

### Research Article

# Stroke Patients: Effects of Combining Sitting Table Tennis Exercise with Neurological Physical Therapy on Brain Waves

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### Abstract

**Purpose:** The purpose of this study is to analyze the brain waves and develop various exercise programs to improve the physical and mental aspects of stroke patients when neurological physical therapy and sitting table tennis exercise are applied to stroke patients.

**Methods:** In this study, an experiment was conducted on 15 patients diagnosed with stroke, and training was performed after changing the ping-pong table to a sitting position to apply ping-pong exercise to stroke patients. After training was conducted for 40 minutes twice a week for 4 weeks, brain waves were measured before and after. EEG was measured using Laxtha's DSI-24 equipment as a measurement tool, and data values were extracted through the Telescan program.

**Results:** Most of the relative beta waves showed a significant difference before and after the intervention. As for the characteristics of beta waves, this result can be seen as being highly activated during exercise or other activities.

**Conclusion:** Ping-pong exercise in a sitting position is a good intervention method for stroke patients, and it can help to use it as basic data in clinical practice by showing brain activity.

**Keywords:** Stroke; Sitting position; Ping-pong exercise; Brain wave

### Introduction

Stroke is the third leading cause of death after cancer and heart disease, and its prevalence is increasing. Stroke is a disruption of the

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blood supply to the brain or bleeding into the brain tissue, resulting in loss of brain function, primarily motor and sensory nerves [1,2]. Approximately 80% of stroke patients have motor impairment, with more than 69% of hemiparetic patients experiencing upper limb motor impairment [3,4]. Even six months after stroke, approximately 50% of patients have chronic upper extremity deficits that limit their activities of daily living, leading to social and economic burdens, making upper extremity rehabilitation an important part of stroke care [5].

Upper extremity function and hand dexterity are crucial, given that most activities of daily living are performed with the hands [6]. Impaired upper extremity motor function impairs the ability of stroke patients to perform activities of daily living and limits their social participation [7]. Therefore, upper extremity motor function rehabilitation is important, and there are several intervention methods for upper extremity motor function rehabilitation, including exercise training robot rehabilitation, bilateral upper extremity training activities, forced guided exercise therapy, mirror therapy, and unilateral upper extremity exercises [8]. Among them, table tennis, a unilateral upper extremity exercise, can help improve upper extremity motor function by using the hands and arms to hit the ball [9].

In addition, table tennis is an activity that involves constant interaction between visual perceptual information and movement execution [10], requiring efficient visual navigation strategies for accurate, concise, and fast movement execution [11]. The region of the brain involved in the development of visual perception, attention, and memory is the parietal lobe, which houses eye movement control functions [12]. Among the various eye movements, rapid eye movements are the fastest eye movements that track moving objects and provide sensory and reflexive visual stimuli [13]. The posterior parietal lobe is located at the back end of the cerebral cortex, where we receive information through vision and is responsible for interpreting visual information [14]. Eye movements can also be considered physical therapy for the visual system, which includes the brain and eyes, and are progressive motor skills of the eye that restore or develop normal seeing skills [15]. Overall, table tennis is a great sport for eye movements because the ball movement is faster and sharper than other sports.

EEG is a technology that measures electrical activity in the brain and provides information about the brain's health by analyzing patterns of activity. Stroke is a brain injury caused by impaired circulation in the brain, and changes in EEG play an important role in the diagnosis and treatment of stroke. Therefore, EEG can be used as a very useful tool for early diagnosis, prevention, treatment, and rehabilitation of stroke [16]. We looked at studies that applied EEG to stroke patients. For example, many interventions have been applied to stroke patients, such as immersive virtual reality, behavioral observation training, task-oriented training, and visual and auditory coordination stimulation [17-20]. However, there is a lack of research on EEG during unilateral upper extremity exercise in stroke patients.

It has been suggested that stroke patients may experience decreased muscle strength and movement anxiety due to hospitalization, and existing studies have not included table tennis in neurological

patients. Furthermore, there is a lack of studies looking at brain changes with table tennis [21]. Therefore, the purpose of this study is to determine what changes occur in the EEG when playing table tennis in a seated position.

