (increased at prefrontal, mid-frontal, central, posterior and temporal but decreased at lateral-frontal and occipital) after seawaves music at all channels but not in depressive group. Depressive group only had significant at occipital and temporal region ($p<0.05$).

4.5.3.4 Beta Power (12-30 Hz)

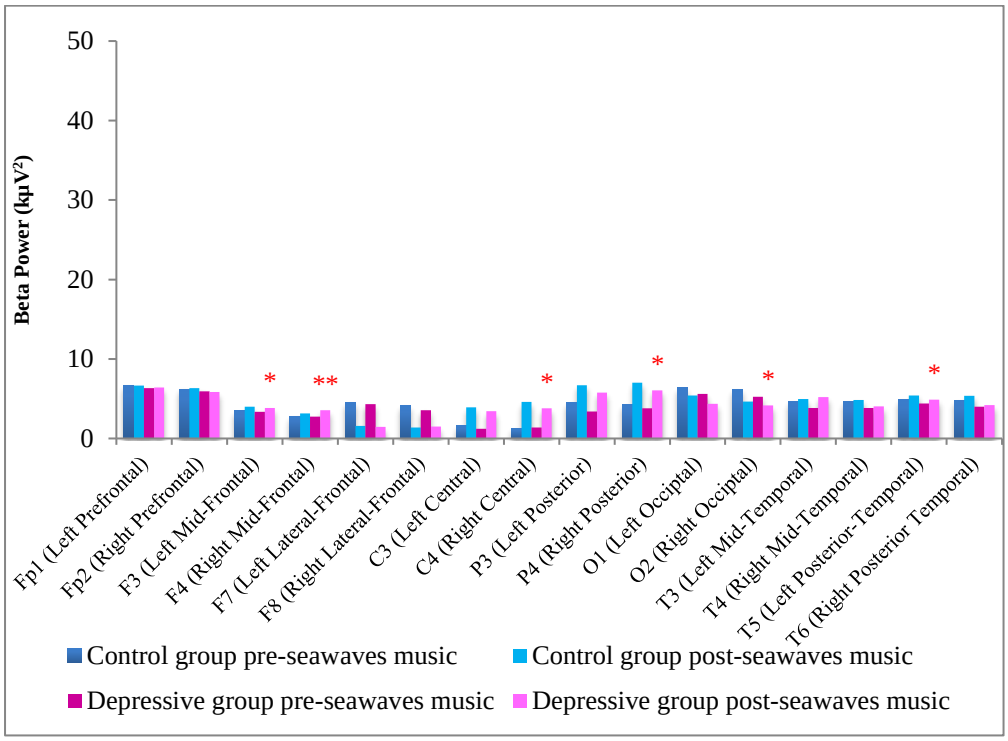

Figure 4.34: Median absolute beta power of pre and post-seawaves music for control and depressive group (*=p<0.05, **=p<0.01, ***=p<0.001:Wilcoxon signed-rank test showed level of significant difference between pre-seawaves and post-seawaves music)

The beta power of control group and depressive group was observed to increase at post-seawaves music at overall channel with decreased at lateral-frontal (F7, F8) and occipital (O1, O2) regions. However, the control group did not showed any significant different according to Wilcoxon signed-rank test. Whereas, depressive group showed significant increase at post-seawaves music at left mid-frontal F3 (Z=-2.304, p=0.021), right mid-frontal F4 (Z=-3.145, p=0.002), right central C4 (Z=-1.994, p=0.046), right posterior P4 (Z=-

2.072, p=0.038) and left posterior-temporal T5 (Z=-2.067, p=0.039) with decreasing beta power at right occipital O2 (Z=-2.065, p=0.039).

The beta power of both control and depressive group did not have obvious distinctive effect by the seawaves music. A study using traditional Indonesian Gamelan music reported that listening to music condition had increased beta power at posterior region compared to resting conditions (Nakamura *et al.*, 1999). It was reported that the beta power was a measure of cortical integrity and as an indicator of cognitive function (Nakamura *et al.*, 1999). The result in this experiment was consistent with the finding in this experiment where beta power increased at posterior for both control group and depressive group. The authors argued that the response of beta power at posterior region during music listening indicated there was interaction of music with cognitive process (Nakamura *et al.*, 1999). Another pilot study found reduced in beta power at all brain region as an effect of music during acute psychotic effect (Morgan *et al.*, 2010). Furthermore, a report on Mozart K.488 music onto normal people reported decreased in beta power at temporal, central and occipital. It was suggested that the decreased in beta power maybe presenting a reduced in cortical functions after listen to music (Lin *et al.*, 2014). This may the explanation on decrease of beta power at occipital region O1 and O2 at post-seawaves condition. However, the effect of post-seawaves music onto the beta power of both control and depressive group could not draw a clear conclusion in helping differentiate the depressive symptoms between control and depressive people.

4.5.4 Summary of EEG power comparison on pre-seawaves music and post-seawaves music for control and depressive groups

Post-seawaves music found increased in the delta, theta and alpha power of both control and depressive group. Seawaves music which was the sound of nature creates pleasant and calming effect to both groups as the significant increase of theta power of both group in this study was further supported by a study that reporting pleasant music increased the theta power at frontal mid-line region (Sammler *et al.*, 2007). Listening to music involved emotion processing and was involving the whole brain regions (Sammler *et al.*, 2007). The extraordinary effect of seawaves music was the occipital region of both control and depressive group found increased in delta and theta power but decreased in low alpha, high alpha and beta power at post-seawaves music. On the other hand, control and depressive group could be differentiated by looking into high alpha power as control group had significant increase in overall alpha power but not in depressive group. Another noteworthy result was the entire frequency power delta, theta, low alpha, high alpha and beta power at lateral frontal F7 and F8 were suppressed at post-seawaves music for both control and depressive group. The mood of both groups was regulated by the seawaves music as lateral-frontal (F7, F8) was related to mood regulation.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The differentiation of brainwaves among depressive and normal among young adults was identified with EEG at eyes-closed resting state. The significant finding for this study is the noteworthy result of the significant decrease in high-alpha (10 - 12 Hz) power in the depressive group as compared to the control group at eyes-closed condition for the whole brain region. Besides that, the change of beta (12 – 30 Hz) power at the post-deep breathing at occipital region suggests that deep breathing maybe an approach to ease detecting the depressive symptoms. The beta power at the occipital region was found suppressed among the depressive group but increased among the control after deep breathing. Lastly, the significant difference of high-alpha power between control and depressive groups at post-seawaves music listening at the whole brain region implying an alternate method to differentiate between normal and depressive participants. Electroencephalogram (EEG) may yield biomarkers for depressive condition in the future to guide identification, diagnosis, and treatment of depression disorder.

