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Investigation of the relationship between motor imagery ability and dual-task ability in chronic stroke patients

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ABSTRACT

Objective: Motor imagery ability increases motor performance by increasing neural activity and stimulating brain plasticity. The dual-task can be an indicator of the transfer of motor performance. This study investigated the relationship between imagery ability and dual-task ability in chronic stroke patients.

Patients and Methods: The Motor Imagery Questionnaire-Revised Second Edition was used to assess imagery ability. The Timed Up and Go test was determined as the main task, and a dual-task test was performed by adding a cognitive and motor task. Mental chronometry recorded single – and dual-task performances as actual and imagined. Dual-task cost and delta scores were calculated for motor-motor and cognitive-motor separately.

Results: There was a moderate correlation between motor imagery ability and motor dual-task performance ($p<0.05$). No correlation was found between cognitive dual-task performance and motor imagery ability ($p>0.05$). The individuals' motor-motor tasks had low performance in the actual and imagined tasks but not in the cognitive-motor tasks ($p>0.05$).

Conclusion: As mental practice increases, patients' motor-motor dual-task abilities also increase. Mental practice can be recommended from the early stages of stroke patients to increase motor imagery ability and motor skills. Cognitive-motor dual-task and motor imagery ability are unrelated because of abundant repetition of the cognitive-motor dual task in the nature of daily living activities.

Keywords: Stroke, Motor imagery, Dual task, Mental practice, Stroke rehabilitation

1. INTRODUCTION

Stroke is the second leading cause of death and high disability worldwide. Motor and functional capacities decrease after stroke [1]. Problems such as upper and lower extremity motor weakness, dystonia, decreased ability, mental or cognitive problems, difficulty in distinguishing between right and left, and impaired body image are chronic consequences that reduce functionality [1]. The main goal of rehabilitation is to provide motor learning-based improvement by taking these problems into consideration in rehabilitation programs.

Motor imagery training and imagery ability, which are some of the current treatment approaches, are becoming increasingly popular. In motor imagery training, patients are asked to think about the desired movement and they are also asked to imagine the movement. Thus, an increase in the activity of the brain regions associated with the imagined movement is observed [2]. Motor imagery provides neural plasticity by reorganizing the structure, function, and neural connections associated with the imagined movement. Unlike the limited laboratory environment where rehabilitation takes place, motor imagery is unlimited because it is in the mind of the participant. The participant can perform the movement in the desired environment, accompanied by the sounds they want, and by focusing on the activity they want. This contributes to the enriched environment and transfer ability of motor learning [3]. For the participant to be able to visualize, their cognitive functions must be sufficient and at a level to ensure compliance with the physiotherapist.

It is not enough to achieve success only for motor functions in order for rehabilitation to be successful in individuals with stroke. This function should become usable in daily life. In daily life activities, a different task is added to most motor activities. Activities such as talking while walking and calculating while shopping are together. Therefore, the goal of rehabilitation is

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not only to correct the gait of an individual with a stroke but also to talk or calculate while walking [4]. These activities performed together are called dual tasks. Cognitive status is also very important in performing the dual task. There may be a relationship between cognitive-based motor imagery and dual-task ability. As a dual task, the participants can be given a cognitive or motor task. Calculating and counting along with walking is considered a cognitive task while carrying a water bottle or carrying a glass is known as a motor task.

There are many studies in which motor imagery training or dual-task training was applied to improve balance and gait in individuals with stroke [1,5,6]. Interventional studies have investigated the effects of motor imagery training and dual-task training separately; moreover, noninterventional studies have investigated the motor imagery abilities of individuals with stroke [7-9]. Only one study compared the effectiveness of both types of training. Both of them were shown to be effective in improving balance and gait [10]. To date, motor imagery and dual task ability have not been investigated together in patients with chronic stroke. Motor imagery ability increases motor performance by increasing neural activity and stimulating brain plasticity; therefore, imagery ability was considered as a component that affects motor performance in this study. The dual task was accepted as an indicator of the transfer of motor gains obtained through rehabilitation in daily living activities. Based on the transfer of abilities, which is one of the basic principles of motor learning, to different environments, we believe that there may be a relationship between these two abilities based on motor performance. In the literature, no study which examined the relationship between motor imagery ability and dual-task ability in individuals with stroke was found. Therefore, the aim of this study was to investigate the relationship between motor imagery ability and dual-task ability in chronic stroke patients.

2. PATIENTS and METHODS

The study was planned as a cross-sectional study. Ethical approval was obtained from the ethical committee of Gaziantep Islam Science and Technology University (date: 30/05/2023, ethics committee decision number: 243.25.20). The participants were informed about the purpose and content of the study. The study was conducted following the Declaration of Helsinki. Informed consent forms were obtained from all participants included in the study.

