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# Do cortisol affects the brain electrical activity (EEG powers)?

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**Abstract:** *Background:* Glucocorticoids at very low/high levels are detrimental for memory performance. But how electroencephalogram (EEG) activity correlates with the cortisol in high and low efficient brains are still controversial. *Objective:* To find the association of cortisol with EEG powers in high and low cognitive brains at the time of examination preparation. *Method:* The EEG was recorded in an eye-closed state for 5-minutes in high (n-59) and low (n-24) cognitive individuals. Their salivary cortisol was estimated and correlated with the EEG activity by Spearman correlation test ($p<0.05$). The cortisol level between two groups was compared by Mann-Whitney U test. *Result:* Cortisol (ng/ml) was high in low cognitive group (1.36) than to the other group (1.32).There was a negative association of cortisol with EEG powers (r= -0.41 to -0.5) in central (beta, alpha2), frontal (alpha2) and left-temporal (alpha2) regions of the low cognitive brains. In high cognitive brains, cortisol was negatively associated with beta activity in right-temporal (r=-0.27) but positively associated with theta activity in mid-frontal (r=0.33) brain area. *Conclusion:* The less efficient brain has high cortisol level during preparation for their examination. This might have decreased the alpha2 activity in them that will impair the processing of long term memory. However, these individuals seem to manage the examination stress by decreasing the firing of the beta activity. Conversely, in the high cognitive brain, the rise in cortisol level seemed to increase the mid-frontal theta activity that might improve the attention and encoding of the information in these individuals.

**Keywords:** Cognition, Memory, Cortisol, Stress, Attention.

## Introduction

Cortisol is a glucocorticoid hormone secreted from the adrenal gland. One of the major conditions that increase its secretion is during the stress response [1]. It has many functions such as anti-immunity, anti-allergic, anti-inflammatory [2], glucose and protein homeostasis [3], generation of basic rhythms of electroencephalogram and permissive action to catecholamines and glucagons [2]. Apart from these functions, cortisol seems to affect the memory and cognitive functions too. There is a curvilinear relationship between glucocorticoids and cognitive functioning [4].

It has been found that both very low and very high levels of glucocorticoids are detrimental for memory performance. It is reported that an elevation of glucocorticoid levels enhances memory consolidation [5]. However, higher serum cortisol was associated with lower brain volumes and impaired memory in younger to middle-aged adults [6]. On the other hand, it is noted that very low levels of glucocorticoids induced pharmacologically, can impair the retrieval of both neutral and emotional information/memory [7].

Electroencephalogram (EEG) is a non-invasive test that detects different forms of brain waves by the placement of metal disc on the scalps. It is clinically used for the diagnosis of epileptic seizures, tumors, stroke and other focal brain disorders [2]. It is also used in the research of memory impairment [8-9], cognitive functions [10], effect of drugs/medications [11], sleep disorders [12-13], evoked [14-15] or event related potentials [16-17], emotions and psychophysiological studies [18]. We decided to study the correlation between EEG powers and cortisol levels in two different cognitive brains. The EEG pattern changes between the high and low cognitive individuals [19]. It changes under the influence of different types of hormones [20].

The EEG beta (β) activity has temporal coupling with cortisol release leading to central alertness in young adult male [21]. However, some studies could not conclude on the effect of cortisol on brain electrical activity (EEG) [22]. Therefore, we aimed to find the relationship of cortisol with brain electrical activity (electroencephalogram powers) in two different cognitive brains at the time of annual examination preparation period.