5.2 Future Work

Future research should be expand to a larger sample size for higher accuracy and reliability result. Larger sample size allows the segregation of different depression level, which could further analysis on the correlation between EEG power and depressive symptoms scores. Furthermore, one of the limitations of this study is the unequal number of male and female. Future study could study the difference in gender correlate to depressive brainwaves. Besides that, the result from this project could be further enhance with other statistical analysis method such as anova or ancova to improve the accuracy of the result.

REFERENCES

Aftanas, L. I. *et al.* (2001) 'Affective picture processing: event-related synchronization within individually defined human theta band is modulated by valence dimension.', *Neuroscience Letters*, 303(2), pp. 115–118. doi: 10.1016/S0304-3940(01)01703-7.

Agelink, M. W. *et al.* (2002) 'Relationship between major depression and heart rate variability. Clinical consequences and implications for antidepressive treatment.', *Psychiatry research*. Beltz Test GmbH, Weinheim, 113(1–2), pp. 139–49. doi: 10.1016/S0165-1781(02)00225-1.

Allen, J. J. B. *et al.* (2004) 'The stability of resting frontal electroencephalographic asymmetry in depression', *Psychophysiology*, 41(2), pp. 269–280. doi: 10.1111/j.1469-8986.2003.00149.x.

American Psychiatric Association (ed.) (2013) *Diagnostic and Statistical Manual of Mental Disorders*. 5th edn. Arlington, VA: American Psychiatric Association (DSM Library). doi: 10.5555/appi.books.9780890425596.x00pre.

Arnett, J. J. (2014) 'Presidential Address: The Emergence of Emerging Adulthood', *Emerging Adulthood*, 2(3), pp. 155–162. doi: 10.1177/2167696814541096.

Assenza, G. *et al.* (2013) 'P 15. Delta waves increase after cortical plasticity induction during wakefulness', *Clinical Neurophysiology*, 124(10), pp. e71–e72. doi: 10.1016/j.clinph.2013.04.094.

Barnhofer, T. *et al.* (2010) 'State Effects of Two Forms of Meditation on Prefrontal EEG Asymmetry in Previously Depressed Individuals.', *Mindfulness*. Springer, 1(1), pp. 21–27. doi: 10.1007/s12671-010-0004-7.

Barry, R. J. *et al.* (2007) 'EEG differences between eyes-closed and eyes-open resting conditions', *Clinical Neurophysiology*, 118(12), pp. 2765–2773. doi: 10.1016/j.clinph.2007.07.028.

Barry, R. J. *et al.* (2009) 'EEG differences in children between eyes-closed and eyes-open resting conditions', *Clinical Neurophysiology*, 120(10), pp.

1806–1811. doi: 10.1016/j.clinph.2009.08.006.

Başar, E. and Schürmann, M. (1999) '"Cross-Modality" Experiments in Humans', in *Brain Function and Oscillations*, pp. 143–153. doi: 10.1007/978-3-642-59893-7_11.

Baskaran, A., Milev, R. and McIntyre, R. S. (2012) 'The neurobiology of the EEG biomarker as a predictor of treatment response in depression', *Neuropharmacology*, 63(4), pp. 507–513. doi: 10.1016/j.neuropharm.2012.04.021.

Bazanova, O. M. and Vernon, D. (2014) 'Interpreting EEG alpha activity', *Neuroscience & Biobehavioral Reviews*, 44, pp. 94–110. doi: 10.1016/j.neubiorev.2013.05.007.

Begić, D. *et al.* (2011) 'Quantitative electroencephalography in schizophrenia and depression.', *Psychiatria Danubina*, 23(4), pp. 355–62. Available at: http://www.ncbi.nlm.nih.gov/pubmed/22075736.

Belmaker, R. H. and Agam, G. (2008) 'Major Depressive Disorder', *New England Journal of Medicine*. Massachusetts Medical Society, 358(1), pp. 55–68. doi: 10.1056/NEJMra073096.

Berger, H. (1993) 'Das Elektrenkephalogramm des Menschen', *Arch F Psychiat*, 98, p. 231–254.

Borrione, L. *et al.* (2017) 'Associations between symptoms of depression and heart rate variability: An exploratory study', *Psychiatry Research*. doi: 10.1016/j.psychres.2017.09.028.

Bottesi, G. *et al.* (2015) 'The Italian version of the Depression Anxiety Stress Scales-21: Factor structure and psychometric properties on community and clinical samples', *Comprehensive Psychiatry*, 60, pp. 170–181. doi: 10.1016/j.comppsych.2015.04.005.

Bronzino, J. D. and Peterson, D. R. (2015) *The biomedical engineering handbook*. CRC. Available at: https://www.crcpress.com/The-Biomedical-Engineering-Handbook-Fourth-Edition-Four-Volume-Set/Bronzino-Peterson/p/book/9781439825334.

Bruder, G. E. *et al.* (2008) 'Electroencephalographic alpha measures predict therapeutic response to a selective serotonin reuptake inhibitor antidepressant: pre- and post-treatment findings.', *Biological psychiatry*. NIH Public Access, 63(12), pp. 1171–7. doi: 10.1016/j.biopsych.2007.10.009.

Carvalho, A., Moraes, H., Silveira, H., Ribeiro, P., Piedade, R. A. M., *et al.*

(2011) ‘EEG frontal asymmetry in the depressed and remitted elderly: Is it related to the trait or to the state of depression?’, *Journal of Affective Disorders*, pp. 143–148. doi: 10.1016/j.jad.2010.08.023.

Carvalho, A., Moraes, H., Silveira, H., Ribeiro, P., Piedade, R. A. M., *et al.* (2011) ‘EEG frontal asymmetry in the depressed and remitted elderly: Is it related to the trait or to the state of depression?’, *Journal of Affective Disorders*, 129(1–3), pp. 143–148. doi: 10.1016/j.jad.2010.08.023.

Castillo-Pérez, S. *et al.* (2010) ‘Effects of music therapy on depression compared with psychotherapy’, *The Arts in Psychotherapy*, 37(5), pp. 387–390. doi: 10.1016/j.aip.2010.07.001.

Chan, A. S., Han, Y. M. Y. and Cheung, M. (2008) ‘Electroencephalographic (EEG) Measurements of Mindfulness-based Triarchic Body-pathway Relaxation Technique: A Pilot Study’, *Applied Psychophysiology and Biofeedback*, 33(1), pp. 39–47. doi: 10.1007/s10484-008-9050-5.

Chan, M. F., Chan, E. A. and Mok, E. (2010) ‘Effects of music on depression and sleep quality in elderly people: A randomised controlled trial’, *Complementary Therapies in Medicine*, 18(3–4), pp. 150–159. doi: 10.1016/j.ctim.2010.02.004.

Chen, S.-S. *et al.* (2008) ‘Impaired frontal synchronization of spontaneous magnetoencephalographic activity in patients with bipolar disorder’, *Neuroscience Letters*, 445(2), pp. 174–178. doi: 10.1016/j.neulet.2008.08.080.

