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**Original Research**

# The Relationship between Self-Regulated Learning (SRL) and Cognitive Function with The Performance of qEEG Examination in First Year Medical Students

Suzy Yusna Dewi[1,5], Audrey Alvura Digna[2], Feda Anisah Makkiyah[3], Taufiq Fredrik Pasiak[4], Ruziana Masiran[6]

[1]Department of Psychiatry, Faculty of Medicine, Pembangunan Nasional "Veteran" Jakarta University, Jakarta, Indonesia
[2]Faculty of Medicine, Pembangunan Nasional "Veteran" Jakarta University, Jakarta, Indonesia
[3]Department of Neurosurgeon, Faculty of Medicine, Pembangunan Nasional "Veteran" Jakarta University, Jakarta, Indonesia
[4]Department of Anatomy, Histology, and Neuroscience, Faculty of Medicine, Pembangunan Nasional "Veteran" Jakarta University, Jakarta, Indonesia
[5]Department of Child and Adolescent Psychiatry, dr. Soeharto Heerdjan Mental Hospital Jakarta, Jakarta, Indonesia
[6]Department of Psychiatry, Faculty of Medicine and Health Sciences, Putra Malaysia University, Malaysia

## Abstracts

**Introductions:** Medical students are required to continue to develop their knowledge. Therefore, it is important for them to have self-regulated learning skills that involve cognitive function processes. Electroencephalography is a neuroscience tool that can be used to record brain wave activity related to a person's cognitive function. This study was conducted to see the relationship between self-regulated learning and cognitive function with quantitative electroencephalogram (qEEG) parameters. **Methods:** This study used an observational analytic approach to assess self-regulated learning and cognitive function using the MSLQ and MoCA-INA questionnaires. qEEG recording to see brain wave activity was done when the eyes were open and closed and seen in alpha and beta waves. The sample of this study amounted to 32 respondents who were willing to carry out each research procedure. The Kruskal-Wallis correlation test was used to see the relationship between variables. **Results:** The study findings reveal a significant correlation between SRL and qEEG parameters. In the open-eye condition, such a correlation exists in the frontal and central regions with regard to alpha waves (P = 0.046 and P = 0.047). In contrast, in the closed-eye condition, it exists in the occipital, central, and parietal regions with alpha waves (P = 0.005, P = 0.021, and P = 0.049) and the central region with beta waves (P = 0.030). There is a significant correlation between cognitive function and qEEG parameters observed in both open and closed-eye conditions within the frontal region beta waves (P = 0.024, P = 0.044, and P = 0.021). **Conclusions:** There is a relationship between SRL and cognitive function with alpha and beta wave activity on qEEG recording.

**Keywords:** Self-regulated Learning, Cognitive Function, Alpha and Beta Wave, Quantitative Electroencephalography (qEEG)

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Correspondence Author:
Email: suzyyusnadewi@upnvj.ac.id

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**Introductions**

Healthcare professionals have two jobs: to perform their tasks and improve them [1]. Due to the constant evolution of medical knowledge, medical students need to develop lifelong learning skills [2]. They are expected to surpass the achievements of current doctors each year. The ideal image of a doctor is not easy to attain. In accordance with the persistent developments within the medical sector, it is vital that a potential doctor possess the skills to accumulate, broaden, and scrutinize current knowledge [3]. Therefore, medical students must possess the capability for self-regulated learning.

Self-regulated learning refers to an individual's capacity to regulate themselves throughout the learning process. The foundational conceptual framework to comprehend the cognitive, motivational, and emotional facets of learning is termed self-regulated learning, and it has substantially impacted educational psychology [4]. A study led by Kuznetsov et al. (2021) found that medical students experienced notable enhancements in executive function, attention, concentration, and memory functions throughout their learning process in medical educational institutions. These cognitive processes are critically important in the learning process [5]. Additionally, Shi Y et al. reported from their study that strong cognitive abilities have a positive impact on academic achievement [6].

The use of electroencephalography (EEG) is becoming increasingly widespread in the neuroscience field. EEG devices, which can measure brain electrical activity, were initially used in research related to brain disorders. However, due to its non-invasive nature and the growing need for accurate psychological measurements, EEG is also being used in research related to broader cognitive functions [7].