The inclusion criteria were (a) being at the ages of 25-75, (b) at least 6 months having passed since the stroke, (c) having walking ability without support of approximately 10 meters, (d) having proper cooperation (participants with a Mini-Mental State Examination score of >24), and (e) absence of any other neurological diseases. The exclusion criteria were (a) having aphasia, (b) having hearing and vision problems (c) having an orthopedic disease that prevents walking, and (d) having psychological or cognitive disorders. The flowchart diagram is presented in Figure 1.

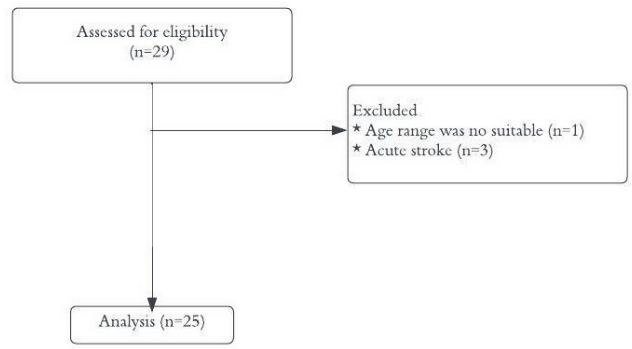

Figure 1. *Flow-chart diagram*

Demographic information (gender, age, education level), affected side, and duration of the stroke were recorded. The Motor Imagery Questionnaire – Revised Second Edition (MIQ-RS) was used to assess imagery ability. The main test used to assess imagery ability and dual-task ability was the Timed Up and Go (TUG) test. In the dual-task ability, a cognitive task was added simultaneously to the TUG test, and the performance time was recorded as dual-task cognitive test performance. In the dual-task motor evaluation, a motor task was added simultaneously to the TUG test and the time was recorded. A 5-minute break was given between dual-task performances to avoid fatigue.

For the motor imagery ability, the individuals were asked to imagine that they were performing the TUG test, and the time was recorded as the mental chronometry. Individuals were asked to imagine the dual-task motor and cognitive tests, and their mental chronometries were recorded. In other words, real times were recorded by performing dual-task tests in the real environment, and the durations of tests that were not performed in the real environment were measured with mental chronometry by imagining that they were doing the same tests without any active movements. Then, the recorded times were calculated according to the dual-task ability effect calculation formula and correlated with the motor imagery ability. After the respective test moves were actually applied, the individuals imagined each test (eyes were kept closed during imagery).

Timed Up and Go (TUG) Test : The test shows the independence and security of an individual's life as it includes most activities in daily life The patient is asked to get up from the chair he is sitting in, walk 3 meters, come back, and sit on the chair again. Individuals performed the test once at the normal pace of their choice, and the performance time was recorded. It is easy to perform and is a reliable test [11]. The prolongation of the test duration indicates a deterioration in individuals' performance.

Movement Imagery Questionnaire-Revised Second Edition (MIQ-RS): This is an adaptation of the Movement Imagery Questionnaire. It consists of 14 items, seven of which are visual and 7 of which are kinesthetic imagery abilities. Before starting the evaluation, the participants were provided with the necessary information about the questionnaire. Scoring was made between 1 and 7, with 1 point: very difficult to see/feel, 7 points: very easy to see/feel. The higher the score, the better the imagery ability. The questionnaire is valid and reliable in individuals with stroke [12]. The Turkish validity and reliability study of the questionnaire was conducted [13].

***Dual Task Assessment**:* For the motor dual-task, individuals were asked to perform the TUG test while holding a glass of water as an additional motor task, and the time was recorded.

The individuals were asked to count by two as an additional cognitive task and the time was recorded. The formula used to calculate the dual-task cost is as follows (Dual-task–Single-task time/Single Task) x 100 [14]. The higher the cost is, the lower the dual-task ability.

***Mental Chronometry Assessment**:* It was used in the evaluation of motor imagery ability. After the TUG test was performed actively, the individual was asked to imagine the same test, and the time was recorded in seconds with a stopwatch. During the assessment, it was said to the participants that they should imagine the same test in their minds with their eyes closed and without revealing any active movements [15]. Single-task TUG test, cognitive dual-task TUG test, and motor dual-task TUG test imagery were requested from individuals, and their mental chronometries were recorded separately for each test.

Actual and imagined movement times were compared by calculating the delta time with mental chronometry ((real movements'-imagined movements' times)/[(real movements'+imagined movements times)/2]x100) [16]. The higher the delta time, the lower the motor imagery ability. Delta times were calculated separately for single-task TUG test, cognitive dual-task TUG test, and motor dual-task TUG test.

Statistical analysis

The G*Power application was used for power analysis. A significance level of 5% and a power (1-b) of 90% were assumed, and a medium effect size (d=0.584) in the population was assumed. The sample size was calculated to be 23 individuals according to the relationship between cognition and dual tasks [17].