Chen, X. *et al.* (2017) ‘Heart rate variability in patients with major depression disorder during a clinical autonomic test’, *Psychiatry Research*, 256, pp. 207–211. doi: 10.1016/j.psychres.2017.06.041.

Child Trends Databank (2015) *Young Adult Depression - Child Trends*. Available at: https://www.childtrends.org/indicators/young-adult-depression/.

Cooley, J. W. and Tukey, J. W. (1965) ‘An algorithm for the machine calculation of complex Fourier series’, *Mathematics of Computation*, 19(90), pp. 297–297. doi: 10.1090/S0025-5718-1965-0178586-1.

Crawford, J. R. and Henry, J. D. (2003) ‘The Depression Anxiety Stress Scales (DASS): Normative data and latent structure in a large non-clinical sample’, *British Journal of Clinical Psychology*. Blackwell Publishing Ltd, 42(2), pp. 111–131. doi: 10.1348/014466503321903544.

Davidson, R. J. *et al.* (2003) ‘Alterations in brain and immune function produced by mindfulness meditation.’, *Psychosomatic medicine*, 65(4), pp. 564–70.

Debener, S. *et al.* (2000) ‘Is resting anterior EEG alpha asymmetry a trait marker for depression? Findings for healthy adults and clinically depressed patients.’, *Neuropsychobiology*, 41(1), pp. 31–7. doi: 26630.

Dyrbye, L. N., Thomas, M. R. and Shanafelt, T. D. (2006) ‘Systematic review of depression, anxiety, and other indicators of psychological distress among U.S. and Canadian medical students.’, *Academic medicine : journal of the Association of American Medical Colleges*, 81(4), pp. 354–73.

El-Badri, S. M. *et al.* (2001) ‘Electrophysiological and cognitive function in young euthymic patients with bipolar affective disorder.’, *Bipolar disorders*, 3(2), pp. 79–87.

Fan, J. *et al.* (2007) ‘The Relation of Brain Oscillations to Attentional Networks’, *Journal of Neuroscience*, 27(23), pp. 6197–6206. doi: 10.1523/JNEUROSCI.1833-07.2007.

Field, T. *et al.* (1998) ‘Music shifts frontal EEG in depressed adolescents.’, *Adolescence*, 33(129), pp. 109–16. Available at: http://www.ncbi.nlm.nih.gov/pubmed/9583665 (Accessed: 13 September 2017).

Fingelkurts, A. A. *et al.* (2006) ‘Composition of brain oscillations in ongoing EEG during major depression disorder’, *Neuroscience Research*, 56(2), pp. 133–144. doi: 10.1016/j.neures.2006.06.006.

Fisch, B. J. and Spehlmann, R. (2000) *Fisch and Spehlmann’s EEG Primer: Basic principles of digital and analog EEG: Basic principles of digital and analog EEG*. 3rd edn. Elsevier Health Sciences.

Flint, A. J. *et al.* (2013) ‘Sustaining remission of psychotic depression: rationale, design and methodology of STOP-PD II’, *BMC Psychiatry*, 13(1), p. 38. doi: 10.1186/1471-244X-13-38.

Flor-Henry, P., Lind, J. C. and Koles, Z. J. (2004) ‘A source-imaging (low-resolution electromagnetic tomography) study of the EEGs from unmedicated males with depression’, *Psychiatry Research: Neuroimaging*, 130(2), pp. 191–207. doi: 10.1016/j.pscychresns.2003.08.006.

Fukui, H. and Toyoshima, K. (2008) ‘Music facilitate the neurogenesis, regeneration and repair of neurons’, *Medical Hypotheses*, 71(5), pp. 765–769. doi: 10.1016/j.mehy.2008.06.019.

Funahashi, S. and Andreau, J. M. (2013) ‘Prefrontal cortex and neural mechanisms of executive function’, *Journal of Physiology-Paris*, 107(6), pp. 471–482. doi: 10.1016/j.jphysparis.2013.05.001.

Garland, E. J. and Solomons, K. (2002) 'Early detection of depression in young and elderly people | BC Medical Journal', *BC Medical Journal*, 44(9), pp. 469–472..

Gelaye, B. *et al.* (2013) 'Validity of the patient health questionnaire-9 for depression screening and diagnosis in East Africa', *Psychiatry Research*, 210(2), pp. 653–661. doi: 10.1016/j.psychres.2013.07.015.

Gerhand, S. (1999) 'THE PREFRONTAL CORTEXEXECUTIVE AND COGNITIVE FUNCTIONS.', *Brain*, 122(5), pp. 994–995. doi: 10.1093/brain/122.5.994.

Gilboa-Schechtman, E., Erhard-Weiss, D. and Jeczemien, P. (2002) 'Interpersonal deficits meet cognitive biases: memory for facial expressions in depressed and anxious men and women.', *Psychiatry research*, 113(3), pp. 279–93.

Gollan, J. K. *et al.* (2014) 'Frontal alpha EEG asymmetry before and after behavioral activation treatment for depression', *Biological Psychology*. Elsevier B.V., 99(1), pp. 198–208. doi: 10.1016/j.biopsycho.2014.03.003.

Gotlib, I. H. (1998) 'EEG Alpha Asymmetry, Depression, and Cognitive Functioning', *Cognition & Emotion*. Taylor & Francis Group , 12(3), pp. 449–478. doi: 10.1080/026999398379673.

Gotlib, I. H., Ranganath, C. and Rosenfeld, J. P. (1987) 'Frontal EEG Alpha Asymmetry, Depression, and Cognitive Functioning', *Cognition and Emotion*. L. Erlbaum Associates, 12(3), pp. 449–478.

Greenberg, L. S. (2002) 'Integrating an emotion-focused approach to treatment into psychotherapy integration.', *Journal of Psychotherapy Integration*, 12(2), pp. 154–189. doi: 10.1037/1053-0479.12.2.154.

Grin-Yatsenko, V. A. *et al.* (2009) 'EEG Power Spectra at Early Stages of Depressive Disorders', *Journal of Clinical Neurophysiology*, 26(6), pp. 401–406. doi: 10.1097/WNP.0b013e3181c298fe.

Güntekin, B. and Başar, E. (2007) 'Brain oscillations are highly influenced by gender differences', *International Journal of Psychophysiology*, 65(3), pp. 294–299. doi: 10.1016/j.ijpsycho.2007.03.009.

Güntekin, B. and Başar, E. (2014) 'A review of brain oscillations in perception of faces and emotional pictures', *Neuropsychologia*, 58, pp. 33–51. doi: 10.1016/j.neuropsychologia.2014.03.014.

Güntekin, B. and Başar, E. (2016) 'Review of evoked and event-related delta

responses in the human brain', *International Journal of Psychophysiology*, 103, pp. 43–52. doi: 10.1016/j.ijpsycho.2015.02.001.