Self-regulated learning (SRL) in a clinical setting is a complex process that arises from the interaction between individuals and their environment [8]. Cognitive function refers to an individual's mental processes that involve knowledge, information processing, and reasoning. Perception, memory, learning, attention, decision-making, and language abilities are examples of cognitive processes [9]. From an experimental standpoint, changes in a person's behavior need to be inferred to determine cognitive phenomena, which are important internal psychological processes [10]. Quantitative electroencephalography (qEEG) provides quantitative information about brain activity that is relevant to anatomical and functional integrity, developmental maturation, mediation of sensory, perceptual, and cognitive processes, as well as the clinical manifestations of mental disorders. The qEEG phenotypes that are created are multidimensional and cross-diagnostic. They are placed on a functional continuum between health and disease within the major domains of function [11].

Considering the challenges encountered by medical students, it is imperative to conduct research that investigates the self-regulated learning (SRL) abilities and cognitive capacities of first-semester medical students in order to equip them with the necessary skills and knowledge to navigate their journey through medical education successfully. This study will investigate the relationship between SRL and cognitive function with the results of quantitative electroencephalography (qEEG) examinations. The aim of this study is to understand the outcomes of quantitative electroencephalography testing in first-semester medical students in relation to SRL and cognitive function.

**Methods**

This research has been conducted with a group of first-year medical students. The data collection process took place from February 2023 to March 2023, with a sample size of 32 participants determined using the minimum sample size formula for hypothesis testing [12]. Inclusion criteria included first-semester students, and also respondents who were willing to participate in all examination procedures. Exclusion criteria included respondents who were absent during data collection, those who have experienced head trauma in the past 12 months, and qEEG test results with significant artifacts. The study evaluated SRL and cognitive function as independent variables using the Motivated Strategies for Learning Questionnaire (MSLQ) and Montreal Cognitive Assessment-Indonesian (MoCA-INA) scores, respectively. Technical abbreviations were explained when first introduced. The MSLQ, which assesses college students' motivational orientation and learning strategies (Cronbach's alpha 0.871), was chosen due to its comprehensive cognitive perspective. The MoCA-INA, a highly sensitive quick screening instrument for assessing cognitive function that was validated using WHO's concept by Neurona in 2010, was used. Adapted from the original MoCA instrument developed in Canada, MoCA-INA was tailored for Indonesia, considering cultural nuances and linguistic context, as an independent variable categorized based on scores. SRL is categorized into three levels: low, moderate, and high. There were two categories of cognitive function: normal cognition and cognitive impairment. The Kruskal-Wallis correlation test was used to assess the correlation between the independent and dependent variables, utilizing IBM SPSS Statistics version 25 software. The data were analyzed using Neuro-Spectrum software from Neuroguide.

The ethical approval for this research was obtained from the Research Ethics Committee of Health, UPN Veteran Jakarta, with reference number 36/II/2023/KEPK.

