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Brain wave pattern in postmenopausal women: A Quantitative EEG analysis

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Abstract

Background: Quantitative EEG (QEEG) helps detect brain wave alterations linked to hormonal, advanced age and oxidative changes in postmenopausal women. **Objective:** To evaluate absolute brain wave power in postmenopausal women using power spectral analysis of QEEG. **Methods:** Twenty postmenopausal women aged 55–60 years and twenty premenopausal controls aged 35–40 years were recruited. EEG recordings were obtained in a 5-minute eyes-closed resting state using Brain Tech 32+ system India. Absolute power of delta, theta, alpha and beta waves was analyzed across 22 electrodes using BT40+ software. Statistical analysis was done using Independent Samples T test to compare groups. **Results:** Postmenopausal women showed significantly lower absolute power in delta, theta and alpha waves. Conversely, beta wave absolute power was significantly higher compared to premenopausal women. **Conclusion:** The results of this study concluded that the altered brain wave pattern of reduced alpha, delta, theta and elevated high-frequency beta waves absolute power reflects cortical hyperexcitability and disrupted brain function in postmenopausal women.

Keywords: Post menopause, EEG, brain waves, absolute power

Introduction

Menopause is a natural physiological event typically occurring between 45 and 55 years of age, marking the end of the reproductive life span due to ovarian hormone depletion.[1-2] In Bangladesh, the age of menopause ranges from 44.7 to 48.96 years, influenced by genetic and sociodemographic factors.[2-4] According to National Institute for Health and Care Excellence(NICE) guidelines, women over 45 years can be clinically diagnosed with menopause based on 12 months of amenorrhea and the presence of vasomotor symptoms, without requiring hormonal assays.[5-7] The marked decline in estrogen, a neuro-protective hormone, affects brain function by altering neurotransmission, synaptic plasticity and neurotrophic factor production.[8-10] Estrogen loss also contributes to cognitive impairment, mood disturbance, oxidative stress with their consequence of neuroinflammation, impairing neuronal integrity and function.[11-14]

Previous QEEG studies have demonstrated distinct alterations in brain electrical activity in postmenopausal women . Consistent findings include an increase in absolute beta power and a reduction in delta power, reflect cortical hyperexcitability and disrupted sleep patterns.[15] Additionally, reduced alpha and increased beta power have been associated with cognitive decline, whereas higher absolute delta and alpha power correlate with better cognitive performance.[16-17] Slow frequency wave activity shows mixed age-related patterns, with some studies reporting decreased delta and theta power [18-19] and others noting increases.[20] Since menopause typically occurs in midlife, these age-related brain wave changes may coincide with menopausal neurophysiological shifts. These EEG pattern changes may serve as valuable neurophysiological markers of brain health in postmenopausal women. The QEEG analysis may help taking care of mental health of postmenopausal women. So we have designed this study to observe the EEG pattern changes in postmenopausal women.

Methods

Design and setting

This cross-sectional study was conducted in the Department of Physiology, Bangladesh Medical University (BMU), Dhaka, from April 2024 to March 2025.

Study participants

Forty female volunteers participated in this study and they were divided into two groups: 20 healthy postmenopausal women aged 55–60 years (study group) with at least 12 months of amenorrhea, right-hand dominance, BMI between 18.2 and 26.5 kg/m² Twenty BMI-matched healthy premeno-pausal women aged 35–40 years (control group) with regular menstrual cycles and were matched for BMI, handedness also participated.[21-23]

Participants were recruited via personal contact and among BMU staff.

Sampling

Purposive sampling technique was used to select both the Postmenopausal group and the control subjects.

Exclusion criteria

Both groups excluded smokers, alcohol users, those with recent trauma or surgery, cardiovascular, respiratory, thyroid, kidney, or diabetic diseases and antioxidant or vitamin supplementation. Additional exclusions for controls included pregnancy, lactation, menstrual period, and hormonal contraceptive use.