Günther, W. *et al.* (1991) 'Brain dysfunction in psychiatric patients during music perception measured by EEG mapping: relation to motor dysfunction and influence of neuroleptic drugs', *European Neuropsychopharmacology*. Elsevier, 1(2), pp. 143–155. doi: 10.1016/0924-977X(91)90716-8.

Hanslmayr, S., Staudigl, T. and Fellner, M.-C. (2012) 'Oscillatory power decreases and long-term memory: the information via desynchronization hypodissertation.', *Frontiers in human neuroscience*. Frontiers Media SA, 6, p. 74. doi: 10.3389/fnhum.2012.00074.

Hart, J. (2013) 'Association between heart rate variability and manual pulse rate.', *The Journal of the Canadian Chiropractic Association*. The Canadian Chiropractic Association, 57(3), pp. 243–50.

Henriques, J. B. and Davidson, R. J. (1991) 'Left frontal hypoactivation in depression.', *Journal of abnormal psychology*, 100(4), pp. 535–45.

Hinrikus, H. *et al.* (2009) 'Electroencephalographic spectral asymmetry index for detection of depression', *Medical & Biological Engineering & Computing*. Springer-Verlag, 47(12), pp. 1291–1299. doi: 10.1007/s11517-009-0554-9.

Hisanobu, Uchida, S. and Kuramoto, I. (1997) *A NEW APPROACH TO THE STUDIES OF SUBTLE ENERGIES*, *Subtle Energies & Energy Medicine Journal Archives*. International Society for the Study of Subtle Energies and Energy Medicine.

Hofmann, S. G. *et al.* (2010) 'The effect of mindfulness-based therapy on anxiety and depression: A meta-analytic review.', *Journal of consulting and clinical psychology*. NIH Public Access, 78(2), pp. 169–83. doi: 10.1037/a0018555.

Hosseinifard, B., Moradi, M. H. and Rostami, R. (2013) 'Classifying depression patients and normal participants using machine learning techniques and nonlinear features from EEG signal', *Computer Methods and Programs in Biomedicine*. Elsevier Ireland Ltd, 109(3), pp. 339–345. doi: 10.1016/j.cmpb.2012.10.008.

Hsu, W.-C. and Lai, H.-L. (2004) 'Effects of music on major depression in psychiatric inpatients.', *Archives of psychiatric nursing*, 18(5), pp. 193–9.

Huang, F. Y. *et al.* (2006) 'Using the patient health questionnaire-9 to measure depression among racially and ethnically diverse primary care patients', *Journal of General Internal Medicine*, 21(6), pp. 547–552. doi:

10.1111/j.1525-1497.2006.00409.x.

Ibrahim, A. K. *et al.* (2013) 'A systematic review of studies of depression prevalence in university students', *Journal of Psychiatric Research*, 47(3), pp. 391–400. doi: 10.1016/j.jpsychires.2012.11.015.

Im, M. L. and Lee, J. I. (2014) 'Effects of art and music therapy on depression and cognitive function of the elderly.', *Technology and health care : official journal of the European Society for Engineering and Medicine*, 22(3), pp. 453–8. doi: 10.3233/THC-140803.

Iwaki, T., Hayashi, M. and Hori, T. (1997) 'Changes in Alpha Band Eeg Activity in the Frontal Area after Stimulation with Music of Different Affective Content', *Perceptual and Motor Skills*, 84(2), pp. 515–526. doi: 10.2466/pms.1997.84.2.515.

Jagadeesan, N. *et al.* (2013) 'Brain monitoring during general anesthesia', *Trends in Anaesthesia and Critical Care*. Elsevier, 3(1), pp. 13–18. doi: 10.1016/j.tacc.2012.12.003.

Joormann, J. and Gotlib, I. H. (2006) 'Is this happiness I see? Biases in the identification of emotional facial expressions in depression and social phobia.', *Journal of Abnormal Psychology*, 115(4), pp. 705–714. doi: 10.1037/0021-843X.115.4.705.

Joormann, J. and Gotlib, I. H. (2010) 'Emotion regulation in depression: relation to cognitive inhibition.', *Cognition & emotion*. NIH Public Access, 24(2), pp. 281–98. doi: 10.1080/02699930903407948.

Kan, D. P. X. and Lee, P. F. (2015) 'Decrease alpha waves in depression: An electroencephalogram(EEG) study', in *2015 International Conference on BioSignal Analysis, Processing and Systems (ICBAPS)*. IEEE, pp. 156–161. doi: 10.1109/ICBAPS.2015.7292237.

Kemp, A. H. *et al.* (2010) 'Disorder specificity despite comorbidity: Resting EEG alpha asymmetry in major depressive disorder and post-traumatic stress disorder', *Biological Psychology*, 85(2), pp. 350–354. doi: 10.1016/j.biopsycho.2010.08.001.

Keune, P. M. *et al.* (2013) 'Approaching dysphoric mood: State-effects of mindfulness meditation on frontal brain asymmetry', *Biological Psychology*, 93(1), pp. 105–113. doi: 10.1016/j.biopsycho.2013.01.016.

Kilavik, B. E. *et al.* (2013) 'The ups and downs of beta oscillations in sensorimotor cortex', *Experimental Neurology*, 245, pp. 15–26. doi: 10.1016/j.expneurol.2012.09.014.

Kim, D.-J. *et al.* (2013) 'Disturbed resting state EEG synchronization in bipolar disorder: A graph-theoretic analysis.', *NeuroImage. Clinical*. Elsevier, 2, pp. 414–23. doi: 10.1016/j.nicl.2013.03.007.

Klados, M. A. *et al.* (2009) 'A Framework Combining Delta Event-Related Oscillations (EROs) and Synchronisation Effects (ERD/ERS) to Study Emotional Processing', *Computational Intelligence and Neuroscience*, 2009, pp. 1–16. doi: 10.1155/2009/549419.

Klem, G. H. *et al.* (1999) 'The ten-twenty electrode system of the International Federation. The International Federation of Clinical Neurophysiology.', *Electroencephalography and clinical neurophysiology. Supplement*, 52, pp. 3–6.

Klimesch, W. (1999) 'EEG alpha and theta oscillations reflect cognitive and memory performance: A review and analysis', *Brain Research Reviews*, 29(2–3), pp. 169–195. doi: 10.1016/S0165-0173(98)00056-3.

Knott, V. J. and Lapierre, Y. D. (1987) 'Computerized EEG correlates of depression and antidepressant treatment.', *Progress in neuro-psychopharmacology & biological psychiatry*, 11(2–3), pp. 213–21.

Knyazev, G. G. *et al.* (2011) 'The default mode network and EEG alpha oscillations: An independent component analysis', *Brain Research*, 1402, pp. 67–79. doi: 10.1016/j.brainres.2011.05.052.

Knyazev, G. G. (2012) 'EEG delta oscillations as a correlate of basic homeostatic and motivational processes', *Neuroscience & Biobehavioral Reviews*, 36(1), pp. 677–695. doi: 10.1016/j.neubiorev.2011.10.002.