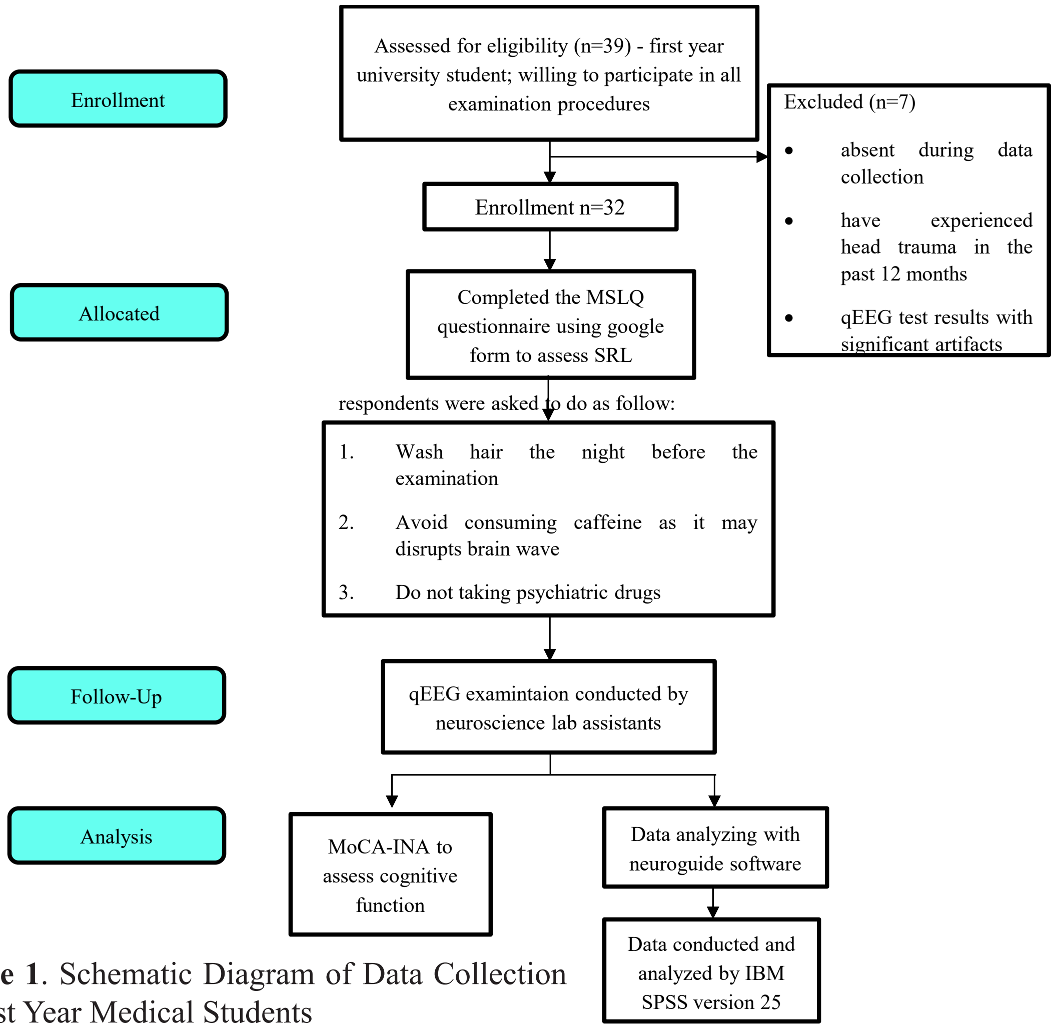


**Figure 1**. Schematic Diagram of Data Collection in First Year Medical Students

**Results**

A one-variable analysis was done to see how the variables being studied, like respondent characteristics, SRL, MoCA-INA, and qEEG parameters, were spread out. The response rate obtained was 100%. The number of respondents required was in line with the target. There were no unanswered questions or statements from the respondents.

**Distribution of Respondents**

The majority of the participants were female (71.8%) with aged 18 (59.3%). The average score for self-regulated learning (SRL) was 182.68, with a range between 149 and 215. Female students had a higher SRL score on average (187.35) than male students (170.78). SRL scores varied among different age groups, with 19-year-old students having slightly higher scores (182.27) than 18-year-old students (181.21).

The majority of students were classified in the moderate SRL category, with a significant effect of gender observed on SRL scores (p=0.005) as depicted in **Table 1**.

Table 1. Distribution of Respondents by SRL and Cognitive Function in First Year Medical Students

| **Category** | | **Self-Regulated Learning** | | | **Total** | **P value** | **Cognitive Function** | | **Total** | **P value** |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | Moderate | High | | | Cognitive Impairment | Normal Cognitive | | |
| **Gender** | Female | 3<br>9.3% | 14<br>43.7% | 6<br>18.7% | 23<br>71.8% | 0.005[a] | 5<br>15.6% | 18<br>56.2% | 23<br>71.8% | 0.796[a] |
| | Male | 2<br>6.2% | 7<br>21.8% | 0<br>0.0% | 9<br>28.1% | | 2<br>6.2% | 7<br>21.8% | 9<br>28.1% | |
| **Age** | 17 | 0<br>0.0% | 0<br>0.0% | 1<br>3.1% | 1<br>3.1% | 0.418[a] | 0<br>0.0% | 1<br>3.1% | 1<br>3.1% | 0.900[a] |
| | 18 | 4<br>12.5% | 12<br>37.5% | 3<br>9.3% | 19<br>59.3% | | 5<br>15.6% | 14<br>43.7% | 19<br>59.3% | |
| | 19 | 1<br>3.1% | 8<br>25.0% | 2<br>6.2% | 11<br>34.3% | | 2<br>6.2% | 9<br>28.1% | 11<br>34.3% | |
| | 20 | 0<br>0.0% | 1<br>3.1% | 0<br>0.0% | 1<br>3.1% | | 0<br>0.0% | 1<br>3.1% | 1<br>3.1% | |