## Research Methods

### Study population

This study was conducted on 15 patients who were diagnosed with stroke and were hospitalized at W Rehabilitation Hospital in Gwangju Metropolitan City from August to October 2021. All subjects were fully informed about the study and signed an informed consent form. The inclusion criteria for the study were: stroke onset more than 6 months ago, current paralysis, ability to maintain a sitting position for more than 40 minutes, no vision or hearing problems, and voluntary signing of the consent form.

### Measurement methods and tools

#### EEG measurement

In this study, EEG was measured using DSI-24 equipment (Wearable sensing Laxtha, USA). It is a research-grade wireless dry electrode EEG headset designed to quickly apply 21 sensors at 10-20 international system locations. There are 21 sensors in 10-20 locations (Figure 1). Since EEG measurements can be interfered with by external factors, we created an environment for the measurement before proceeding. For accurate measurements, two to three repeated measurements were performed, minimizing movement and keeping the eyes open for one minute. Data were extracted using the TELESCAN program (Laxtha, USA).

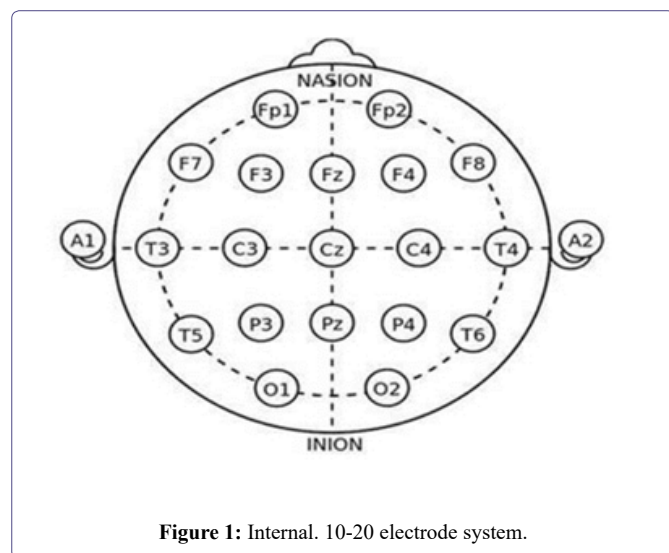


Figure 1: Internal 10-20 electrode system.

### Intervention methods and procedures

Patients in this study received unilateral upper extremity exercises after basic inpatient treatment at a neurological hospital. In order to perform unilateral upper limb exercises, subjects who met the study selection criteria were selected who voluntarily agreed to participate in the study and then played table tennis, one of the unilateral upper limb exercises. Before playing table tennis, the researchers explained and educated the subjects about the basic knowledge of table tennis in advance. To prevent stroke patients from falling, the table tennis table was modified into a sitting position. In a sitting position, the subject

held the ping-pong bat with the non-paralyzed hand and exchanged the ping-pong ball with the experimenter. One research assistant was positioned next to the subject to prevent falls. The subjects' table tennis performance was measured for 40 minutes once a day, twice a week, for a total of 4 weeks.

### Data analysis

The data collected in this study were analyzed using SPSS version 22.0 for Windows. Descriptive statistics were used to calculate the mean and standard deviation to determine the general characteristics of the subjects. The parametric Paired t-test was used for electrodes that met normality using the Shapiro-Wilk test, and the non-parametric Wilcoxon signed-rank test was used for electrodes that did not meet normality, and the significance level was set at  $p < .05$ .

## Results

### General characteristics of the study subjects

This study was conducted on 15 stroke patients, 11 males and 4 females, with a mean age of  $48.53 \pm 5.54$  years, a mean height of  $169.80 \pm 5.35$  cm, and a mean weight of  $65.27 \pm 10.03$  kg. The BMI index was  $22.51 \pm 2.38$   $\text{km/m}^2$ , the paralyzed side was 13 on the right and 2 on the left, and the etiology was 12 cerebral hemorrhage and 3 cerebral infarction (Table 1).