Data collection

After obtaining informed written consent, detailed medical histories, clinical examinations and anthropometric measurements were performed. Handedness was evaluated in both groups with the Edinburgh Handedness Inventory.[22-23] Participants were instructed to complete dinner by 9:00 p.m., ensure adequate sleep in the night before the testing day to reduce fatigue and to avoid physical or mental stress, sedatives, or

medications affecting the central nervous system from the previous night until EEG recording has been done. To optimize electrode contact, participants washed their hair with mild, non-fragrant shampoo the day before and avoided sprays, antiperspirants, or perfumes on hair or body for at least 12 hours prior. On the test day, participants consumed a light breakfast and avoided caffeine for at least 3 hours before EEG recording. Upon arrival, they wore clean, odorless gowns and rested quietly for 10–15 minutes in a controlled noise free laboratory environment, temperature maintained at 23–25°C.[24-26]

EEG data were recorded using the Brain Tech 32+ CMEEG-01 system with 22 scalp electrodes placed according to the international 10–20 system, with A1 and A2 earlobe electrodes referenced.[25] Recordings lasted 5 minutes during an eyes-closed resting state in a noise-free, dimly lit room. The EEG signals were digitized using a 24-bit analog-to-digital converter, sampled at 1024 Hz and filtered with a 1 Hz high-pass and 35 Hz low-pass filter, plus a 50 Hz notch filter to reduce electrical interference.[27] Electrode impedance was kept below 20 kÙ. Fast Fourier Transformation (FFT) was applied to the digitized signals to extract power spectral parameters, calculating absolute power in delta, theta, alpha, and beta frequency bands.

Statistical analysis
Normality of data was assessed using the Shapiro-Wilk test. Normally distributed data were presented as mean ± SD. Group differences in absolute power values were analyzed using Independent Samples T test with SPSS version 25.

Results

There was no significant difference in BMI, resting pulse, blood pressure, respiratory rate, temperature, or oxygen saturation between the groups (p>0.05), except for age.(Table I)

EEG analysis showed that postmenopausal women had significantly lower absolute power of delta, theta and alpha waves across all cortical regions compared to premenopausal controls. In contrast, beta wave absolute power was significantly higher in the postmenopausal group. (Table II-V) These findings were consistent across all electrodes and supported by brain t-mapping patterns in representative participants. (Figure 1).

Table I: The baseline characteristics of the participants (N=40)

Parameters	PostM (n=20)	PreM(n=20)	p value
Age(years)	57.85±1.63	37.35±1.63	0.000
BMI(Kg/m²)	21.20±1.30	21.31±1.37	0.792
Resting pulse(beats/min)	80.57±7.12	80.57±6.76	0.997
Resting SBP(mmHg)	122.40±8.13	121.90±8.39	0.849
Resting DBP(mmHg)	77.55±7.96	74.60±8.16	0.255
Respiratory rate (breaths/min)	13.76±1.26	14.10±1.48	0.439
Temperature(°F)	98.47±0.29	98.39±0.25	0.350
Oxygen saturation (SpO2)	98.90±0.88	98.57±0.90	0.257
Handedness (Score)	79.50±7.45	81.50±9.445	0.462

Data were expressed as mean±SD Here, N- Total number of subjects; n-number of subjects in each group; BMI-Body Mass Index; SBP- Systolic Blood Pressure; DBP- Diastolic Blood Pressure; SpO2-Peripheral oxygen saturation. PostM= Postmenopause

Table II: Absolute power (μV^2) of Delta wave in PostM and PreM (N=40)