a. Kruskal-wallis

Distribution of qEEG Parameters

This study examined qEEG parameters, specifically the absolute power of alpha and beta wave bands, in various brain regions in both eyes-open and eyes-closed conditions. Females displayed significantly higher average alpha wave band parameters (216.98 mvl) than males (171.83 mvl) in the eyes-open condition. Females also exhibited higher average beta wave band parameters (190.04 mvl) than males (162.86 mvl). The highest beta wave band value was documented among females at 404.06 mvl, and the lowest value was seen in males at 77.2 mvl. The alpha wave band value showed the highest rate among females at 724.81 mvl, while the lowest value was recorded among males at 44.65 mvl. Additionally, the participant who was 18 years of age demonstrated the highest alpha wave band value at 724.81 mvl, whereas the 19-year-old participant revealed the lowest value at 44.65 mvl. For the beta wave band, the 18-year-old participant recorded the lowest value of 77.2 mvl, whereas the 19-year-old participant recorded the highest value of 404.06 mvl.

In the closed-eye condition, females indicated higher average alpha wave band parameters (259.16 mvl) compared to males (209.52 mvl). The highest alpha wave band value (748.91 mvl) was observed in females, while the lowest (101.61 mvl) was found in males. Females also indicated higher average beta wave band parameters (163.09 mvl) compared to males (152.33 mvl). Within the beta wave band, males had both the lowest (75.81 mvl) and the highest (390.09 mvl) values. The 18-year-old participant had the highest alpha wave band value (748.91 mvl), while the 19-year-old participant had the lowest (101.61 mvl). Similarly, the 18-year-old participant showed the highest beta wave band value (390.09 mvl), while the 19-year-old participant had the lowest (75.81 mvl). These findings contributed to understanding brain activity under different conditions. **(Table 2).**

Table 2. Distribution of qEEG Parameters in First Year Medical Students

| **Category** | | **qEEG Parameter Alpha (open eye)** | | | **Total** | **qEEG Parameter Beta (open eye)** | | | **Total** |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean (mvl) | Min (mvl) | Max (mvl) | | Mean (mvl) | Min (mvl) | Max (mvl) | |
| **Gender** | Female | 216.98 | 83.65 | 724.81 | 23 | 190.04 | 112.5 | 404.06 | 23 |
| | Male | 171.83 | 44.65 | 270.17 | 9 | 162.86 | 77.2 | 310.76 | 9 |
| **Age** | 17 | 123.88 | 123.88 | 123.88 | 1 | 191.79 | 191.79 | 191.79 | 1 |
| | 18 | 220.28 | 60.32 | 724.81 | 19 | 186.39 | 77.2 | 310.76 | 19 |
| | 19 | 163.11 | 44.65 | 236.12 | 11 | 171.56 | 86.87 | 404.06 | 11 |
| | 20 | 106.4 | 106.4 | 106.4 | 1 | 226.41 | 226.41 | 226.41 | 1 |
| **Category** | | **qEEG Parameter Alpha (close eye)** | | | **Total** | **qEEG Parameter Beta (close eye)** | | | **Total** |
| | | Mean (mvl) | Min (mvl) | Max (mvl) | | Mean (mvl) | Min (mvl) | Max (mvl) | |
| **Gender** | Female | 259.16 | 117.87 | 748.91 | 23 | 163.09 | 103.24 | 316.82 | 23 |
| | Male | 209.52 | 101.61 | 486.62 | 9 | 152.33 | 75.81 | 390.09 | 9 |
| **Age** | 17 | 161.83 | 161.83 | 161.83 | 1 | 160.33 | 160.33 | 160.33 | 1 |
| | 18 | 287.01 | 108.97 | 748.91 | 19 | 164.10 | 103.24 | 390.09 | 19 |
| | 19 | 150.32 | 101.61 | 259.93 | 11 | 146.47 | 75.81 | 316.82 | 11 |
| | 20 | 168.14 | 168.14 | 168.14 | 1 | 158.83 | 158.83 | 158.83 | 1 |