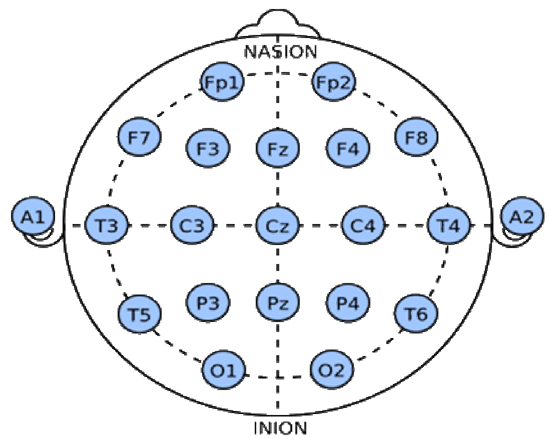
## Material and Methods

*Recruitment of Participants:* The participants were first year medical students without any history of drugs or substance abuse. Eighty three students of age 18-28 years voluntarily participated in the study. Students were divided into two groups as high (n-59) and low (n-24) cognitive groups by the cognitive test having 0.69 reliability coefficient [23]. We recorded cardio-respiratory variables (Heart rate, Systolic blood pressure, Diastolic blood pressures and Respiratory Rate), cortisol and EEG powers in both the cognitive groups.

*Study Time Point Selection:* This study is the continuation of the previous study [19]. Previously, we compared the EEG of the high and the low cognitive brains in two time points i.e. at the start and end of the course. Here in this study, we are correlating the cortisol level with EEG powers at the exam preparation period i.e. EEG at the end of course when they are preparing for the annual examination.

*Electroencephalogram Recording and Frequency Analysis:* EEG was recorded in two groups in an eye-closed state by the standard electrode placement method i.e. 10-20 international common average reference system (Figure 1). This study is the part of our previous study. Thus, the detailed procedure for the EEG pre-testing, recording setup and electrode placement was elaborated in the method section of our previous study [19]. The EEG waves were analyzed for frequency analysis by using Focus software version (1.1). For each participant, 5 minutes of EEG was recorded. From each minute, artifact-free-5-Sec epoch was taken and subjected to fast Fourier transformation (FFT). The total of five epochs was averaged from each subject. The obtained frequency bands were powers of delta (0.5-4 Hz), theta (4-7 Hz), alpha1 (7-10 Hz), alpha (7-13 Hz) and alpha2 (10-13 Hz) and beta (13-32 Hz) Figure 2.

**Fig-1:** Standard electrode placement method i.e. 10-20 international common average reference system




*Salivary Cortisol Estimation:* The whole saliva (unstimulated) was collected for the estimation of cortisol from all the students. The collected saliva was centrifuged for 10 min at 3000 x g revolution. The clear, colorless supernatant of saliva was used for cortisol hormone estimation by DRG Salivary Cortisol ELISA Kit with reliability of 0.872. The ELISA microplate washer (Lab Life EW, 2007) and ELISA microplate reader (Lab Life ER 2007) of Diagnova Company were used to read salivary cortisol levels.

*Statistical analysis:* Cortisol level between two groups were compared by Mann-Whitney U test. The Spearman correlation test was applied to find the association of EEG frequency power with cortisol level. The level of significance was kept at 0.05.

## Results

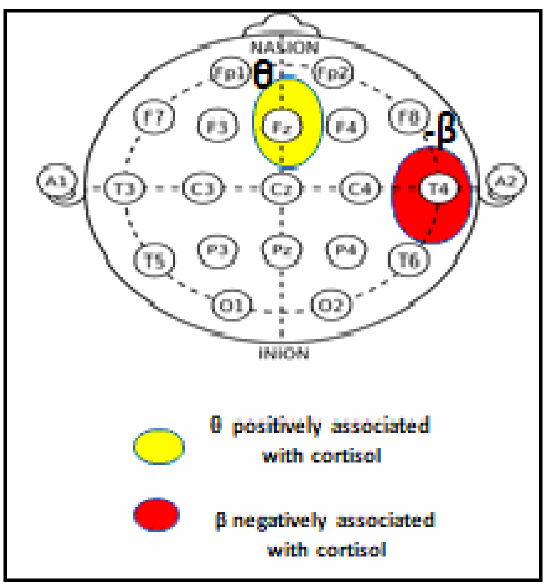
The age and cardiorespiratory variables were comparable between two groups except for the heart rate (table1). The heart rate and cortisol level was significantly higher in low cognitive group as compared to high cognitive group (table 1).

