

Comparative Analysis of Brain Activation between Healthy Elderly Women and Healthy Adult Women

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Abstract. [Purpose] This study determined the differences in the brain activation between healthy elderly women (75.89 ± 6.44 years of age) and healthy adult women (22.11 ± 2.04 years). [Subjects] Twenty-seven healthy elderly women who could independent daily living with no history of brain diseases such as stroke or schizophrenia and 27 healthy adult women who are studying at S university in Busan were as participants in this study. [Methods] Examinations used twenty electrodes attached to the head to capture electrical brain signals during brain activated states such as the awaked state and the data were compared between the two groups of women. The AT index is the ratio of theta waves and SMR waves. The AC index is the ratio of alpha waves to low beta waves. The ST index is the ratio of high beta waves to alpha waves. The Mann-Whitney test was conducted to examine changes in EEG. [Results] Fp1, Fp2, Fz, F3, F4, F7, F8, and Pz areas indicate a significantly lower AT index in the healthy elderly women than in the healthy adult women. The Fp1, Fp2, Fz, F3, F4, F7, F8, Pz, P3, and P4 areas all showed a significantly higher AC index in the healthy elderly women, they who also had a significantly higher ST index than the healthy adult women in the Fz, F3, F4, F8, Pz, P3, and P4 areas. [Conclusion] We showed that the brain of the healthy elderly women lacks rest for processing information which is received during eyes open. We also demonstrated the capability of the quantitative EEG in the examination of cognitive impairments.

Key words: Quantitative EEG, Healthy elderly women, Healthy adult women

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INTRODUCTION

One of the most serious problems in aging is cognitive disabilities, including calculation errors, disorientation, judgment disorder, and intelligibility disorder^{1,2)}. It has become important to assess cognitive ability due to the number of parameters associated with functional changes of the brain³⁾. There are several ways to examine cognitive functions. According to a recent study, assessment of the cognitive function of brain activity using EEG is recognized as a useful for examining the changes in the brain during perceptive or cognitive activity and is known to be capable of objective evaluation of brain function^{4,5)}.

The brain controls all the sensory, motor and cognitive functions needed by the participants in our study. Therefore, in the cranial nerve cells, electrical changes occur constantly and the changes can be measured using the electrodes of an electroencephalogram (EEG)⁶⁾. Human thinking and behavior are controlled by cerebral cortex function which depends on the activities of many cranial nerve cells whose activities can be observed in brain-waves, and brain-wave monitoring is a useful tool for objective and continuous evaluation of the cerebral cortex function^{7,8)}. Recently, a mapping function has been added to EEG equipment, and the mathematical analysis of EEG as well

as its visual interpretation has become possible. Through the development of quantitative EEG analysis methods, it has become possible to ascertain the differences between signals which could not be previously be detected, and it has also become possible to express them as quantitative numeric values^{9,10)}. Furthermore, quantitative EEG (qEEG) analysis has an advantage in that non-specialists can be easily record brain waves with a computer¹¹⁾. The EEG measurements can be separated into the component wavelengths using Fourier transformations and quantitative EEG (qEEG) analysis involves summation of the component wavelength. Quantitative EEG can be expressed in numerical values because discrete wavelengths can be calculated from the component frequencies. A variety of brain functions change with increasing age and the changes can be found using EEG because the change in cognitive functions is reflected in the change of the electric signals between the cranial nerves. Furthermore, EEG can be used to determine the degree of cognitive function decline¹²⁾. The volume of research using quantitative EEG the analyzing brain functions and the basic data from such research is much less than that of qualitative EEG analysis. And research using the ratios of frequency bands to evaluate the brain activation is especially scarce.

EEG measurements of healthy elderly women will differ

from the EEG of healthy adults due to the deterioration of cognitive functions in healthy elderly women. Few studies have investigated cognitive function or brain activation using quantitative EEG analysis. And research comparing EEG between healthy elderly and adult participants with respect to their cognitive EEG functions is scarce. Therefore, the purpose of this study was to clarify and compare the differences in brain activation between healthy elderly women and healthy adult women through quantitative EEG analysis using frequency band ratios. This study also examined the possibility of using quantitative EEG to detect cognitive function decline by analyzing the differences in brain activation between healthy elderly and adult participants.