## Correlation Test Result

There was a significant relationship between SRL and the Fz and Cz channels in the alpha wave band during the eyes-open condition. These channels showed low positive correlations (coefficients of 0.356 and 0.354, respectively) with SRL. However, there were no significant correlations found in other alpha wave channels, and there were no beta wave channels associated with SRL. The research findings indicated a significant relationship between SRL and specific qEEG channel parameters during the eyes-closed condition. In the alpha wave band, significant correlations were found in the O2, Cz, and Pz channels. The Cz channel also showed a significant correlation in the beta wave band. However, no significant correlations were observed in other channels in both frequency bands (Table 3).

There was a significant correlation between MoCA-INA and the F3 channel in the beta wave band when the respondents' eyes were open ($p = 0.024$, $r = 0.399$, positive correlation). No significant correlations were found in other channels within the beta wave band or in any channels within the alpha wave band, indicating a lack of relationship between Running Title MoCA-INA and those variables. A significant correlation was found between MoCA-INA and two channels in the beta wave band when the respondents' eyes are closed: F4 and Fz (p = 0.044 and

0.021, respectively). These correlations had low magnitude and were positively oriented, with correlation coefficients of 0.358 and 0.406, respectively. No significant correlations were found in other channels within the beta wave band or in any channels within the alpha wave band, indicating a lack of relationship between MoCA-INA and those variables **(Table 3)**.

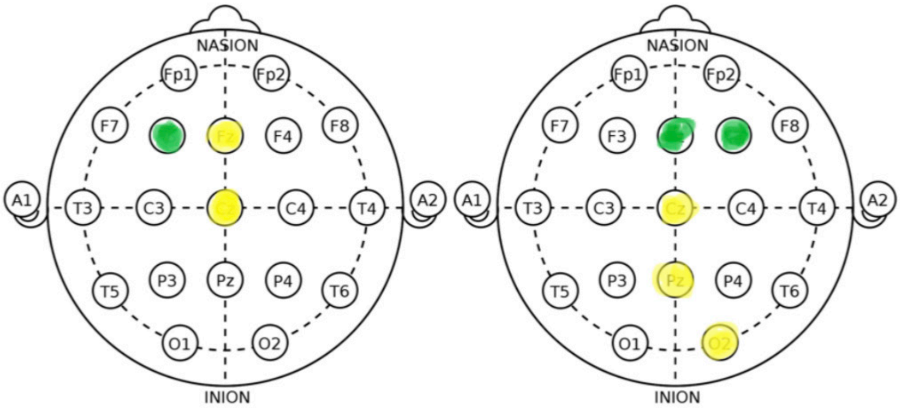


**Figure 2**. EEG Electrodes Placement in First Year Medical Students

*Yellow scribble represents the specific brain region that exhibits a correlation with the self-regulated learning.
*Green scribble represents the specific brain region that exhibits a correlation with the cognitive function

**Table 3**. Bivariate Analysis Results in First Year Medical Students

| Independent variable | Dependent variable | P Value | Correlation Coefficient |
|---|---|---|---|
| **SRL (open eye)** | **Alpha** | | |
| | Fz | 0.046 | 0.356 |
| | Cz | 0.047 | 0.354 |
| **SRL (close eye)** | **Alpha** | | |
| | O2 | 0.005 | 0.480 |
| | CZ | 0.021 | 0.407 |
| | PZ | 0.049 | 0.351 |
| | **Beta** | | |
| | CZ | 0.030 | 0.384 |
| **MoCA-INA (open eye)** | **Beta** | | |
| | F3 | 0.024 | 0.399 |
| **MoCA-INA (close eye)** | **Beta** | | |
| | F4 | 0.044 | 0.358 |
| | FZ | 0.021 | 0.406 |

**Discussions**

Medical students are required to continue to develop their knowledge. Therefore, it is important for them to have self-regulated learning skills that involve cognitive function processes. Electroencephalography is a neuroscience tool that can be used to record brain wave activity related to a person's cognitive function. This study was conducted to see the relationship between self-regulated learning and cognitive function with quantitative electroencephalogram (qEEG) parameters.