Koelsch, S. *et al.* (2011) 'Effects of Music Listening on Cortisol Levels and Propofol Consumption during Spinal Anesthesia', *Frontiers in Psychology*. Frontiers, 2, p. 58. doi: 10.3389/fpsyg.2011.00058.

Korb, A. S. *et al.* (2009) 'Rostral anterior cingulate cortex theta current density and response to antidepressants and placebo in major depression', *Clinical Neurophysiology*, 120(7), pp. 1313–1319. doi: 10.1016/j.clinph.2009.05.008.

Kroenke, K., Spitzer, R. L. and Williams, J. B. W. (2001) 'The PHQ-9', *Journal of General Internal Medicine*. Springer, 16(9), pp. 606–613. doi: 10.1046/j.1525-1497.2001.016009606.x.

Krygier, J. R. *et al.* (2013) 'Mindfulness meditation, well-being, and heart rate variability: A preliminary investigation into the impact of intensive vipassana meditation', *International Journal of Psychophysiology*. Elsevier B.V., 89(3),

pp. 305–313. doi: 10.1016/j.ijpsycho.2013.06.017.

Lam, R. W. *et al.* (2016) ‘Canadian Network for Mood and Anxiety Treatments (CANMAT) 2016 Clinical Guidelines for the Management of Adults with Major Depressive Disorder’, *The Canadian Journal of Psychiatry*, 61(9), pp. 510–523. doi: 10.1177/0706743716659416.

Lee, A. and Campbell, D. (2009) *Perfect breathing : transform your life, one breath at a time*. Sterling.

Lee, J. *et al.* (2014) ‘Differential resting-state EEG patterns associated with comorbid depression in Internet addiction’, *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, 50, pp. 21–26. doi: 10.1016/j.pnpbp.2013.11.016.

Lehrer, P. M. and Gevirtz, R. (2014) ‘Heart rate variability biofeedback: how and why does it work?’, *Frontiers in psychology*. Frontiers Media SA, 5, p. 756. doi: 10.3389/fpsyg.2014.00756.

Lin, I. M., Tai, L. Y. and Fan, S. Y. (2014) ‘Breathing at a rate of 5.5breaths per minute with equal inhalation-to-exhalation ratio increases heart rate variability’, *International Journal of Psychophysiology*, 91(3), pp. 206–211. doi: 10.1016/j.ijpsycho.2013.12.006.

Lin, L.-C. *et al.* (2014) ‘Listening to Mozart K.448 decreases electroencephalography oscillatory power associated with an increase in sympathetic tone in adults: a post-intervention study’, *JRSM Open*. SAGE Publications, 5(10), p. 205427041455165. doi: 10.1177/2054270414551657.

Liu, Z.-X., Woltering, S. and Lewis, M. D. (2014) ‘Developmental change in EEG theta activity in the medial prefrontal cortex during response control’, *NeuroImage*, 85, pp. 873–887. doi: 10.1016/j.neuroimage.2013.08.054.

Lubar, J. F., Congedo, M. and Askew, J. H. (2003) ‘Low-resolution electromagnetic tomography (LORETA) of cerebral activity in chronic depressive disorder’, *International Journal of Psychophysiology*, 49(3), pp. 175–185. doi: 10.1016/S0167-8760(03)00115-6.

Manoilov, P. (2006) ‘EEG eye-blinking Artefacts power spectrum analysis’, in.

Marksberry, K. (2012) *Take a Deep Breath, The American Institute of Stress*. Available at: https://www.stress.org/take-a-deep-breath/.

McConnell, A. (2011) *Breathe strong, perform better*. Human Kinetics.

McCormick, U., Murray, B. and McNew, B. (2015) ‘Diagnosis and treatment

of patients with bipolar disorder: A review for advanced practice nurses', *Journal of the American Association of Nurse Practitioners*. Wiley-Blackwell, 27(9), pp. 530–542. doi: 10.1002/2327-6924.12275.

Melrose, S. (2017) 'Persistent Depressive Disorder or Dysthymia: An Overview of Assessment and Treatment Approaches', *Open Journal of Depression*. Scientific Research Publishing, 6(1), pp. 1–13. doi: 10.4236/ojd.2017.61001.

Menon, V. and Levitin, D. J. (2005) 'The rewards of music listening: Response and physiological connectivity of the mesolimbic system'. doi: 10.1016/j.neuroimage.2005.05.053.

Miller, A. (2007) 'Social neuroscience of child and adolescent depression.', *Brain and cognition*. NIH Public Access, 65(1), pp. 47–68. doi: 10.1016/j.bandc.2006.02.008.

Morgan, K. A. *et al.* (2010) 'The effect of music on brain wave functioning during an acute psychotic episode: A pilot study', *Psychiatry Research*. Elsevier, 178(2), pp. 446–448. doi: 10.1016/j.psychres.2010.04.020.

Morrow, J. and Nolen-Hoeksema, S. (1990) 'Effects of responses to depression on the remediation of depressive affect.', *Journal of personality and social psychology*, 58(3), pp. 519–27.

Mukhtar, F. and Oei, T. P. S. (2011) 'A review on assessment and treatment for depression in malaysia.', *Depression research and treatment*. Hindawi, 2011, p. 123642. doi: 10.1155/2011/123642.

Mulert, C. *et al.* (2007) 'Rostral Anterior Cingulate Cortex Activity in the Theta Band Predicts Response to Antidepressive Medication', *Clinical EEG and Neuroscience*, 38(2), pp. 78–81. doi: 10.1177/155005940703800209.

Nakamura, S. *et al.* (1999) 'Analysis of music–brain interaction with simultaneous measurement of regional cerebral blood flow and electroencephalogram beta rhythm in human participants', *Neuroscience Letters*. Elsevier, 275(3), pp. 222–226. doi: 10.1016/S0304-3940(99)00766-1.

National Collaborating Centre for Mental Health (2010) *THE TREATMENT AND MANAGEMENT OF DEPRESSION IN ADULTS (UPDATED EDITION)*. The British Psychological Society and The Royal College of Psychiatrists.

National Institute of Mental Health (2011) 'Depression'.

Neuper, C. and Pfurtscheller, G. (2001) 'Event-related dynamics of cortical rhythms: Frequency-specific features and functional correlates', *International*

Journal of Psychophysiology, 43(1), pp. 41–58. doi: 10.1016/S0167-8760(01)00178-7.

Olbrich, S. and Arns, M. (2013) 'EEG biomarkers in major depressive disorder: Discriminative power and prediction of treatment response', *International Review of Psychiatry*, 25(5), pp. 604–618. doi: 10.3109/09540261.2013.816269.

Orekhova, E. *et al.* (2006) 'EEG theta rhythm in infants and preschool children', *Clinical Neurophysiology*, 117(5), pp. 1047–1062. doi: 10.1016/j.clinph.2005.12.027.