SUBJECTS AND METHODS

From among voluntary elderly women living in Busan, 27 healthy elderly women (75.89 ± 6.44 year) who could sustain independent daily living, who had no history of brain disease such as stroke or schizophrenia and who had scores above 24 on the MMSE-K scale were chosen as research subjects. 27 healthy adult women (22.11 ± 2.04 year) who were studying at S university in Busan participated in this study. The selected elderly did not have overactive muscles such as facial spasm that might have affected EEG or visual problems in distinguishing objects; also, they did not have hearing impairments or difficulties with language communication. EEG was measured by using an electroencephalographic monitor (Nihonkhoden, Inc., Japan). The attachment site of the electrodes was determined following the international standard of the 10-20 electrode method and included Fp1, Fp2, Fpz, F3, F4, F7, F8, Cz, C3, C4, T3, T4, T5, T6, Pz, P3, P4, O1 and O2, with the earlobe acting as the earth. For the measurement of EEG, the time constant was 0.3 seconds, sensitivity was $10 \mu\text{V}$, and the cutoff frequency was 60 Hz. Brain-waves were categorized following convention into theta (4–7 Hz), alpha (8–13 Hz), SMR (12–15 Hz), low beta (14–20 Hz), and high beta waves (21–30 Hz). The attention index (AT index) is the ratio of theta waves to SMR waves, The activation index (AC index) is the ratio of low beta waves to alpha waves, and the stress index (ST index) is the ratio of high beta waves to alpha waves¹³⁾. A high AT index implies low wakefulness, a high AC index implies active use of the brain, and a high ST index implies heavy stress on the brain. In order to examine whether there is a difference in brain activation between healthy elderly women and healthy adult women, the Mann-Whitney test was conducted because the data did not have a normal distribution. SPSSWIN (ver. 19.0) was used for data analysis and the significance level was chosen as $\alpha < 0.05$.

RESULTS

Fp1 ($p < 0.05$), Fp2 ($p < 0.05$) and Fz ($p < 0.05$) in the prefrontal lobe, F3 ($p < 0.05$), F4 ($p < 0.05$), F7 ($p < 0.05$) and F8 ($p < 0.05$) in the frontal lobe, Pz ($p < 0.05$) in the parietal lobe showed a significantly lower AT index in the healthy elderly women than in the healthy adult women. These

results show that in the healthy elderly women, the theta wave was low relative to the SMR wave. In contrast, the theta wave was high relative to the SMR wave in the healthy adult women. Thus, the attention index (AT index) of the healthy elderly women was higher than that of the healthy adult women. Fp1 ($p < 0.05$) and Fp2 ($p < 0.05$) and Fz ($p < 0.05$) in the prefrontal lobe, F3 ($p < 0.05$), F4 ($p < 0.05$), F7 ($p < 0.05$) and F8 ($p < 0.05$) in the frontal lobe, and Pz ($p < 0.05$), P3 ($p < 0.05$) and P4 ($p < 0.05$) in the parietal lobe all showed a significantly higher AC index in the healthy elderly women than in the healthy adult women. These results show that in the healthy elderly women, the low beta wave was high relative to the alpha wave, whereas the alpha wave was high relative to the low beta wave in the healthy adult women. Therefore, the activation index (AC index) of the healthy elderly women was higher than that of the healthy adult women. Also, the healthy elderly women had a significantly higher ST index than the healthy adult women in Fz ($p < 0.05$) in the prefrontal lobe, in F3 ($p < 0.05$), F4 ($p < 0.05$) and F8 ($p < 0.05$) in the frontal lobe, and in Pz ($p < 0.05$), P3 ($p < 0.05$) and P4 ($p < 0.05$) in the parietal lobe. These results show that in the healthy elderly women, the high beta wave was high relative to the alpha wave, whereas the alpha wave was high relative to the high beta wave in the healthy adult women. Therefore, the stress index (AC index) of the healthy elderly women was higher than that of the healthy adult women (Table 1).

DISCUSSION

The brain controls all sensory and cognitive functions within the body. It manages instincts including eating and sleeping; handles simple sensory data from watching and listening, and manages complicated actions such as painting or solving equations. As the thinking activity in complex brain functions are carried out by synergic activity of cranial nerves over the whole brain centered in the frontal lobe, it is possible to analyze the activity state of the brain in the frontal region including the prefrontal regions¹⁴⁾. Attention and working memory are known to be influenced by the prefrontal regions and the parietal lobe in general¹⁵⁾. Thus EEG we measured EEG in the prefrontal lobe, frontal lobe, and parietal lobe in this study.

In the brain-waves that appear while at rest (eyes closed), the theta wave shows up before sleeping when in a dozy state or about to fall asleep; hence, it indicates decreased brain activity. The alpha wave, which is observed when processing and memorizing data obtained from outside indicates normal brain function¹³⁾. The SMR wave frequency is between those of the alpha wave and the beta wave and indicates a clearly awakened brain. The low beta wave is a waveform that is activated by mental activity such as concentration, while the high beta wave is activated when amounts of data in excess of the decision-making ability of the cerebral cortex are present¹⁶⁾.

