Measuring Spectral Power to Potentially Measure Correlations in the MMSE Test

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Background/Objective: Alzheimer's disease (AD) and frontotemporal dementia (FTD) are two types of neurological diseases associated with cognitive decline. Electroencephalography (EEG) offers a low-cost method for measuring brain activity. This study explores if an association exists between the spectral power in standard EEG frequency bands and Mini-Mental State Examination (MMSE) scores in AD, FTD, and control groups to analyze the relationship between spectral power and cognitive decline.
Methods: A statistical analysis was performed on a publicly available EEG dataset from Miltiadous et al., 2023 containing three patient groups - AD, FTD, and healthy controls (HC). Welch's unequal-variance t-tests were conducted in the five frequency bands within each group and the band-specific spectral powers were also compared between AD vs. HC, FTD vs. HC, and AD vs. FTD.
Results: The dementia cohort (AD + FTD) showed significantly reduced alpha spectral power compared to the control group. The results for other bands were statistically inconclusive. A clear spectral power differentiator did not emerge between the AD and FTD group even though the MMSE scores were lowest in AD, intermediate in FTD, and highest in HC.
Conclusion: The results are indicative of the alpha-band spectral power as a potential group-level EEG marker for dementia. A study of larger samples is needed to determine if differences in spectral power impacts cognitive decline in individuals.

Keywords: Alzheimer's Disease, frontotemporal dementia, EEG, spectral power, MMSE

Introduction

Alzheimer's disease (AD) and frontotemporal dementia (FTD) are two progressive neurological diseases that, in total, affect over 7 million Americans. AD, the most common form of dementia accounting for 60-80% of cases, is commonly characterized by overall cognitive decline and memory loss. Behavioral symptoms for FTD, specifically, account for 5-10% of cases. There is a common overlap between FTD and AD regarding cognitive decline. However, there are key differences in behavioral symptoms regarding the following: disinhibition, apathy, hyperorality, dietary changes, psychotic symptoms such as delusions and hallucinations, schizophrenia, and bipolar disorder. Diagnosis for neurological diseases such as AD and FTD requires clinical evaluation, neurological testing, neuropsychological testing, and imaging tests such as positron emission tomography (PET) or magnetic resonance imaging (MRI). Currently, MRI and PET are the preferred diagnostic methods for dementia. However, these are expensive and not always available in community settings. These limitations result in the delayed diagnosing of AD or FTD. As both these conditions are progressive neurological diseases, behavioral and psychological symptoms worsen increasing cost and decreasing quality of life. Considering these challenges, there is a need for an additional ancillary tool that can supplement the traditional neuroimaging methods for these diseases. Electroencephalography (EEG) is a low-cost and non-invasive technique that is readily available in clinical scenarios. This study aims to explore EEG as a cost-effective supplemental tool that can enhance established neuroimaging processes.

EEG is a non-invasive neurophysiological technique that records the electrical activity of a patient's brain to observe neuronal activity by recording brain signals from electrodes placed on the scalp, capturing voltage fluctuations generated by synchronized neuronal firing, particularly from cortical pyramidal cells. These signals are represented as brain waves across specific frequency bands (delta, theta, alpha, beta, and gamma), each associated with different cognitive and functional states. Changes in these frequency patterns serve as critical indicators of neural dysfunction and cognitive deterioration. Since the five bands used in this study are widely accepted in EEG research on dementia and each is involved with cognitive processes, changes of spectral power across all five frequency bands were also investigated. Research has shown that individuals experiencing cognitive decline, including those with AD and mild cognitive impairment (MCI), ex-

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hibit significant alterations in EEG rhythms, such as increased slow-wave activity and abnormal gamma band synchronization[1,2]. These disruptions reflect impaired neural connectivity and inefficient information processing, which are closely linked to memory loss and reduced cognitive performance[3]. Furthermore, quantitative EEG (qEEG) analysis has been increasingly applied in detecting early-stage cognitive decline, as subtle spectral power changes can be observed even in subjective cognitive decline populations before clinical diagnosis[4]. Among the many quantitative EEG features, two commonly discussed metrics associated with EEG analysis include spectral power and spectral phase. Spectral power looks at underlying brain activity, and spectral phase, indexes the timing relationships between neuronal oscillations. In the present study, spectral power has been exclusively focused on for two reasons. First, prior work has reported more consistent associations between spectral band power and dementia related cognitive impairment, and second, spectral power can be interpreted using relatively simpler and transparent methods. On the other hand, spectral phase often requires complex modeling techniques and is therefore marked as out of scope for this study.