The Statistical Package for the Social Sciences version 22.0 software was used for statistical analysis. The frequencies (%) and mean±standard deviation (X ± SD) of the study variables are presented. The normality of distribution was tested with the Kolmogorov-Smirnov test. Paired Samples t test was used to compare the cognitive and motor additional tasks in dual-task costs and delta times of the individuals. Pearson correlation was used to investigate the relationship among imagery ability, dual-task cost, and delta time. The statistical significance level was set at $p < 0.05$.

3. RESULTS

The sociodemographic characteristics of the individuals included in the study are presented in Table I. In the sample, there was no difference between the number of right and left hemiplegia cases. The sample consisted of individuals with ischemic stroke. The education level of the individuals was high school or higher. Only one individual was a primary school graduate.

***Table I.** The Sociodemographic characteristics of the participants*

Variables	Participants (n=25)
Gender (n)	
Female	14
Male	11
Age (years)	42.88±15.11
Affected Side	
Right	13
Left	12
Time passed after the stroke (years)	8.36±4.36

The MIQ mean score of all individuals was 51.92±6.67. The delta score of the single-task TUG test recorded with mental chronometry was 19.07±13.35. The delta times and dual-task cost scores of the individuals are presented in Table II. When the cognitive and motor additional tasks in the imagined performances of the individuals were compared, the results were similar (p=0.923) (Table II). In actual dual-task performances, motor additional task performances were worse than cognitive performances (p=0.000) (Table II).

***Table II.** Comparison of the individuals' delta times and dual-task cost*

Variables	X±SD	t	P
Delta Cognitive TUG (score)	19.32±11.96	0.098	0.923
Delta Motor TUG (score)	19.00±10.86		
Cost Cognitive TUG (score)	15.45±7.48	6.109	0.000*
Cost Motor TUG (score)	38.60±22.21		

**p<0.05 is statistically significant, TUG: Timed Up and Go test*

There was no statistically significant relationship between the real dual-task performance with cognitive additional task and the parameters of motor imagery ability (MIQ-RS, Delta TUG, Delta Cognitive TUG, and Delta Motor TUG) (p=0.851, p=0.324, p=0.767, p=0.269, respectively) (Table III). There was a moderate correlation between the real dual-task performance with a motor additional task and the MIQ-RS, and Delta motor TUG (r=-0.409, p=0.042; r=0.466, p=0.019, respectively) (Table III). However, motor dual-task cost in real performance and delta TUG, delta Cognitive TUG were unrelated (p=0.413, p=0.762, respectively).

***Table III.** The correlations between motor imagery, dual-task cost, and delta time*

	MIQ-RS	Delta TUG	Delta Cognitive TUG	Delta Motor TUG
Cost Cognitive TUG	r=0.040 p=0.851	r=0.206 p=0.324	r=0.062 p=0.767	r=0.230 p=0.269
Cost Motor TUG	r=-0.409 p=0.042*	r=0.171 p=0.413	r=0.064 p=0.762	r=0.466 p=0.019*

**p<0.05 is statistically significant, MIQ: Movement Imagery Questionnaire-Revised Second Edition, TUG: Timed Up and Go test.*

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4. DISCUSSION

The aim of this study was to investigate the relationship between motor imagery ability and dual-task ability in chronic stroke patients. In our study, it was observed that there is a relationship between motor imagery ability and motor dual-task performance. No correlation was found between cognitive dual-task performance and mental imagery ability. While there was no difference between the imagined cognitive and motor performances of individuals, actual motor dual-task performance was also worse than cognitive dual-task performance. The individuals' motor-motor tasks had low-performance values in actual and imagined assessments, unlike cognitive-motor tasks. This can be explained that due to the nature inherent in daily life, the cognitive-motor dual tasks are repeated frequently during the day, and they are constantly repeated with actions such as talking while walking. Thus, individuals did not have difficulty in cognitive-motor dual-task performance.

Motor imagery ability is related to actual motor performance [10]. The brain regions that are responsible for the actual movement are activated by using motor imagery in the motor preparation phase of the movements. Even observation of a simple passive movement without revealing the movement stimulates the relevant motor cortex regions, increasing neural activation [18]. In addition, motor imagery plays an intrinsic role in recovery after brain damage, so it supports brain plasticity and increases motor performance. In other words, there is a bidirectional relationship between motor performance and motor imagery. Motor imagery is motor performance-based, and it increases brain plasticity as imagined; in other words, it improves actual motor performance. Therefore, in the present study, it is thought that as the deficit in the motor-motor dual-task ability increases, the imagery ability decreases. In other words, increasing the mental practice ability in these two parameters based on motor performance increases the motor-motor dual-task ability. We believe that it is important to develop practical ability for the success of rehabilitation by aiming at the transfer of ability, which is one of the basic principles of motor learning. In addition, considering the physical disability of patients with stroke, it is very important in terms of rehabilitation to increase dual-task ability through mental practice without any movements. The existence of motor ability obtained by motor imagery ability in the acute period also supports this view [19].