Pavlygina, R. A., Sakharov, D. S. and Davydov, V. I. (2004) 'Spectral Analysis of the Human EEG during Listening to Musical Compositions', *Human Physiology*. Kluwer Academic Publishers-Plenum Publishers, 30(1), pp. 54–60. doi: 10.1023/B:HUMP.0000013765.64276.e6.

Pitzalis, M. V *et al.* (1998) 'Effect of respiratory rate on the relationships between RR interval and systolic blood pressure fluctuations: a frequency-dependent phenomenon.', *Cardiovascular research*, 38(2), pp. 332–9.

Pizzagalli, D. A., Oakes, T. R. and Davidson, R. J. (2003) 'Coupling of theta activity and glucose metabolism in the human rostral anterior cingulate cortex: An EEG/PET study of normal and depressed participants', *Psychophysiology*, 40(6), pp. 939–949. doi: 10.1111/1469-8986.00112.

Pozzi, D. *et al.* (1995) 'Quantified electroencephalographic changes in depressed patients with and without dementia', *Biological Psychiatry*, 38(10), pp. 677–683. doi: 10.1016/0006-3223(94)00371-8.

Price, G. W. *et al.* (2008) 'Appraisal of Sessional EEG Features as a Correlate of Clinical Changes in an rTMS Treatment of Depression', *Clinical EEG and Neuroscience*, 39(3), pp. 131–138. doi: 10.1177/155005940803900307.

Reid, S. A., Duke, L. M. and Allen, J. J. (1998) 'Resting frontal electroencephalographic asymmetry in depression: inconsistencies suggest the need to identify mediating factors.', *Psychophysiology*, 35(4), pp. 389–404.

Roiser, J. P., Elliott, R. and Sahakian, B. J. (2012) 'Cognitive Mechanisms of Treatment in Depression', *Neuropsychopharmacology*, 37(1), pp. 117–136. doi: 10.1038/npp.2011.183.

Rosner, B. (Bernard A. . (2011) *Fundamentals of biostatistics*. Brooks/Cole, Cengage Learning.

Rushton, J. L., Forcier, M. and Schectman, R. M. (2002) 'Epidemiology of

Depressive Symptoms in the National Longitudinal Study of Adolescent Health', *Journal of the American Academy of Child & Adolescent Psychiatry*, 41(2), pp. 199–205. doi: 10.1097/00004583-200202000-00014.

Sammler, D. *et al.* (2007) 'Music and emotion: Electrophysiological correlates of the processing of pleasant and unpleasant music', *Psychophysiology*. Blackwell Publishing Inc, 44(2), pp. 293–304. doi: 10.1111/j.1469-8986.2007.00497.x.

Sanei, S. and Chambers, J. A. (2007) *EEG Signal Processing*. West Sussex, England: John Wiley & Sons Ltd,. doi: 10.1002/9780470511923.

Sasaki, K. *et al.* (1996) 'Frontal mental theta wave recorded simultaneously with magnetoencephalography and electroencephalography.', *Neuroscience research*, 26(1), pp. 79–81.

Sawaguchi, T. and Goldman-Rakic, P. S. (1991) 'D1 dopamine receptors in prefrontal cortex: involvement in working memory.', *Science (New York, N.Y.)*, 251(4996), pp. 947–50.

Schaefer, R. S., Vlek, R. J. and Desain, P. (2011) 'Music perception and imagery in EEG: Alpha band effects of task and stimulus', *International Journal of Psychophysiology*. Elsevier, 82(3), pp. 254–259. doi: 10.1016/j.ijpsycho.2011.09.007.

Schwilden, H. (2006) 'Concepts of EEG processing: From power spectrum to bispectrum, fractals, entropies and all that', *Best Practice and Research: Clinical Anaesthesiology*, 20(1), pp. 31–48. doi: 10.1016/j.bpa.2005.09.001.

Shamsuddin, K. *et al.* (2013) 'Correlates of depression, anxiety and stress among Malaysian university students', *Asian Journal of Psychiatry*, 6(4), pp. 318–323. doi: 10.1016/j.ajp.2013.01.014.

Sharp, L. K. and Lipsky, M. S. (2002) 'Screening for depression across the lifespan: a review of measures for use in primary care settings.', *American family physician*, 66(6), pp. 1001–8.

Sherina, M. S., Arroll, B. and Goodyear-Smith, F. (2012) 'Criterion validity of the PHQ-9 (Malay version) in a primary care clinic in Malaysia.', *The Medical journal of Malaysia*, 67(3), pp. 309–15.

Siedliecki, S. L. and Good, M. (2006) 'Effect of music on power, pain, depression and disability', *Journal of Advanced Nursing*, 54(5), pp. 553–562. doi: 10.1111/j.1365-2648.2006.03860.x.

Sih, G. C. and Tang, K. K. (2013) 'On–off switching of theta–delta brain

waves related to falling asleep and awakening', *Theoretical and Applied Fracture Mechanics*, 63–64(63–64), pp. 1–17. doi: 10.1016/j.tafmec.2013.03.001.

Singh Solanki, M. (2016) 'Music: A Non-invasive Biological Therapy or Just a Soothing Melody?' doi: 10.21767/2254-609X.100044.

Smith, S. J. M. (2005) 'EEG in the diagnosis, classification, and management of patients with epilepsy', *Journal of Neurology, Neurosurgery & Psychiatry*, 76(suppl_2), p. ii2-ii7. doi: 10.1136/jnnp.2005.069245.

Somsen, R. J. *et al.* (1997) 'Growth spurts in brain maturation during middle childhood as indexed by EEG power spectra.', *Biological psychology*, 44(3), pp. 187–209.

Song, H.-S. and Lehrer, P. M. (2003) 'The effects of specific respiratory rates on heart rate and heart rate variability.', *Applied psychophysiology and biofeedback*, 28(1), pp. 13–23.

Šušmáková, K. (2004) 'Human Sleep and Sleep EEG', *MEASUREMENT SCIENCE REVIEW*, 4(2).

Tas, C. *et al.* (2015) 'EEG power, cordance and coherence differences between unipolar and bipolar depression', *Journal of Affective Disorders*, 172, pp. 184–190. doi: 10.1016/j.jad.2014.10.001.

Tement, S., Pahor, A. and Jaušovec, N. (2016) 'EEG alpha frequency correlates of burnout and depression: The role of gender', *Biological Psychology*, 114, pp. 1–12. doi: 10.1016/j.biopsycho.2015.11.005.

Teplan, M. (2002) 'Fundamentals of EEG measurement', *Measurement Science Review*, 2(2), pp. 1–11. doi: 10.1021/pr070350l.

Thoma, M. V. *et al.* (2013) 'The Effect of Music on the Human Stress Response', *PLoS ONE*. Edited by R. L. Newton, 8(8), p. e70156. doi: 10.1371/journal.pone.0070156.