In EEG, spectral power refers to the distribution of signal power over the frequency components of the signal. It is calculated by decomposing the EEG timeseries into its frequency components, squaring each component separately and calculating the total power (or energy) in each frequency band. Neuroscientists typically partition the EEG spectrum into five primary frequency bands: delta (0.5 - 4 Hz), high during deep sleep and possibly accentuated with severe cortical dysfunction, theta (4 - 8 Hz), of drowsiness or other mental processes involving memory, alpha (8 - 12 Hz), indicating relaxed wakefulness or visual attentiveness, beta (13 - 30 Hz) reflecting active thought or sensorimotor processing and gamma (30 - 45 Hz in this study) suggesting cognitive integration at higher levels. Alterations of band-specific spectral power can be utilized as a parameter to reflect on the severity and topographical pattern in dementia-related cognitive decline. qEEG can be used in conjunction with machine learning to identify electrophysiological markers of cognitive decline[5].

The Mini-Mental State Examination (MMSE), a widely used clinical screening tool to estimate global cognitive function in dementia, is scored out of 30 points and has components concerning orientation, memory, attention, language and the ability for simple visuospatial tasks. MMSE scores are commonly used in clinical and research contexts to classify cognitive status, and approximate severity of dementia whereby lower MMSE scores correspond with greater impairment. In EEG studies, MMSE is commonly used as a comparison standard for linking spectral abnormalities with cognitive condition and before it has been reported the alpha, beta and/or theta power changes in dementia have relationships with MMSE scores (e.g., [1,4,6]). As the Miltiadous et al. dataset includes MMSE scores for all participants and since it is widely used in the dementia EEG literature, the present study utilizes MMSE as the primary cognitive measure for comparing AD, FTD, and HC groups.

Miltiadous et al., 2023 collected EEG recordings of three groups of patients AD, FTD, and healthy controls (HC), where they found that the AD group of individuals exhibited increased broadband spectral power on average relative to FTD and HC through observing the correlation between spectral power and cognitive decline. MMSE was specifically used as a benchmark for observing cognitive decline. Their test results indicated that "MMSE score ranges from 0 to 30, with a lower MMSE indicating more severe cognitive decline." It was found that "the average MMSE for the AD group was 17.75 (SD = 4.5), for the FTD group in the original study was 22.17 (SD = 8.22), and for the CN group it was 30." This suggests that spectral power may have an impact on the scores of the MMSE test and thus, cognitive decline. As Jeong et al., 2021 put it, "on AD related to the MMSE score, the lower the score, the higher the relative power of theta waves was found in the entire hemisphere... the decrease in alpha power was greater in the posterior lead of the MCI group." Multiple studies demonstrate significant relationships between reduced alpha and beta power, increased gamma activity, and lower MMSE scores in individuals with AD and mild cognitive impairment[1,2,4] although findings for beta and gamma have been less consistent across the broader literature. To investigate the above further, the present study adopts a similar overall strategy to compare power spectral density (PSD) in each frequency band between AD vs. HC, FTD vs. HC, and AD vs. FTD, by using Welch's t-tests.

Based on the prior findings, this study hypothesizes that AD participants will show higher theta power and lower alpha power compared with healthy controls, and that FTD participants will show reduced alpha power relative to controls. In addition, the study explores whether MMSE scores are associated with posterior alpha-band spectral power within the AD and FTD groups, while beta and gamma band findings are treated as exploratory because the evidence for robust associations in these higher frequency bands remains mixed.

