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On the Interaction between Electroencephalogram Bands of Normal Elderly Women and Demented Elderly Women

MISOOK HA, PhD, PT[1)], DONGWOOK HAN, PhD, PT[2)]

[1)]Department of Physical Therapy, Choonhae College
[2)]Department of Physical Therapy, College of Medical and Life Science, Silla University: 100 Silladaehakgil, Sasanggu, Busan, 617-736 Republic of Korea.
TEL: 82 51-999-6238, FAX: 82 51-999-5176, E-mail: dwhan@silla.ac.kr

Abstract. [Purpose] This study investigated the potential of quantitative electroencephalogram (EEG) analysis for dementia diagnosis by examining the correlation between each frequency band of EEG using a sample of normal and demented elderly women. [Subjects] Thirty-three elderly women (17 normal, 16 demented) without history of brain disease were participated in this study. [Methods] EEGs of the subjects were measured continuously for 5 minutes while subjects' eyes were closed. The AT index was defined as the ratio of the theta wave to the SMR wave; the AC index was defined as the ratio of the low beta wave to alpha wave; and the ST index was defined as the ratio of the high beta wave to the alpha wave. The differences in brain activity between normal and demented elderly women were analyzed using the Mann-Whitney test and the SPSSWIN (ver. 12.0) program. [Results] All areas showed a lower AT index among normal elderly women compared to demented elderly women. In the P4 area, the AC index and the ST index were significantly higher in normal than in demented elderly women, indicating there is a difference in brain activity between normal and demented elderly women. [Conclusion] These results show that quantitative EEG analysis can be used for dementia diagnosis.
Key words: Quantitative EEG, Dementia diagnosis, Brain activity

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INTRODUCTION

Persons with normal cognitive function can experience a sudden decrease in intellectual function such as deterioration in memory, visuospatial ability, executive function, language ability, calculating ability and judgment through degenerative changes or vasculogenic changes. A disease that causes such changes is dementia. Dementia is a mental disability that causes gradual deterioration in ability to perform activities of daily living and social activity after starting as a disability in cognitive function. In severe cases of dementia, an elderly individual cannot independently perform activities of basic daily living.

Even though early diagnosis of dementia is very important in preventing the progress of dementia and cognitive rehabilitation, the accuracy of diagnosis depending on the clinical method is as low as 60–80%. Moreover, the symptoms of early dementia patients are not distinguishable from the cognitive functional disabilities of normal elderly people or those of depression patients. Hence, a method for objectively diagnosing dementia is necessary. Single photon emission computed tomography (SPECT), positron emission tomography (PET), functional magnetic resonance imaging (FMRI), and electroencephalography (EEG) are widely used for diagnosing dementia. EEG captures electrical changes that appear during the signal transition process among cranial nerve cells and has the advantages of non-invasiveness and relative ease of use for monitoring brain functions. Human thinking and behavior are controlled by the cerebral cortex function which depends on the activities of the many cranial nerve cells whose activities can be observed in brain-waves. Considering this, brain-wave monitoring is a useful tool for objectively and continuously evaluating cerebral cortex function. Quantitative EEG (qEEG) has recently been developed and implemented. It has an advantage in that non-specialists can easily analyze brain waves using a computer.

This study provides evidence supporting the future usage of quantitative EEG analysis dementia diagnosis. We examined the correlation between each frequency band of brain waves in an EEG analysis using data collected from a research sample of normal elderly women and demented elderly women.

SUBJECTS AND METHODS

Thirty-three women from among the elderly women living in three care facilities for the elderly located in Busan and the rural area of Buyeo-gun who agreed to voluntary participation were chosen as study subjects. All the subjects could sustain independent daily living and had no history of brain disease such as stroke and schizophrenia. The medical records of the demented elderly were used to confirm the brain disease. The selected subjects did not have overactivity of the muscles, such as facial spasm, that could affect EEG or visual problems in distinguishing objects. The sample subjects did not have hearing impairments or difficulties with language communication. The total sample consisted of 33 persons. Among them 17 subjects with MMSE-K score higher than 24 were classified as normal elderly women and the remaining 16 subjects who had MMSE-K score lower than 19 were classified as demented elderly women. The average age of the normal elderly women was 80.36 years and that of the demented elderly women was 79.32 years.