The AT index determines the concentration level as it is the ratio of theta waves that show a sleepy state and SMR waves that show an awake state. A high AT index indicates poor ability to focus on outside stimulus with low wakefulness of the brain. The AC index is the ratio of alpha

Table 1. The comparison of brain activation (unit: μV)

	AT		AC		ST	
	Elderly	Adult	Elderly	Adult	Elderly	Adult
Prefrontal lobe						
Fp1	1.99 \pm 2.11	3.22 \pm 1.39*	0.62 \pm 0.57	0.23 \pm 0.13*	0.98 \pm 1.74	0.27 \pm 0.23
Fp2	2.12 \pm 2.67	3.09 \pm 1.58*	0.61 \pm 0.52	0.24 \pm 0.14*	0.83 \pm 0.92	0.36 \pm 0.32
Fz	1.82 \pm 1.09	4.06 \pm 2.87*	0.53 \pm 0.46	0.18 \pm 0.11*	0.52 \pm 0.60	0.12 \pm 0.07*
Frontal lobe						
F3	1.47 \pm 0.95	3.46 \pm 1.95*	0.59 \pm 0.56	0.24 \pm 0.12*	0.67 \pm 1.05	0.16 \pm 0.12*
F4	1.71 \pm 1.15	3.52 \pm 2.24*	0.61 \pm 0.52	0.21 \pm 0.13*	0.60 \pm 0.67	0.16 \pm 0.10*
F7	1.54 \pm 1.07	3.24 \pm 1.55*	0.53 \pm 0.47	0.24 \pm 0.15*	0.55 \pm 0.59	0.23 \pm 0.20
F8	1.65 \pm 1.29	3.02 \pm 1.51*	0.54 \pm 0.44	0.24 \pm 0.14*	0.57 \pm 0.61	0.20 \pm 0.13*
Parietal lobe						
Pz	1.53 \pm 1.36	2.02 \pm 0.99*	0.56 \pm 0.57	0.15 \pm 0.08*	0.46 \pm 0.62	0.09 \pm 0.05*
P3	1.38 \pm 1.39	1.70 \pm 0.94	0.56 \pm 0.60	0.18 \pm 0.09*	0.46 \pm 0.67	0.12 \pm 0.06*
P4	1.37 \pm 1.16	1.70 \pm 0.83	0.57 \pm 0.57	0.16 \pm 0.07*	0.47 \pm 0.60	0.10 \pm 0.05*

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

waves, which appear when the brain remembers outside stimulus, to low beta waves, which show active cognitive function such as calculation. A high AC index implies high cognitive activity in the brain. The ST index is the ratio of high beta wave and is high when much thought or a sensitive response to outside stimulus is taking place¹³⁾.

According to our results, the healthy elderly women had significantly lower AT indices in the prefrontal regions which are related to cognitive function, the frontal lobe, which is related to motor function, and the partial parietal lobe, which is related to sensory function than the healthy adult women. A lower AT index means that SMR, which shows an awake state, was higher than the theta wave, which shows a sleepy state. Thus, it shows that the wakefulness that supports strong concentration ability in the healthy elderly women was better than that of the healthy adult women in the eyes closed and mental resting condition. However, even though the healthy elderly women had a lower AT index than the healthy adult women, the cognitive functions of the healthy elderly women were not better than those of the healthy adult women. Generally, theta waves do not appear during consciousness, and the appearance of a theta wave indicates a cognitive impairment because theta waves are related to the sleepy state. Theta waves increase in a state of deep peace of mind as practiced in Zen meditation or being lost in contemplation¹³⁾. Theta waves are related to physical, emotional and mental activities under internalized and quiet conditions or in a sleepy state^{17,18)}. So, the lowering of the AT index in the healthy elderly women compared to the healthy adult women may mean they have not rested sufficiently and is in a state of the brain wakefulness responding continuously to stimulation even though their eyes were closed.

The healthy elderly women had a significantly higher AC index, the ratio of the alpha waves and low beta wave in the prefrontal regions, the frontal lobe, and the parietal than the healthy adult women. Because alpha waves are a primary wave in healthy adults, their absence means a tension or anxiety, a stressed state. The brain has rest and recharges through deep sleep needs once a day. However, even when the brain is awake, the brain needs a rest time to

process external information. The brain has rest and recharge through the blinking of the eyes during wakening, and at that time alpha waves are seen¹⁰⁾. Thus, alpha waves are evidence of the brain resting during wakening. However, low beta waves emerge during mental activities, such as learning, memorization and calculations. So, a high AC index means that the brain is activated without rest even if the eyes are closed. According to the ST index, the healthy elderly women had a significantly higher ST index than the healthy adult women in some prefrontal regions, which are related to cognitive function, some frontal regions, which are related to motor function, and all of the parietal regions, which are related to sensory function. A high AT index means that high beta waves. Which show over-activity and stress states of the brain, are greater than alpha waves, which show a relaxed condition¹³⁾. Accordingly, the results of this study show that the brain activity of the healthy elderly women was lower than that of the healthy adult women as shown by the high ST index, which showed that the efficiency of their brain activity had declined.

In conclusion, the brain activation of healthy elderly women and healthy adult women is clearly different. In the results of this study, we showed that the healthy elderly women in the eyes closed and mental resting condition had higher wakefulness of the brain and higher response to outside stimulus in sensory area than the healthy adult women. Therefore we think that the brains of the healthy elderly women lack rest for processing the information which is acquired when the eyes are open. Furthermore lack of rest for processing information may be a cause of cognitive function decline. We also showed that quantitative EEG has the capability to examine cognitive impairments.

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