Methods

This study is a cross-sectional secondary analysis of deidentified EEG recordings from AD, FTD, and HC participants made publicly available by Miltiadous et al., 2023, containing 88 subjects: 36 subjects diagnosed with AD, 23 subjects diagnosed with FTD, and 29 HC. Four FTD participants were excluded due to incomplete or poor EEG data and/or MMSE performance, leaving 19 FTD participants as the final sample. This led to a final population size of 84 subjects: 36

subjects diagnosed with AD, 19 subjects diagnosed with FTD, and 29 HC. Demographic variables (age, sex, MMSE) were reported by group, but specific details about medication exposure and the presence of comorbid conditions or disease duration were not consistently present in the source data. EEG preprocessing was in line with the process outlined for Miltiadous et al. (2023) (including band-pass filtering, re-referencing and artifact rejection based on motion, eye blink and muscle activity). Power spectral density (PSD) was calculated over 0.5 - 45 Hz with a preprocessed EEG sampling rate of 500 Hz, employing a Hann window on data portions of 4 s (50% overlap - in MNE using Welch's method). The MNE toolbox was then used to process the data by extracting spectral power values. To do this, the "welch method" was used to extract an estimate of spectral power by dividing the data into segments, computing modified periodogram for each segment and averaging the periodograms. Through the Welch method, the data could then be separated into frequency bands and ranges (Delta, Theta, Alpha, Beta, and Gamma). This was done using the Fmin and Fmax parameters in the Welch method, set to 0 and 45. Through a for-loop, the average spectral power values within each frequency band were then able to be calculated through all 19 scalp electrodes for each patient. This topographical image was then produced depicting the spectral power (in dB units) for all 5 frequency bands recorded for the three dataset groups. After extracting the spectral power values, statistical analyses of these data were performed comparing AD vs. HC, FTD vs. HC, and AD vs. FTD with a Welch's unequal variances t–tests to find the most significant differences within the different frequency bands (representing parts of the brain) with an uncorrected value of $\alpha = 0.05$. P-values were reported at two-tailed significance and were calculated using the SciPy statistics library in Python. The estimated degrees of freedom were approximated using the Welch-Satterthwaite method and are reported with decimal values. To perform the T-test, the average and standard deviation values were taken for each frequency band of each population. Exploratory Pearson product-moment correlations were also calculated, in addition to group comparisons, to analyze the relationship between cognitive performance and EEG spectral power. The correlations were established between MMSE and alpha-band spectral power in AD group, FTD group, combined dementia group (AD + FTD participants), and all participants. Correlations were not calculated for the HC group due to a lack of MMSE variance (every participant scored 30). Lastly, data was collated in a spreadsheet for visualization rather than for the underlying statistical calculation.

Results

Three Welch's t-Test comparisons were processed to measure the statistical difference in spectral power of the 5 frequency bands: delta, theta, alpha, beta, and gamma between AD vs. HC, FTD vs. HC, and AD vs. FTD.

For the first comparison between AD vs. HC the theta power was found to be the strongest in the AD group (M = 10.58 dB, SD = 1.13) relative to the HC group (M = 10.10 dB, SD = 1.14), ($t(60.03) = 1.68$, $p = .098$, $d = 0.42$) but this effect did not reach significance. Additionally, alpha power was found to be the strongest in the HC group (M = 8.65 dB, SD = 2.71) relative to the AD group (M = 6.33 dB, SD = 1.93), ($t(49.03) = -3.88$, $p < .001$, $d = -1.00$), indicating a significant decrease in alpha power in AD relative to HC with a large effect size. No significant differences were observed in groups in gamma power, $t(62.98) = 1.01$, $p = .317$, $d = 0.25$. Furthermore, no significant difference in beta power between the groups, $t(54.20) = -1.47$, $p = .147$, $d = -0.38$. Lastly, there seemed to be no significant difference in delta power between the groups, $t(60.55) = -0.52$, $p = .603$, $d = -0.12$.