| Table-1: Cardiorespiratory and Cortisol level in two cognitive groups | | | |
|---|---|---|---|
| **Variables** | **High (n-59) Median (Q1-Q3)** | **Low (n-24) Median (Q1-Q3)** | **P value** |
| Heart Rate (beats/min) | 66 (59.5-72) | 69.5 (65.25-74.5) | 0.04 |
| Respiratory rate (breaths/min) | 19 (16-21) | 18 (16-19.75) | NS |
| Systolic blood pressure (mm/Hg) | 110 (108-120) | 110 (110-119) | NS |
| Diastolic blood pressure (mm/ Hg) | 72 (69-80) | 75 (70-80) | NS |
| Cortisol (ng/ml) | 1.32 (1.29-1.35) | 1.36 (1.33-2.18) | 0.01 |

**Relationship of EEG with Cortisol:**

*High cognitive group:* There was negative association of cortisol with the beta activity in T4 (r=-0.27, p=0.04) site but positive relationship with the theta activity in Fz (r=0.33, p=0.01) site Table 2. There was no association of cortisol level with the other EEG powers (Alpha1, alpha, alpha2 and delta) figure 2.

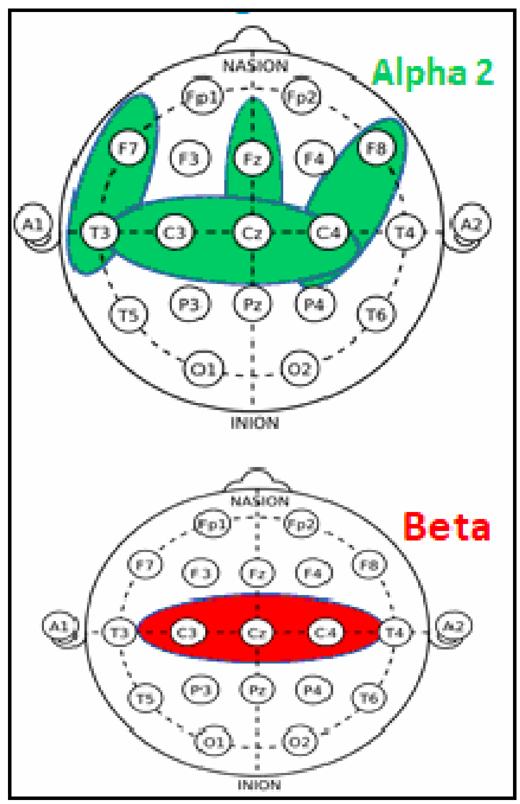
**Fig-2:** EEG map to show the relation of EEG power bands with cortisol in high cognitive brain.




The Fz theta activity (yellow) is positively associated with cortisol level and beta (red) activity is negatively associated with the cortisol level.

*Low cognitive group:* There was a negative association of cortisol with beta and alpha2 activities (r= -0.41 to -0.5) in many brain areas, particularly central (beta, alpha2), frontal (alpha2) and left temporal region (alpha2) Table 2.There was no association of cortisol with other EEG power bands (theta, delta, alpha1) figure 3.

**Fig-3:** EEG map to show the negative relation of EEG waves with cortisol in low cognitive brains.




The α2 activity of EEG is negatively associated with cortisol in many brain areas (marked with green). The β activity is also negatively associated with cortisol but mainly in central brain areas (marked with red).