Cortical region	Electrode	PostM (n=20)	PreM (n=20)	p value
Prefrontal	FP1	2.36±1.16	3.26±1.24	0.013
	FP2	2.86±1.22	3.76±1.23	0.000
	Region	2.61±1.20	3.51±1.25	0.000
Frontal	F7	1.57±0.48	2.00±0.65	0.001
	F3	1.38±0.55	1.83±0.39	0.005
	FZ	1.67±0.39	2.45±0.41	0.000
	F4	1.96±0.68	3.20±1.34	0.001
	F8	1.46±0.63	1.75±0.48	0.032
	CZ	1.33±0.45	2.23±0.71	0.000
	Region	1.56±0.57	2.24±0.87	0.000
Parietal	C3	1.52±0.55	2.37±0.72	0.000
	C4	1.41±0.36	2.13±0.62	0.000
	P3	1.38±0.43	1.92±0.66	0.000
	PZ	1.83±0.72	2.13±0.80	0.040
	P4	1.98±1.01	2.37±0.88	0.009
	Region	1.62±0.68	2.18±0.75	0.000
Temporal	T3	1.09±0.46	1.90±0.93	0.004
	T4	1.04±0.52	1.53±0.51	0.000
	T5	2.01±0.54	2.35±0.72	0.010
	T6	1.65±0.46	2.51±0.75	0.002
	Region	1.45±0.64	2.07±0.82	0.000
Occipital	O1	1.74±0.71	2.41±0.81	0.001
	O2	2.01±0.75	2.70±0.97	0.000
	Region	1.87±0.73	2.56±0.89	0.000

Data were expressed as Mean ± SD. Comparison of data was done by Independent-Samples T Test. N= Total number of subjects; n= Total number in each group; p value <0.05 was considered as significant. PostM =Postmenopause ; PreM = Premenopause

Table III: Absolute power (μV^2) of Theta wave in PostM and PreM (N=40)

Cortical region	Electrode	PostM (n=20)	PreM (n=20)	p value
Prefrontal	FP1	1.14±0.42	1.37±0.37	0.006
	FP2	1.31±0.51	1.76±0.43	0.001
	Region	1.17±0.44	1.57±0.44	0.000
Frontal	F7	0.81±0.50	1.21±0.44	0.001
	F3	1.01±0.47	1.47±0.34	0.001
	FZ	1.36±0.22	1.74±0.36	0.000
	F4	1.09±0.53	1.59±0.54	0.000
	F8	1.27±0.24	1.64±0.24	0.000
	CZ	0.71±0.62	1.38±0.92	0.001
	Region	1.03±0.50	1.51±0.54	0.000
Parietal	C3	0.61±0.34	1.31±0.66	0.001
	C4	0.56±0.26	0.93±0.49	0.010
	P3	1.68±1.18	2.05±1.20	0.000
	PZ	1.55±0.81	1.85±0.85	0.000
	P4	1.13±0.48	1.47±0.52	0.000
	Region	1.11±0.83	1.52±0.87	0.000
Temporal	T3	1.41±0.73	1.94±0.76	0.000
	T4	0.45±0.28	0.89±0.34	0.000
	T5	0.63±0.41	1.40±0.42	0.000
	T6	1.46±0.97	1.86±0.87	0.000
	Region	0.99±0.79	1.52±0.75	0.000
Occipital	O1	1.49±0.96	1.99±0.89	0.000
	O2	1.47±0.83	1.95±0.87	0.001
	Region	1.48±0.88	1.97±0.87	0.000

Data were expressed as Mean ± SD. Comparison of data was done by Independent-Samples T Test. N= Total number of subjects; n= Total number in each group; p value <0.05 was considered as significant. PostM =Postmenopause ; PreM = Premenopause