The takeaways found from the next statistical comparison between FTD vs. HC were that delta power was strongest in the HC group (M = 24.15 dB, SD = 0.34) relative to FTD group (M = 23.84 dB, SD = 0.515) ($t(28.20) = -2.31$, $p = .028$. $d = -0.74$). Additionally, alpha power was strongest in the HC group (M = 8.65 dB, SD = 2.71) relative to the FTD group (M = 6.35 dB, SD = 2.08), ($t(44.75) = -3.31$, $p = .0019$, $d = -0.92$). No significant difference in gamma power between the groups, $t(28.78) = 1.00$, $p = .32$, $d = 0.32$. Furthermore, there seemed to be no significant difference in beta power between the groups, $t(34.16) = -0.92$, $p = .36$, $d = -0.28$) Lastly, there seemed to be no significant difference in theta power between the groups, $t(40.06) = -0.19$, $p = .85$, $d = -0.06$.

For the final comparison between AD vs. FTD, Theta power was slightly stronger in the AD group (M = 10.58 dB, SD = 1.13) relative to the FTD group (M = 10.04 dB, SD = 1.08), but this effect did not reach statistical significance, $t(38.38) = 1.73$, $p = .092$, $d = 0.48$. There was no significant difference in delta power between the groups, $t(37.12) = 1.73$, $p = .091$, $d = 0.49$. No significant difference in alpha power between the groups, $t(34.48) = -0.04$, $p = .97$, $d = -0.01$; in beta power between the groups, $t(27.65) = -0.13$, $p = .90$, $d \approx -0.04$; or in gamma power between the groups, $t(31.34) = -0.27$, $p = .79$, $d = -0.08$.

The topography map is also consistent with the statistical results and depicts the AD and FTD groups as having reduced alpha power relative to controls and FTD showing lower delta power. The apparent differences in theta, beta, and gamma do not reach statistical significance.

The MMSE scores were highest in the HC group ($M = 30.00$, $SD = 0.00$), intermediate in the FTD group ($M = 21.58$, $SD = 2.48$), and lowest in the AD group ($M = 17.75$, $SD = 4.50$). MMSE scores in AD were significantly lower than in HC, $t(35) = -16.33$, $p < .001$, and FTD scores were also significantly lower than HC, $t(18) = -14.81$, $p <$

Table 1 Welch's t-tests for AD vs HC group differences in EEG spectral power

Frequency Band	AD Mean	AD SD	HC Mean	HC SD	t-statistic	df	p-value	Cohen's d	Significant?
Delta (0-4 Hz)	24.09	0.52	24.15	0.34	-0.52	60.55	0.604	-0.12	No
Theta (4-8 Hz)	10.58	1.13	10.1	1.14	1.68	60.02	0.098	0.42	No
Alpha (8-12 Hz)	6.33	1.93	8.65	2.71	-3.88	49.05	$<.001$	-1	Yes
Beta (12-30 Hz)	-0.26	1.46	0.34	1.77	-1.47	54.2	0.146	-0.38	No
Gamma (30-45 Hz)	-4.33	2.61	-4.92	2.13	1.01	62.98	0.316	0.25	No

Table 2 Welch's t-tests for FTD vs HC group differences in EEG spectral power

Frequency Band	FTD Mean	FTD SD	HC Mean	HC SD	t-statistic	df	p-value	Cohen's d	Significant?
Delta (0-4 Hz)	23.84	0.51	24.15	0.34	-2.31	28.2	0.028	-0.74	Yes
Theta (4-8 Hz)	10.04	1.08	10.1	1.14	-0.19	40.06	0.851	-0.06	No
Alpha (8-12 Hz)	6.35	2.08	8.65	2.71	-3.31	44.75	0.002	-0.92	Yes
Beta (12-30 Hz)	-0.19	2.08	0.34	1.77	-0.92	34.17	0.363	-0.28	No
Gamma (30-45 Hz)	-4.1	3.14	-4.92	2.13	1	28.78	0.325	0.32	No

.001. Across dementia participants (AD and FTD combined), MMSE scores were not significantly correlated with alpha power, $r = 0.06$, $p = .68$, suggesting that within these patient groups, variation in alpha power did not closely track variation in MMSE performance.

Discussion

This paper, focused on three comparisons: AD vs. HC, FTD vs. HC, and AD vs FTD in order to observe statistical differences in power spectral density within the five frequency bands observed. The study initially hypothesized that PSD values in the AD group will be higher in the theta frequency band and lower in the alpha frequency band compared to the HC group. Also, it was expected for the alpha band to have lower PSD in the FTD group compared to HC. Finally, it was also hypothesized that within the dementia group (AD + FTD), lower MMSE scores would be associated with higher theta and lower alpha power.