Ping-Pong exercise group (N=15)	
Gender (Male/Female)	11/4
Type of stroke (Infarction/Hemorrhage)	12/3
Paretic side (Rt./Lt.)	13/2
Age (year)	$48.53 \pm 5.54$
Height (cm)	$169.80 \pm 5.35$
Weight (kg)	$48.53 \pm 5.35$
Body mass index ( $\text{km/m}^2$ )	$22.51 \pm 2.38$

**Table 1:** General characteristics of the subject.  
Mean  $\pm$  standard deviation

### EEG

The inter-electrode changes in relative beta waves in this study were significantly different ( $p < 0.05$ ) at electrodes Fp1, Fp2, F3, and F7 in the frontal and parietal regions (Table 2). T3, T4, T5, and T6 electrodes in the temporal lobe region showed significant differences ( $p < 0.05$ ) (Table 2). Pz, O1, and O2 electrodes in the parietal and posterior parietal lobe regions ( $p < 0.05$ ) (Table 2).

### Discussion

This study aimed to find out what changes occurred in the EEG of stroke patients after playing table tennis in a seated position for four weeks. The results showed a significant increase in relative beta waves at electrodes Fp1, Fp2, F3, and F7 in the frontal and parietal regions. On the other hand, relative beta waves were significantly

Location	Pre	Post	Post-pre difference	t/z	p
Fp1	0.233±0.023	0.264±0.044	-0.031±0.059	-2.201	.028*
Fp2	0.196±0.024	0.238±0.043	-0.042±0.054	-3.012	.009**
Fz	0.270±0.037	0.306±0.059	-0.036±0.068	-2.031	.062
F3	0.231±0.026	0.276±0.034	-0.045±0.053	-2.338	.019*
F4	0.251±0.025	0.251±0.025	-0.018±0.052	-1.377	.190
F7	0.220±0.031	0.254±0.037	-0.034±0.059	-2.389	.017*
F8	0.188±0.048	0.213±0.049	-0.024±0.073	-1.304	.213
Cz	0.306±0.045	0.341±0.054	-0.035±0.071	-1.917	.076
C3	0.248±0.029	0.263±0.049	-0.014±0.056	-1.007	.331
C4	0.321±0.059	0.309±0.054	0.012±0.067	0.689	.502
T3	0.366±0.022	0.275±0.048	0.090±0.054	6.419	.000**
T4	0.356±0.029	0.270±0.056	0.086±0.062	5.349	.000**
T5	0.416±0.026	0.296±0.048	0.120±0.061	7.546	.000**
T6	0.434±0.012	0.279±0.043	0.154±0.043	13.801	.000**
Pz	0.439±0.096	0.350±0.056	0.088±0.119	-2.701	.007*
P3	0.624±0.132	0.362±0.078	0.042±0.125	-1.793	.073
P4	0.386±0.027	0.362±0.077	0.024±0.086	1.074	.301
O1	0.450±0.029	0.295±0.038	0.154±0.056	10.688	.000**
O2	0.480±0.020	0.328±0.056	0.152±0.060	9.656	.000**

**Table 2:** Electrode-specific changes in relative beta waves.

Paired t-test (\*\*p<.05)

Wilcoxon signed rank test (\*p<.05)

decreased at electrodes T3, T4, T5, and T6 in the sensory areas of the temporal lobe and at electrodes Pz, O1, and O2 in the parietal and occipital lobes. The motor areas, C3 and C4 electrodes, did not show significant differences, which may be due to a variety of factors, including the fact that motor-related activity occurs in different brain regions, the intensity and duration of motor-related activity, and inter-individual differences [22].