Many studies have investigated the effects of motor-motor and cognitive-motor dual tasks on walking function in stroke [20,21]. Yang et al., emphasized that cognitive-motor dual tasks improved cortex activation, facilitated the remodeling of brain function, and improved motor function [21]. Motor-motor dual tasks such as walking while tapping or kicking a ball stimulate postural control and motor training. However, cognitive-motor dual tasks improve both cognition and motor function. Five main cognitive tasks that are frequently used in the literature can be listed as differentiation and decision-making tasks, information tracking tasks, reaction time tasks, verbal fluency tasks, and working memory tasks [22]. In our study, the task of counting in pairs was used. The cognitive tasks added to the motor task in stroke patients were investigated by Elwish et al., and it was stated that the subtraction task was more difficult than the phonologic fluency [23]. Cognitive-motor dual-task performance is used more in actual life and is more adapted to the external environment. Since, the participants are more familiar with cognitive-motor tasks in daily life, we think that there is no significant relationship between cognitive-motor cost and our parameters.

When performing dual tasks, individuals use both motor and attention resources at the same time. Resources are divided into motor ability and cognition according to priority. The act of walking is automatic, but it frequently involves cognitive activity and necessitates the use of extra cognitive resources, such as language, attention, and judgment abilities [24]. Both motor task and cognitive task performance levels decreased during walking in stroke patients. Memory performance is lower, gait speed is slower, and stride length is smaller [21]. Adding a motor task to a motor task becomes more difficult due to the greater use of the same resources, while adding a cognitive task requires different resources. This implies that the more challenging the motor task is, the more likely there will be interference with the cognitive task, and it also shows how much cognitive processing resource is needed for the task of walking in stroke patients [25]. The deficit in the engine-motor dual-task cost can also be explained by using the same resources. In addition, the correlation of this performance with delta time can be explained by individuals transferring their physical disability into the imagined environment. In addition verbal cues such as "imagine being able to do the test" are not used to warn the subjects during the tests.

When our findings are interpreted together with the literature, motor imagery ability is related to motor-motor dual-task cost but not cognitive-motor dual-task cost. Cognitive-motor dual-tasks are more practical in daily life. The lack of a significant relationship in this task can be explained by the fact that individuals with stroke are more accustomed to the task. In addition, the lower performances of individuals in the actual and imagined environment of the motor-motor dual task may be related to the simultaneous use of the same resource. In the literature, the relationship between motor imagery and dual-task ability was not investigated; therefore, the present study is unique in this aspect.

This study needs to account for the following limitations. First, it did not use a scale that evaluated cognitive and cognition statuses. Second, the task used in cognitive-motor tests was of one type. Because calculation and alphabetic tasks activate different parts of the brain, their results may differ. Therefore, our results for the cognitive-motor dual task were limited to calculations. Speech and perception are differently affected in individuals with right and left hemiplegia. This will affect both dual-task and motor imagery abilities. Moreover, the level of education of individuals may also influence these abilities. Our study's limitations included the fact that these characteristics were not considered. In contrast, our study did not investigate how the difference between the motor imagery motor-cognitive dual task and the real task affected healthy controls. Including a control group would have been more informative. The

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diversification of cognitive tasks in future studies will contribute to a more detailed examination of the relationship. There is a need for follow-up studies comparing motor imagery ability in the acute phase with dual-task abilities in the chronic phase of stroke patients.

In this study, we investigated the relationships between motor imagery and dual-task ability in chronic stroke patients. It was found that motor imagery ability and motor-motor dual-task ability were related to each other. As mental practice increases the quality of motor performance, the success of rehabilitation, and the patients' motor-motor dual-task abilities also increase. Increasing the dual-task ability facilitates the daily life activities of the patients, which is the main goal of rehabilitation. Therefore, it is important to develop motor imagery abilities to increase the rehabilitation success of patients. We think that the mental practices of stroke patients with physical disability should be increased, starting from the period when they are immobilized. The reason why individuals' cognitive-motor dual-task and motor imagery abilities are unrelated might be explained by the abundant repetition of the cognitive-motor dual-task in the nature of daily living activities.

Compliance with Ethical Standards

Ethical approval: This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by Gaziantep Islam Science and Technology University Gaziantep, Turkiye, (date: 30/05/2023, approval number: 243.25.20). Informed consent forms were obtained from all participants.

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Author contributions: TM: Writing – review and editing, Writing original draft, Supervision, Formal analysis, TM and DGK: Methodology, Investigation, Conceptualization. TB and EB: Data curation and investigation. All authors approved the final manuscript.

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