The results seem to support the hypothesis for the alpha-band, as there is a consistent PSD reduction in the alpha-band in the dementia (AD + FTD) group relative to the control. In the AD vs HC group, a significantly lower alpha power was observed with a large size while the predicted increase in the theta power did not reach any significance. Spectral power in the beta, gamma, and delta frequency bands in the AD population however showed no reliable difference compared to the control. For the PSD values in the FTD vs HC group, it was hypothesized that spectral power would be lower in the alpha frequency bands compared to the control. The results support the hypothesis as the alpha frequency band was lower in the FTD population compared to the control. However, delta power was actually weaker in the FTD population compared to the control. This reduction in delta power for FTD pattern is less common in the dementia EEG literature and should be interpreted cautiously regarding it as exploratory in nature due to the small sample size and testing of multiple frequency bands without formal correction. Spectral power in the beta, gamma, and theta bands showed no substantial statistical difference compared to the control. For the third group, AD vs FTD, the theta power did show a slight increase in AD, but this was not enough to be significant. The remaining spectral frequency bands showed no significant statistical difference between the two groups. The differences in beta and gamma bands for the dementia (AD + FTD) group relative to HC were inconsequential. The beta and gamma insignificance for the dementia groups (AD + FTD) presumably stems from both a smaller effect in the higher frequency range and larger variability of beta and gamma activity associated with the smaller sample size. Nevertheless, both beta and gamma were included in the analysis as a few prior studies have reported altered beta power[7] and an abnormal synchronization of gamma rhythms[8] in AD. Thus, spectral power metrics within alpha and maybe even theta frequency bands should be carefully monitored within AD patients, while spectral power metrics within the alpha band should be monitored with FTD patients.

Regarding the correlation between spectral power and MMSE scores, it was hypothesized that there would be a direct correlation between PSD values and MMSE scores in the alpha frequency band of the AD and FTD population. The average MMSE scores for the populations were as follows: AD population was 17.75 ($SD = 4.5$), the FTD group was 22.17 ($SD = 8.22$), and the HC group was 30. The Pearson

Table 3 Welch's t-tests for AD vs FTD group differences in EEG spectral power

Frequency Band	AD Mean	AD SD	FTD Mean	FTD SD	t-statistic	df	p-value	Cohen's d	Significant?
Delta (0-4 Hz)	24.09	0.52	23.84	0.51	1.73	37.11	0.092	0.49	No
Theta (4-8 Hz)	10.58	1.13	10.04	1.08	1.73	38.37	0.093	0.48	No
Alpha (8-12 Hz)	6.33	1.93	6.35	2.08	-0.04	34.49	0.969	-0.01	No
Beta (12-30 Hz)	-0.26	1.46	-0.19	2.08	-0.13	27.66	0.9	-0.04	No
Gamma (30-45 Hz)	-4.33	2.61	-4.1	3.14	-0.27	31.34	0.786	-0.08	No

Fig. 1 Power Distribution across all frequency bands and groups

correlations within each participant group did not reveal any strong individual-level relationships between alpha power and MMSE. Thus, the alpha power appears to be a robust cross-dementia biomarker when compared to controls. Predicting