EEGs were measured using an electroencephalograph (Nihonkhoden, Inc., Japan). The attachment sites of the electrodes were determined following the international standard of the 10–20 electrode method: Fp1, Fp2, Fpz, F3, F4, F7, F8, Cz, C3, C4, T3, T4, T5, T6, Pz, P3, P4, O1, and O2, linked to the earlobe. EEGs were measured continuously for 5 minutes with subjects' eyes closed and keeping awake. This study used quantitative approach to analyze the brain waves. In the measurement of EEG, the time constant was 0.3 seconds, the sensitivity was 10 μV, and the highest frequency was 60 Hz. Brain waves were categorized following convention into theta waves (4–7Hz), alpha waves (8–13Hz), SMR waves (12–15Hz), low beta waves (14–20Hz), and high beta waves (21Hz–30Hz). The attention index (AT index) was defined as the ratio of the theta wave to the SMR wave; the activation index (AC index) was defined as the ratio of the low beta wave to the alpha wave; and the stress index (ST index) was defined as the ratio of the high beta wave to the alpha wave. A high AT index implies low activation with a not-alert brain; a high AC index implies active use of the brain; and a high ST index implies a continuous response to outside stimulation in the brain even when the eyes are closed to block out outside information. In order to examine whether there is a difference in brain activity between normal elderly women and demented elderly women, the nonparametric Mann-Whitney test was conducted. SPSSWIN (ver. 12.0) was used for the data analysis with a significance level of $\alpha<0.05$.

RESULTS

The AT index indicates the concentration level through the ratio of the theta wave that shows the sleep state and the SMR wave that shows the awakeness states. In the comparison of the AT indexes between the normal elderly women and the demented elderly women, Fp1 ($p<0.05$) and Fp2 ($p<0.05$) in the prefrontal lobe that is closely related with cognitive function, F3 ($p<0.05$), F4 ($p<0.05$), F7 ($p<0.05$), and F8 ($p<0.05$) in the frontal lobe of the motor area, and Pz ($p<0.05$), P3 ($p<0.05$), and P4 ($p<0.05$) in the parietal lobe of the sensory area all showed lower AT indexes in the normal elderly women than in the demented elderly women. In the AC index, Fp1 and Fp2 in the prefrontal lobe, F4 and F7 in the frontal lobe, and Pz, P3, and P4 in the parietal lobe showed higher AC indexes in the normal elderly women than in the demented elderly women; however, only P4 ($p<0.05$) showed a significant difference. The normal elderly women also had higher ST indexes than the demented elderly women in Fp1 and Fp2 in the prefrontal lobe, F3, F4, F7, and F8 in the frontal lobe, and Pz, P3, and P4 in the parietal lobe. However, only P4 ($p<0.05$) showed a significant difference (Table 1).

DISCUSSION

The brain controls all the sensory and cognitive functions of the body, manages instincts including eating and sleeping, handles simple sensory data from watching and

Table 1. Comparison of brain activity (unit: μV)