Post-stroke EEG measurements can reveal changes in interhemispheric balance, changes in activity in areas connected to the injured region, and reorganization of the body representation map, identifying reorganization of brain regions that support clinical recovery [23-25]. Although table tennis, a unilateral upper extremity exercise, was performed in a seated position in this study, it is thought to increase the anterior cingulate and parietal lobe regions in exercises with greater physical activity in the upper extremities. A 2014 study examined EEG activation in table tennis players and found increased activation in the frontal and parietal lobes during table tennis [26]. These results suggest that table tennis is conducive to activating the frontal and parietal regions of the brain because it involves a lot of upper extremity use and requires quick judgment and reaction [27].

The frontal and parietal lobes are associated with executive functions of the brain, such as motor planning, execution, and control, and various studies have shown that activity in the frontal lobe is associated with motor-related cognitive functions and motor-related tasks, such as sensory processing, motor planning, execution, control, and feedback [28]. This is consistent with previous studies that have reported that motor recovery in stroke patients is positively correlated with relative beta waves in the parietal lobe [29]. The generation and inhibition of goal-directed movements, such as hitting a ball with a ping-pong stick in a stroke patient, occurs in nested brain regions of neural networks [30,31]. Interactive inhibition occurs throughout the

entire process from action planning to execution, and inhibitory control allows the human brain to develop adaptive and flexible behavioral strategies to regulate movement [32]. Thus, circuit reorganization and neuroplasticity in the injured brain occurs [25,26].

Stroke patients often experience sensory deficits [33]. Loss of somatosensory or visual fields negatively impacts functional outcomes in patients with hemiparesis [34]. It is not surprising that motor recovery can be enhanced by sensory stimulation. In patients with severe motor impairment, changes in effective connectivity can be seen after stroke at all stages of sensorimotor integration, from primary sensory areas to associated multisensory areas, and among the various neurofeedback protocols used to inhibit or enhance brain waves, sensorimotor training protocols have been suggested as an effective way to improve motor performance [35,36]. In the present study, changes in brain waves with golf putting performance were shown to increase or decrease various brain wave activities in specific areas of the cerebral cortex to develop a neural system for correct patterns or activities [37].

In this study, EEG activity decreased in the temporal lobe, parietal lobe, and posterior parietal lobe. These areas are sensory areas, and it is thought that the decrease in EEG activity is due to the tactile sensation from the table tennis bat and ball, the auditory sensation from the sounds that occur regularly in table tennis, and the visual sensation from constantly looking at the ball. However, the mechanisms for the changes in EEG activity in stroke patients are uncertain [16,38,]. Therefore, further research is needed to understand the mechanisms of sensory deficits and EEG changes in stroke patients. In the present study, stroke patients were receiving general neurological treatment at the hospital, but many of them had difficulties due to their long stay in the hospital, so the researcher conducted a study to increase their participation in exercise as a means of motivation. In the interviews

of the participants, most of them had experienced sports activities at school in the past, and they seemed to be motivated to exercise by reminiscing about the past.

Limitations of this study include the fact that the EEG results were obtained by combining physical therapy and table tennis exercise in a single group of stroke patients. Although this study did not provide evidence that the changes in EEG could be attributed to table tennis exercise alone, previous studies have shown that table tennis exercise can help restore brain function in stroke patients, and this study confirmed that it can be used in combination with physical therapy. The changes in brain waves identified in this study can be interpreted as indicative of recovery of brain function in stroke patients. Consequently, this study confirms that the combination of physical therapy and table tennis exercise in stroke patients can help restore brain function, which is consistent with previous studies.

The advantage of a before-and-after comparison study of a single group is that it is a temporally separated before-and-after study within a single group, so that the differences between the before-and-after groups can be identified to determine the causal relationship between cause and effect. This is one of the most powerful ways to identify causal relationships and is an alternative method when a control group is not available [39]. For these reasons, the before-and-after design of a single-group comparison study is necessary. However, while there were changes in the outcomes of the study, the lack of a comparison group makes it impossible to say whether the changes were natural over time or due to table tennis. Therefore, future studies should include a control group. In conclusion, this study confirmed that playing table tennis in a seated position changed EEG in stroke patients. Future studies should be conducted with different methods.

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