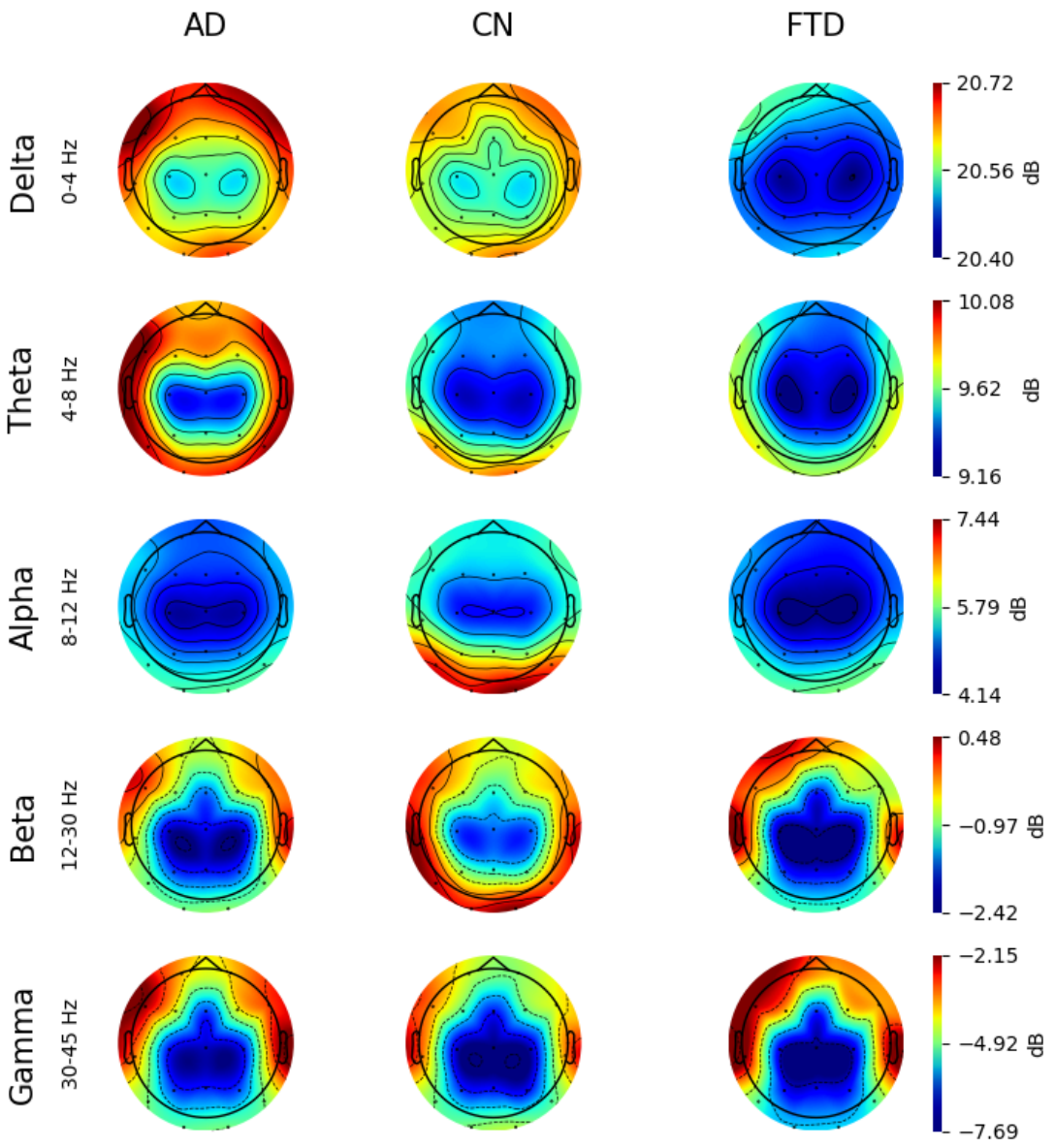

Fig. 2 Topographical maps of mean spectral power (dB) for each frequency band and group

individual cognitive decline needs additional testing with a robust, repeatable, and larger dataset.

There are several limitations with this study. The small sample size in the FTD group ($n = 19$), limits the statistical power, leading to additional possibility of Type II errors, especially for non-significant results in beta and gamma frequency bands. Therefore, these lack of differences in some frequency bands should be interpreted with caution and further validation in larger FTD populations is suggested. The study also performed 15 independent t-tests (five frequency bands * three group comparisons) with an uncorrected $\alpha = 0.05$ raising the Type I error rate. Consequently, the statistical results presented here are exploratory and need to be replicated in larger samples with correction methods employed. Due to the small size of the FTD data, some selective bias cannot be avoided along with the risk that the studied FTD group might not fully reflect the general FTD population. The study of a single EEG recording for each participant in this study does not allow to investigate how spectral power evolves throughout disease progression. Longitudinal studies tracking EEG and MMSE over time are necessary to establish whether changes in spectral power could predict cognitive decline. The generalizabil-