	AT Normal	AT Demented	AC Normal	AC Demented	ST Normal	ST Demented
Prefrontal lobe						
Fp1	1.29 ± 0.61*	3.28 ± 1.21*	0.59 ± 0.53	0.48 ± 0.29	0.74 ± 0.77	0.47 ± 0.39
Fp2	1.31 ± 0.57*	3.45 ± 1.25*	0.60 ± 0.53	0.48 ± 0.30	0.86 ± 1.00	0.46 ± 0.37
Fz	1.52 ± 0.68*	3.00 ± 1.77*	0.46 ± 0.41	0.44 ± 0.26	0.50 ± 0.60	0.31 ± 0.29
Frontal lobe						
F3	1.27 ± 0.58*	2.42 ± 1.43*	0.51 ± 0.48	0.52 ± 0.32	0.54 ± 0.63	0.40 ± 0.36
F4	1.32 ± 0.53*	2.52 ± 1.10*	0.57 ± 0.53	0.50 ± 0.30	0.62 ± 0.71	0.39 ± 0.35
F7	1.25 ± 0.65*	2.69 ± 0.91*	0.51 ± 0.50	0.47 ± 0.27	0.52 ± 0.54	0.41 ± 0.33
F8	1.17 ± 0.53*	2.66 ± 1.02*	0.47 ± 0.39	0.53 ± 0.31	0.53 ± 0.56	0.52 ± 0.38
Parietal lobe						
Pz	1.02 ± 0.56*	2.42 ± 1.49*	0.78 ± 0.15	0.30 ± 0.23	0.56 ± 0.69	0.22 ± 0.27
P3	0.89 ± 0.68*	2.27 ± 1.86*	0.58 ± 0.56	0.28 ± 0.17	0.48 ± 0.63	0.20 ± 0.20
P4	0.94 ± 0.53*	2.57 ± 1.62*	0.66 ± 0.62*	0.26 ± 0.21*	0.59 ± 0.64*	0.19 ± 0.22*

Mean ± SD. *: $p<0.05$. AT: Attention index, AC: Activation index, ST: Stress index.

listening, and manages complicated actions such as painting or solving equations. As the thinking activity in these complex brain functions is carried out by cranial nerves and the frontal lobe, it is possible to analyze the activity of the brain in the frontal region including the prefrontal regions. Also, attention and working memory are known to be influenced by the prefrontal regions and the parietal lobe in general. Accordingly, the cranial nerve cells are ceaselessly active and EEG measures the electrical changes generated by their activity using electrodes.

Among the brain waves that appear when taking a rest with the eyes closed, the theta wave shows up before sleeping in conditions such as being dozy or about to fall asleep, and hence it indicates decreased brain function. Meanwhile, the alpha wave, which is observed when processing and memorizing data obtained from outside is indicative of normal brain function. The SMR wave indicates a clearly awakened brain. The low beta wave is a waveform that is manifested in mental activity requiring concentration, while the high beta wave is manifested when excessive amounts of data in excess of the decision-making ability of the cerebral cortex.

The AT index is the ratio of the theta wave showing the sleep state and the SMR wave that shows the awakening state. A high AT index indicates poor ability to focus on outside stimulus and low wakefulness of the brain. The AC index is the ratio of the alpha wave, that appears when the brain recalls outside stimulus from memory, to the low beta wave, that shows active cognitive function such as calculation. A high AC index indicates active cognitive activity of the brain. The ST index is the ratio of the high beta wave to the alpha wave, and is high during thinking or responding sensitively to outside stimulus.

According to the study results, the normal elderly women had a significantly lower AT index in the prefrontal regions which is related to cognitive function, the frontal lobe which is related to motor function, and the parietal lobe which is related to sensory function than demented elderly women. This shows that the wakefulness that supports strong concentration ability in the normal elderly women was better than that in the demented elderly women. Meanwhile, normal elderly women had AC and ST indexes that were significantly higher in the right parietal lobe (P4) as well as in the left parietal lobe (P3) though without statistical significance. Considering that the parietal lobe is the area which receives external sensory stimulus, high AC and ST indexes in the parietal lobe may imply that normal elderly women respond more sensitively to outside stimuli with stronger analytical ability than demented elderly women. To sum up, the normal elderly women had better cognitive ability than the demented elderly women in their responses to external stimuli and learning, and these results show that it may be possible to use quantitative EEG analysis for the diagnosis of dementia.

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