Walker, J. E., Kozlowski, G. P. and Lawson, R. (2007) 'A Modular Activation/Coherence Approach to Evaluating Clinical/QEEG Correlations and for Guiding Neurofeedback Training: Modular Insufficiencies, Modular Excesses, Disconnections, and Hyperconnections', *Journal of Neurotherapy*. Taylor & Francis Group, 11(1), pp. 25–44. doi: 10.1300/J184v11n01_03.

Weiss, S. and Mueller, H. M. (2012) '"Too Many betas do not Spoil the Broth": The Role of Beta Brain Oscillations in Language Processing.', *Frontiers in psychology*. Frontiers Media SA, 3, p. 201. doi:

10.3389/fpsyg.2012.00201.

Wigram, T., Pedersen, I. N. and Bonde, L. O. (2002) *A comprehensive guide to music therapy : theory, clinical practice, research, and training*. Jessica Kingsley Publishers.

World Health Organization (2017) *Depression*. Available at: http://www.who.int/mediacentre/factsheets/fs369/en/.

Yordanova, J. and Kolev, V. (1997) 'Developmental changes in the event-related EEG theta response and P300', *Electroencephalography and Clinical Neurophysiology/Evoked Potentials Section*, 104(5), pp. 418–430. doi: 10.1016/S0168-5597(97)00054-3.

Yordanova, J. and Kolev, V. (1998) 'Developmental changes in the theta response system: A single-sweep analysis', *Journal of Psychophysiology*, 12, pp. 113–126.

Yuan, Q. *et al.* (2000) 'Effects of noise and music on EEG power spectrum', *Space medicine & medical engineering*, 13(6), pp. 401–4. Available at: http://www.ncbi.nlm.nih.gov/pubmed/11767781.

APPENDICES

APPENDIX A: Publication

Publication available online:

Kan, D. P. X. and Lee, P. F. (2015) 'Decrease alpha waves in depression: An electroencephalogram(EEG) study', in 2015 International Conference on BioSignal Analysis, Processing and Systems (ICBAPS). IEEE, pp. 156–161. doi: 10.1109/ICBAPS.2015.7292237.

Kan, D. P. X., Lim, V. W. W. and Lee, P. F. (2015) 'Signal Conversion from Attention Signals to Light Emitting Diodes as an Attention Level Indicator', in. Springer, Cham, pp. 251–255. doi: 10.1007/978-3-319-12262-5_70.

Lee, P. F. and Kan, D. P. X. (2017) 'A PILOT STUDY ON THETA FREQUENCY OF PRESCHOOL CHILDREN WITH DIFFERENT PLAYING ACTIVITIES AT PREFRONTAL CORTEX', Biomedical Engineering: Applications, Basis and Communications. World Scientific Publishing Company , 29(1), p. 1750004. doi: 10.4015/S1016237217500041.

Mohan, Y. et al. (2016) 'Artificial neural network for classification of depressive and normal in EEG', in 2016 IEEE EMBS Conference on Biomedical Engineering and Sciences (IECBES). IEEE, pp. 286–290. doi: 10.1109/IECBES.2016.7843459.

Lee, P. F., Kan, D. P. X., Croarkin, P., Phang, C. K. And Doruk, D. (2018) 'Neurophysiological Correlates Of Depressive Symptoms In Young Adults: A Quantitative EEG Study', Journal Of Clinical Neuroscience. Churchill Livingstone, 47, Pp. 315–322. Doi: 10.1016/J.Jocn.2017.09.030.

Journal paper accepted in Neurophysiology, Springer (2018): pending for publication

Kan, D.P.X. Croarkin P., Phang C.K and Lee P.F , EEG Differences Between Eyes-closed And Eyes-open Conditions At The Resting Stage For Euthymic Participants

APPENDIX B: Consent Letter

Application No.
(Official use only)

(PARTICIPATION IN THIS RESEARCH IS VOLUNTARY)

1. Investigator's Name	:	Dr. Lee Poh Foong	**Faculty** :	FES
Title of research project	:	A Study on Using Electroencephalogram (EEG) to Detect Depressive Symptoms and Effective Therapies		
Purpose of study	:	To investigate the differences of brainwave pattern for normal and people with depressive symptoms.		
Procedure	:	Electroencephalogram, pulse rate, blood oxygen saturation, and blood pressure data collection. Questionnaires to be answered.		
Risk and Discomfort	:	None		
Benefit	:	Able to detect, understand and relate brainwaves pattern, pulse rate, blood pressure and blood oxygen saturation with depression		
Payment	:	None		
Alternatives	:			
Contact Person	:	Lee Poh Foong 016-9799216 Donica Kan Pei Xin 017-3841180		

Note: 1. All volunteers involved in this study will not be covered by insurance
2. Contact person must be the principal investigator

2. Particulars of Volunteer (Volunteer Identifier/Label)
(Please use separate form if more than one volunteer)

Full Name	:			
Chinese character *(if applicable)*	:			
Date of Birth	:		Age :	
New Identity Card No.	:		Gender :	
Ethnic	:			
Blood Type	:			
Correspondence Address	:			
Telephone	:		Fax :	
Email	:			

3. Medical History

A brief medical history will be taken as detailed in **Appendix A**

4. Voluntary participation

You understand that participation in this study is voluntary and that if you decide not to participate, you will experience no penalty or loss of benefits to which you would otherwise be entitled. If you decide to participate, you may subsequently change your mind about being in the study, and may stop participating at any time. You understand that you must inform the principal investigator of your decision immediately.

5. Available Medical Treatment

If you are injured during your participation or in the course of the study or whether or not as a direct result of this study, UTAR will not be liable for any loss or damage or compensation or absorb the costs of medical treatment. However, assistance will be provided to you in obtaining emergency medical treatment.

6. Confidentiality

All information, samples and specimens you have supplied will be kept confidential by the principal investigator and the research team and will not be made available to the public unless disclosure is required by law.

7. Disclosure

Data, samples and specimens obtained from this study will not identify you individually. The data, samples and specimens may be given to the sponsor and/or regulatory authorities and may be published or be reused for research purposes not detailed within this consent form. However, your identity will not be disclosed. The original records will be reviewed by the principal investigator and the research team, the UTAR Scientific and Ethical Review Committee, the sponsor and regulatory authorities for the purpose of verifying research procedures and/or data.

By signing this consent form, you authorize the record review, publication and re-utilisation of data, information and sample storage and data transfer as described above

8. Declaration

I have read or have the information above read to me, in the language understandable to me. The above content has been fully explained to me.

I have asked all questions that I need to know about the study and this form. All my questions have been answered. I have read, or have had read to me, all pages of this consent form and the risks described. I voluntarily consent and offer to take part in this study. By signing this consent form, I certify that all information I have given, including my medical history, is true and correct to the best of my knowledge. **I will not hold UTAR or the research team responsible for any consequences and/or liability whatsoever arising from my participation in this study.**

- **9. Consent**

If you wish to participate in this study, please sign below.