**Table IV:** Absolute power (μV^2) of Alpha wave in PostM and PreM (N=40)

Cortical region	Electrode	PostM (n=20)	PreM (n=20)	p value
Prefrontal	FP1	3.12±1.73	3.93±1.68	0.040
	FP2	2.16±0.75	4.06±1.99	0.000
	Region	2.64±1.40	3.99±1.82	0.000
Frontal	F7	1.62±0.49	2.64±1.18	0.000
	F3	1.57±0.80	3.04±1.57	0.000
	FZ	1.75±0.88	3.58±1.78	0.000
	F4	1.56±0.98	3.03±1.84	0.000
	F8	1.73±1.03	2.59±1.32	0.000
	CZ	2.08±0.38	3.62±1.22	0.000
	Region	1.72±0.80	3.08±1.53	0.000
Parietal	C3	1.20±0.58	2.87±1.58	0.000
	C4	2.30±0.79	3.18±0.81	0.000
	P3	2.03±0.91	4.01±2.17	0.000
	PZ	1.98±0.81	5.04±2.23	0.000
	P4	2.01±0.68	4.26±2.40	0.000
	Region	1.90±0.83	3.87±2.04	0.000
Temporal	T3	1.10±0.54	2.03±0.96	0.000
	T4	2.47±0.79	1.71±0.67	0.000
	T5	2.27±0.60	4.60±2.12	0.000
	T6	2.44±0.95	5.02±2.27	0.000
	Region	1.88±0.87	3.53±2.10	0.000
Occipital	O1	2.62±0.90	4.88±2.13	0.000
	O2	2.63±0.95	5.11±2.23	0.000
	Region	2.63±0.91	4.99±2.16	0.000

Data were expressed as Mean ± SD. Comparison of data was done by Independent-Samples T Test. N= Total number of subjects; n= Total number in each group; p value <0.05 was considered as significant. PostM =Postmenopause ; PreM = Premenopause

Table V: Absolute power (μV^2) of Beta wave in PostM and PreM (N=40)

Cortical region	Electrode	PostM (n=20)	PreM(n=20)	p value
Prefrontal	FP1	3.52±1.28	1.34±0.54	0.000
	FP2	2.71±0.79	1.45±0.50	0.000
	Region	3.12±1.13	1.40±0.52	0.000
Frontal	F7	2.88±1.11	1.09±0.38	0.000
	F3	3.14±1.48	1.13±0.47	0.000
	FZ	3.98±1.68	1.18±0.41	0.000
	F4	3.08±1.79	1.25±0.53	0.000
	F8	3.07±1.43	1.02±0.43	0.032
	CZ	3.61±1.21	1.11±0.63	0.000
	Region	3.33±1.52	1.13±0.48	0.032
Parietal	C3	2.82±1.55	0.92±0.39	0.017
	C4	3.43±1.06	1.15±0.54	0.000
	P3	3.99±2.16	1.37±0.71	0.000
	PZ	5.03±2.23	1.37±0.65	0.000
	P4	4.25±2.40	1.28±0.56	0.000
	Region	3.90±2.05	1.22±0.59	0.000
Temporal	T3	2.23±0.97	0.96±0.41	0.001
	T4	2.55±0.81	1.07±0.39	0.000
	T5	4.61±2.14	1.49±0.73	0.000
	T6	1.38±0.61	1.39±0.61	0.002
	Region	3.61±2.06	1.22±0.58	0.000
Occipital	O1	5.03±2.22	1.52±0.87	0.001
	O2	5.16±2.17	1.57±0.87	0.000
	Region	5.09±2.17	1.54±0.86	0.000