Brain development is crucial for cognitive control. During pre-adolescence, individuals rapidly enhance their ability to avoid repetitive responses and apply cognitive control. The anterior cortex plays a significant role in cognitive performance variability. Its characteristics are associated with impulsivity, attention, and executive function impairments in neurodevelopmental disorders, indicating that neural foundations are involved in self-control from normal to pathological states [13].

**Nearest Brodmann area to the electrodes**
Fz : BA6
Cz: BA4
F3 : BA9
F4: BA9
Pz : BA7
O2 : BA18

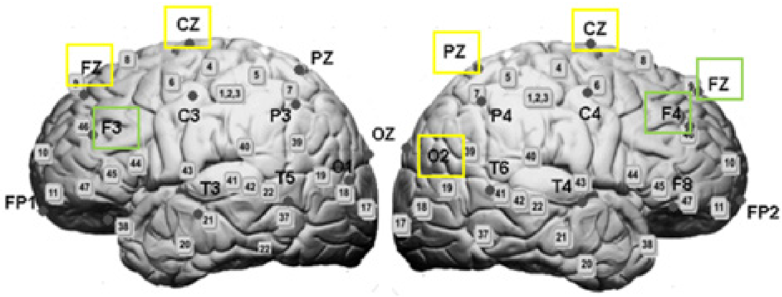


**Figure 3.** Brodmann areas and EEG electrodes in First Year Medical Students [14, 15]

**Self-regulated Learning and qEEG**

This research shows that the frontal lobe, near Brodmann area 6 (Figure 3), correlates with self-regulated learning. This finding is in line with a study conducted in 2012 by Collins and Koechlin that stated the frontal lobe plays a crucial role in integrating logical thinking, learning, and creativity to regulate executive functions and decision-making. It is responsible for generating and managing adaptive behavior strategies to facilitate actions in environments characterized by uncertainty, change, and openness [16].

This research also shows that the parietal lobe, near Brodmann area 7 (Figure 3), correlates with self-regulated learning. The parietal lobe activity for linguistic processing, or limited modal mnemonic, is primarily localized in the left angular gyrus (AG). This posterior region is not spatially significant compared to those involved in writing execution, but it is an area frequently observed in functional imaging studies of language [17].

While the frontal lobe is considered more crucial for self-regulation, the parietal lobe can contribute to specific aspects of self-control and learning. It is important to note that the brain is a complex organ, and multiple regions work together to support various cognitive functions. The frontal and parietal lobes likely interact with each other and with other brain regions to facilitate the processes of self-regulation and learning.
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crucial for self-regulation, the parietal lobe can contribute to specific aspects of self-control and learning. It is important to note that the brain is a complex organ, and multiple regions work together to support various cognitive functions. The frontal and parietal lobes likely interact with each other and with other brain regions to facilitate the processes of self-regulation and learning.

This research also shows that the occipital lobe, near Brodmann area 18 (Figure 3), correlates with self-regulated learning. The occipital lobe is the visual processing area in the brain. It is associated with visuospatial processing, depth perception, color determination, object and face recognition, as well as memory formation. While the occipital lobe is not directly involved in self-regulation and learning processes, it provides crucial visual information that contributes to various cognitive functions. The integration of visual information with other brain regions, including the frontal lobe involved in self-regulation, is necessary for effective learning and cognitive control [18]. While this research found that the central region closest to Brodmann Area 4 (Figure 3) correlates with SRL, This region, often referred to as the primary motor cortex, is highly important in initiating motor movements and coordinating them. It is not directly related to self-regulation and learning. The cortex is primarily involved in the execution of movements and sends direct projections to the spinal cord. However, self-regulation and learning involve networks from various brain regions, including the prefrontal co The findings in this study are consistent with these theories, as they reveal a significant relationship between alpha rhythm and SRL, especially in the frontal lobe. On the other hand, the connections found between SRL and other brain regions, such as the parietal and occipital lobes, require further research. rtex, which interacts with the primary motor cortex [19].