**Table-2: Correlation of EEG powers with cortisol in two cognitive groups**

| EEG sites and power activity | Correlation coefficient (r) & p | Low CFS (n-24) | High CFS (n-59) |
|---|---|---|---|
| | | Cortisol | Cortisol |
| FZ Alpha2 | r | -0.44 | -0.07 |
| | p | 0.03* | NS |
| CZ Alpha2 | r | -0.47 | -0.01 |
| | p | 0.02* | NS |
| CZ Beta | r | -0.47 | -0.08 |
| | p | 0.02* | NS |
| F8 Alpha2 | r | -0.41 | -0.09 |
| | p | 0.05* | NS |
| C4 Alpha2 | r | -0.41 | 0.01 |
| | p | 0.05* | NS |
| C4 Beta | r | -0.44 | -0.06 |
| | p | 0.03* | NS |
| F7 Alpha2 | r | -0.47 | -0.07 |
| | p | 0.02* | NS |
| T3 Alpha2 | r | -0.40 | -0.13 |
| | p | 0.05* | NS |
| C3 Alpha | r | -0.48 | -0.06 |
| | p | 0.02* | NS |
| C3 Alpha2 | r | -0.49 | -0.02 |
| | p | 0.01* | NS |
| C3 Beta | r | -0.50 | -0.01 |
| | p | 0.01* | NS |
| FZ Theta | r | -0.07 | 0.33 |
| | p | NS | 0.01* |
| T4 Beta | r | -0.05 | -0.27 |
| | p | NS | 0.04* |

## Discussion

This study presents the relationship of cortisol with brain electrical activity (EEG powers) during the examination preparation period of two different cognitive brains. This period is selected because they are preparing for the annual examination that is obviously considered as a cognitively demanding period. Since they are studying and preparing for the examination, they might be in an exam related stress too, which is likely to change the cortisol level in their body. This cortisol might affect the brain electrical activity. With this hypothesis, we conducted this study to explore how the level of cortisol affects the brain electrical activity in two different cognitive brains i.e. high efficient and low efficient brains.

The finding shows that the low cognitive group has higher cortisol level and heart rate as compared to the high cognitive ones. This implies that the low efficient brains are in elevated examination stress as compared to the high cognitive groups. It is well established that salivary cortisol level is a valid biomarker for the stress [24].

Interestingly, this study finds that the high level of cortisol has association with the decreasedα2 activity in the central, frontal and temporal brain areas of the low cognitive brains. The decreased α2 activity might decrease the long term memory consolidation [25] in low efficient brains. Contrary, such effect is absent in the high cognitive brain. Nevertheless, the high level of cortisol seemed to increase the θ activity in the mid-frontal region of the high cognitive brains. Thus, cortisol might improve the attention and encoding of the information in these individuals by altering the theta activity. It is evident that the θ oscillation in hippocampo-cortical feedback loops reflects the encoding of the new information [25].

Similarly, it is stated that θ waves as encoding of episodic memories were clustered in right temporal and frontal cortex [26]. Here, we found positive association of θ waves with cortisol at mid-frontal site in the high cognitive brains.

Further, in both the groups, β wave has a negative relation with cortisol at some sites. Mainly, this effect was seen in the low cognitive group in the central (Cz, C3, C4) brain areas and in the right temporal (T4) site of the high cognitive brain. Increase in the β activity is considered as an anxiety indicator [27]. Contrary, others have proposed that hypothalamo-pituitary axis activity and EEG β activity represent the psychoneuroendocrine regulation of alertness for an arousal system [21]. Thus, we speculate that may be as a part of the coping mechanism on moderate degree of examination stress the cortisol level decreases the firing of β activity in the midline (central) brain areas and right temporal site in the cognitively active minds. Additionally, our study did not find the association of cortisol with other EEG power bands (delta, alpha1) in both the cognitive groups.

## Conclusion

In conclusion, the less efficient brain has high cortisol level at the examination preparation time that seemed to decrease the alpha2 activity. This decreased activity might impair the processing of long term memory in low cognitive brain. However, the less cognitive brain seems to manage the examination stress by decreasing the beta firing (anxiety indicator) on the central brain areas as a part of the stress coping mechanism. Conversely, in the high cognitive brain, the cortisol level has no association with the alpha2 activity. But the rise in cortisol level seemed to increase the mid-frontal theta activity which may improve their attention and encoding of the new information.

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