Data were expressed as Mean ± SD. Comparison of data was done by Independent-Samples T Test. N= Total number of subjects; n= Total number in each group; p value <0.05 was considered as significant. PostM =Postmenopause ; PreM = Premenopause
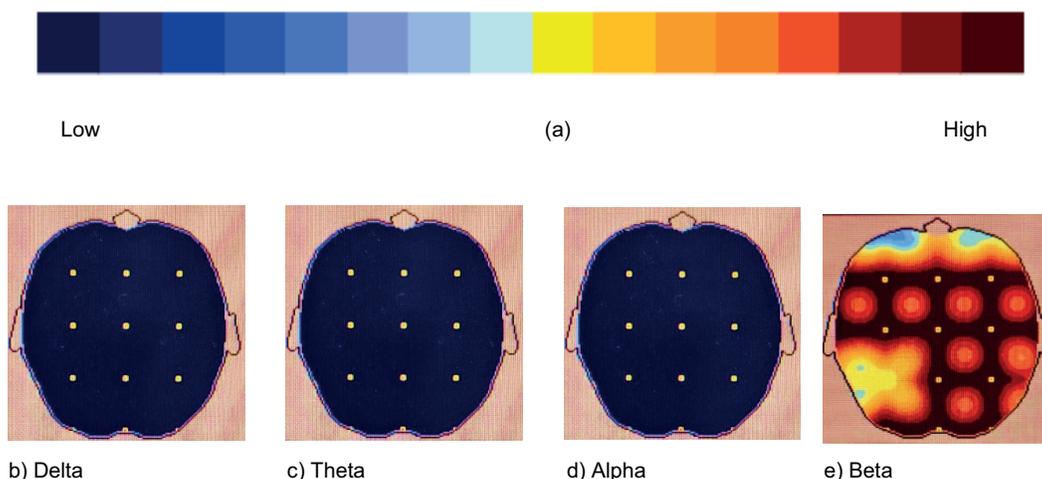
Figure 1: Topographical presentation of Absolute power (μV^2) in PostM group. a) a colour coded scale representing lower to higher absolute power value; b) delta; c) theta; d) alpha and e) beta wave

Discussion

This study revealed a characteristic pattern of altered absolute EEG power in postmenopausal women, reflecting neurophysiological changes associated with aging and estrogen depletion. There was a significant reduction in absolute power of delta and theta waves across multiple cortical regions. Delta waves (1–4 Hz), which are associated with restorative sleep, neuronal recovery, and reduced arousal, were markedly diminished, indicating impaired brain restoration capacity and compromised sleep quality in this group.[19,28-29] Similarly, theta waves (4–7.5 Hz), typically linked to deep relaxation and reduced cortical excitation, were also significantly reduced, suggesting difficulty in achieving deeply relaxed states and heightened baseline alertness or stress in postmenopausal women.[30-31]

A notable reduction in alpha wave absolute power was observed particularly in parietal, occipital, and temporal cortical regions. Alpha waves are closely tied to relaxation, cognitive processing, and mental integration, and their reduction caused decreased cognitive readiness and elevated psychological distress, such as anxiety and depression.[28,32-34] This reduction may stem from dysregulation of thalamocortical pathways and reduced cholinergic transmission, both of which are exacerbated by the post-menopausal decline in estrogen .[35]

In contrast, absolute beta power was significantly elevated, particularly in the prefrontal, frontal and temporal lobes. Beta activity is typically associated with increased cortical excitability, alertness and stress and its elevation reflects a hyperexcitable cortical state, consistent with the anxiety, restlessness, and sleep disturbance reported in the postmenopausal group.[36-38] The increased beta activity also aligns with findings in individuals experiencing generalized anxiety and chronic stress, conditions more frequently reported among postmenopausal women.[34]

In summary, the absolute EEG power pattern in postmenopausal women is characterized by reduced delta, theta and alpha power and increased beta power, suggesting a shift toward cortical hyperexcitability, reduced mental calmness, and impaired cognitive-emotional regulation. These findings underscore the neurophysiological impact of estrogen withdrawal, oxidative stress, and aging on the brain's resting electrical activity.

Conclusion

It can be concluded that in postmenopausal women, brain wave patterns often shift in a way that reflects increased mental tension and reduced relaxation. Specifically, there is a drop in the absolute power of delta and theta waves, typically linked to restlessness and anxiety as well as a decline in alpha waves, which are associated with lack of relaxed state. At the same time, beta wave power, which signals mental stress, tends to rise. This overall pattern suggests the brain becomes more excitable and less able to regulate itself, which may contribute to symptoms like anxiety, poor sleep, and mental fatigue.

Conflict of interest

The authors declare no conflicts of interest related to this study.

Ethical clearance

The ethical aspects of this study involving human subjects adhered to the principles outlined in the Declaration of Helsinki (1964). The study protocol reviewed and approved by the Institutional Review Board (IRB) of BMU.

Acknowledgement

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