The findings in this study are consistent with these theories, as they reveal a significant relationship between alpha rhythm with SRL, especially in the frontal lobe. On the other hand, the connections found between SRL with other brain regions, such as the parietal and occipital lobes require further research.

The study conducted by Zhang et al. (2022) aligns with the findings of this research, which demonstrate a relationship between SRL and EEG recordings in the occipital region [20].

Several factors may contribute to the lack of correlation between SRL and EEG recordings. These factors include influences on SRL, such as family support and monitoring, peer influence as positive or negative influences, competent instructors, the educational environment, and individual characteristics of the students themselves. Similarly, various factors can affect EEG recordings, including fasting-induced hypoglycemia, excessive body and eye movements, intense lighting, sedative medications, caffeine consumption, and factors related to hair [21, 22].

**Cognitive Function and qEEG**

The respondents with cognitive deficits showed no significant result in qEEG recording, as there were no significant differences observed compared to respondents with normal cognitive function. This may be because administering MoCA-INA to healthy individuals may yield significantly different results compared to individuals with pathological conditions such as stroke. Factors that can influence MoCA scores include age, educational level, living environment, marital status, and occupation [23].

This research found that cognitive function and qEEG correlate in the frontal lobe, specifically near Brodmann areas 6 and 9 (Figure 3). The frontal lobe plays a role in various everyday functions. The Broca's area in the frontal lobe aids in language production and speech, while the primary motor cortex controls specific motor skills. The frontal lobe is also involved in object comparison, long-term memory formation, understanding and reacting to others' emotions, personality formation, managing reward-seeking behavior and motivation, as well as attention management, including selective attention. Frontal lobe damage can affect these aspects, including speech, motor, cognitive, and social abilities [24].

Frontal lobe damage can affect cognitive abilities, particularly in the areas of executive function, attention, and working memory. The concept of frontal network syndromes provides a more accurate understanding of the neurobiological impact, encompassing five main syndromes and various secondary manifestations. Fundamental deficits include impairments in working memory, executive function, abulia, impulse control, and emotional dysfunction. Secondary manifestations may involve behavioral disorders such as social norm loss, imitation behavior, compulsions, and obsessions [25]. Other studies have also indicated distinct behavioral differences between patients with frontal lobe damage and control groups. Patients with frontal lobe damage are often aware of their altered behavior following the injury and acknowledge the difficulties they experience [26].

The findings of this study are consistent with previous research conducted by Wang et al. (2013) which also found a relationship between cognitive function scores and beta EEG rhythm. However, the strength of the relationship differs between the two studies. This study shows a weak correlation, while the study by Wang et al. showed a significant correlation [27]. This difference may be attributed to the different participants involved in the two studies, with this study involving healthy subjects and subjects with a history of cerebral infarction and cognitive impairments. Conversely, this study does not align with the previous research conducted by Asmedi et al. (2022) which did not find a relationship between MoCA-INA and beta rhythm [28].

Limitation

There are certain limitations that must be recognized. First, the sample size is relatively small, which may limit the generalizability of the findings to a larger population. Furthermore, the study solely concentrated on first-year medical students across different educational settings and disciplines.

A cross-sectional design only offers information for one specific moment in time. In order to gain a more complete understanding of the relationship between variables and any changes that may occur over time, a longitudinal study design should be employed. This study only focused on the alpha and beta wave bands in qEEG recordings, while other frequency bands and brain regions may also play a role in SRL and cognitive function. Future research could explore a broader range of frequency bands and brain regions to gain a more comprehensive understanding.

## Conclusions

The results of this study suggest that most first-year medical students have moderately self-regulated learning abilities and normal cognitive function. Variations in alpha and beta wave levels were found under different conditions. A correlation between SRL and qEEG was found in the prefrontal, frontal, parietal, and occipital regions, while such a correlation was only observed between cognitive function and qEEG in the frontal region.

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## Conflict of Interests

None.

## Fundings

None.

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