_____
_____

Signature of Volunteer IC. No.

1. _____
_____

Name of Volunteer Date

2. _____
_____

Signature of witness IC. No.

_____
_____

Name of witness Date

10. Statement of Principal Investigator

I have fully explained to the volunteer taking part in this study what he / she can expect by virtue of his / her participation. The volunteer who is giving consent to take part in this study

- Understands the language that I have used.
- Reads well enough to understand this form, or is able to hear and understand the contents of the form when read to him or her.
- Is of the age of majority of 18 or above.

To the best of my knowledge, when the volunteer signed this form, he or she understands:

- That taking part in the study is voluntary.
- What the study is about.
- What needs to be done.
- What are the potential benefits.
- What are the known risks.

A copy of this consent form has been given to the volunteer.

_____
_____
Name of Principal Investigator IC. No.

3.

4.

5. _____

_____

Signature of Principal Investigator Date

Note: *1. The principal investigator conducting the informed consent process, must sign* ***and*** *date form* ***at the same time as the volunteer****.*

Appendix A

Project Title :	A Study on Using Electroencephalogram (EEG) to Detect Depressive Symptoms and Effective Therapies	Application No. *(As provided by* UTAR*)*	
		Volunteer Identifier / Label	

Medical History of Volunteer			
Have you ever had any of the following:		**Yes**	**No**
a	a serious illness or accident?		
b	an operation/ investigative procedure?		
c	contact with any infectious disease?		
d	heart disease?		
e	high blood pressure (>140/90 mmHg)?		
f	asthma?		
g	kidney disease?		
h	diabetes?		
Do you or family have any of the following:			
i	Cancer?		
j	A serious illness or accident?		
k	An operation/ investigative procedure?		
l	Psychiatric disease/ mental problem?		

Signature of Principal Investigator

APPENDIX C: Patient Health Questionnaires (PHQ-9)

Serial No. : _____

Age : _____ Date of Birth : _____ Gender : _____

Occupation : _____ Education : _____

Part A

Over the **last 2 weeks**, how often have you been bothered by any of the following problems? (Please circle your answer)

		Not at all	Several days	More than half the days	Nearly every day
1	Little interest or pleasure in doing things	0	1	2	3
2	Feeling down, depressed, or hopeless	0	1	2	3
3	Trouble falling or staying asleep, or sleeping too much	0	1	2	3
4	Feeling tired or having little energy	0	1	2	3
5	Poor appetite or overeating	0	1	2	3
6	Feeling bad about yourself – or that you are a failure or have let yourself or your family down	0	1	2	3
7	Trouble concentrating on things, such as reading the newspaper or watching television	0	1	2	3

8	Moving or speaking so slowly that other people could have noticed? Or the opposite – being so fidgety or restless that you have been moving around a lot more than usual	0	1	2	3
9	Thoughts that you would be better off dead or of hurting yourself in some way	0	1	2	3

APPENDIX D: Depression Anxiety Stress Scale (DASS-21)

Part B

Please read each statement and **circle a number** 0, 1, 2 or 3 which indicates how much the statement applied to you **over the past week**. There are no right or wrong answers. Do not spend too much time on any statement.

The rating scale is as follows:

0 = Did not apply to me at all

1 = Applied to me to some degree, or some of the time

2 = Applied to me to a considerable degree, or a good part of time

3 = Applied to me very much, or most of the time

1	I found it hard to wind down	0 1 2 3
2	I was aware of dryness of my mouth	0 1 2 3
3	I couldn't seem to experience any positive feeling at all	0 1 2 3
4	I experienced breathing difficulty (e.g. excessively rapid breathing, breathlessness in the absence of physical exertion)	0 1 2 3
5	I found it difficult to work up the initiative to do things	0 1 2 3
6	I tended to over-react to situations	0 1 2 3
7	I experienced trembling (e.g. in the hands)	0 1 2 3
8	I felt that I was using a lot of nervous energy	0 1 2 3
9	I was worried about situations in which I might panic and make a fool of myself	0 1 2 3
10	I felt that I had nothing to look forward to	0 1 2 3
11	I found myself getting agitated	0 1 2 3

12	I found it difficult to relax	0 1 2 3
13	I felt down-hearted and blue	0 1 2 3
14	I was intolerant of anything that kept me from getting on with what I was doing	0 1 2 3
15	I felt I was close to panic	0 1 2 3
16	I was unable to become enthusiastic about anything	0 1 2 3
17	I felt I wasn't worth much as a person	0 1 2 3
18	I felt that I was rather touchy	0 1 2 3
19	I was aware of the action of my heart in the absence of physical exertion (e.g. sense of heart rate increase, heart missing a beat)	0 1 2 3
20	I felt scared without any good reason	0 1 2 3
21	I felt that life was meaningless	0 1 2 3

APPENDIX E: Self Report-Measures Assessment

Name: Serial no:

After each the sequenced activities below, please tick the things that you are doing with your mind.

1. Eyes closing:

   - ☐ Day dreaming
   - ☐ Sleepy / Drowsiness
   - ☐ Relaxing (breathing)
   - ☐ Others : _____

2. Eyes opening:

   - ☐ Day dreaming
   - ☐ Sleepy / Drowsiness
   - ☐ Relaxing (breathing)
   - ☐ Others : _____

3. 1st music:

   - ☐ Day dreaming
   - ☐ Sleepy / Drowsiness
   - ☐ Focus on music
   - ☐ Others : _____

4. Relaxing with eyes open:

   - ☐ Day dreaming
   - ☐ Sleepy / Drowsiness
   - ☐ Relaxing (breathing)
   - ☐ Others : _____

5. 2nd music:

   - ☐ Day dreaming
   - ☐ Sleepy / Drowsiness
   - ☐ Focus on music
   - ☐ Others : _____

6. Relaxing with eyes open:

   - ☐ Day dreaming
   - ☐ Sleepy / Drowsiness
   - ☐ Relaxing (breathing)
   - ☐ Others : _____

7. 3rd music:

- [ ] Day dreaming
- [ ] Sleepy / Drowsiness
- [ ] Focus on music
- [ ] Others : _____

8. Relaxing with eye open:

- [ ] Day dreaming
- [ ] Sleepy / Drowsiness
- [ ] Relaxing (breathing)
- [ ] Others : _____

9. Breathing with guidance:

- [ ] Day dreaming
- [ ] Sleepy / Drowsiness
- [ ] Focus on breathing
- [ ] Others : _____

10. Breathing without guidance:

- [ ] Day dreaming
- [ ] Sleepy / Drowsiness
- [ ] Focus on breathing
- [ ] Others : _____

Can you focus on the breath counting on your own from 1 to 10?

[ ] Yes [ ] No