Table 4 Pearson correlations between MMSE and posterior alpha power

Group	n	MMSE ($M \pm SD$)	Alpha ($M \pm SD$, dB)	r(MMSE, α)	t(df)	p (two-tailed)	Notes
AD	36	17.75 ± 4.50	6.33 ± 1.93	0.08	0.49 (34)	0.63	No significant MMSE–alpha correlation
FTD	19	21.58 ± 2.48	6.35 ± 2.08	-0.01	-0.03 (17)	0.98	No significant MMSE–alpha correlation
HC	29	30.00 ± 0.00	8.65 ± 2.71	-	-	-	Correlation not computed (MMSE has no variance)
Dementia (AD & FTD)	55	19.07 ± 4.31	6.33 ± 1.97	0.06	0.41 (53)	0.68	No significant MMSE–alpha correlation
All participants	84	22.85 ± 6.28	7.13 ± 2.49	0.39	3.82 (82)	< 0.001	Higher alpha associated with higher MMSE

ity of the observed spectral power pattern to other EEG devices, montages, or clinical environments is in question since this analysis drew from only a single EEG acquisition system and electrode set-up. In addition, future studies regarding spectral power within the alpha, theta, and delta frequency bands should be undertaken. This will enable a better understanding of the significance of correlations between spectral power and other EEG metrics when determining cognitive decline and other changes in brain activity in dementia patients.

The most consistent finding presented by this study was an observed reduction in alpha power in dementia patients when compared to controls. Exploratory Pearson correlations between MMSE scores and alpha-band spectral power were inconsequential indicating that EEG spectral power was not a strong predictor of individual MMSE performance. Altogether, these results demonstrate that decreased alpha power is a candidate group-level biomarker of dementia-associated cognitive deterioration whereas delta and theta patterns are less consistent. Given the relatively small sample size and absence of adjustment for multiple testing, these findings should be considered as exploratory. Larger studies that include more detailed clinical characterization are required to determine whether combinations of EEG features might consistently monitor or predict cognitive decline in individual participants, and thereby potentially play a role in dementia assessment.

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Appendix

Table 5 Extracted spectral power values for the AD group

participant_id	Gender	Age	Group	MMSE	delta	theta	alpha	beta	gamma
sub-001	F	57	A	16	23.56	9.98	4.11	-1.88	-5.77
sub-002	F	78	A	22	23.44	9.77	8.51	-0.93	-5.76
sub-003	M	70	A	14	22.76	11.16	9.88	-1.92	-8.36
sub-004	F	67	A	20	24.26	10.03	4.05	-0.82	-2.63
sub-005	M	70	A	22	23.76	9.69	4.66	-1.08	-4.69
sub-006	F	61	A	14	24.35	9.21	10.63	0.48	-4.90
sub-007	F	79	A	20	23.80	10.16	4.62	-1.68	-6.12
sub-008	M	62	A	16	24.86	10.44	5.17	-0.76	-4.81
sub-009	F	77	A	23	23.16	9.91	8.34	0.25	-4.58
sub-010	M	69	A	20	23.34	8.74	4.91	-1.26	-5.30
sub-011	M	71	A	22	24.32	11.18	7.89	0.18	-2.02
sub-012	M	63	A	18	24.60	10.35	6.22	-0.72	-6.08
sub-013	F	64	A	20	24.41	10.53	5.19	-1.26	-5.78
sub-014	M	77	A	14	24.53	10.38	4.65	0.25	-1.74
sub-015	M	61	A	18	24.03	9.68	7.74	-1.33	-5.98
sub-016	F	68	A	14	24.42	10.09	4.02	-2.45	-7.77
sub-017	F	61	A	6	24.57	11.23	5.56	-1.17	-6.41
sub-018	F	73	A	23	24.29	11.92	8.05	1.43	-4.87
sub-019	F	62	A	14	24.02	9.44	4.77	-0.66	-3.03
sub-020	M	71	A	4	24.83	9.87	4.36	-1.69	-5.38
sub-021	M	79	A	22	24.22	10.01	4.99	0.06	-2.43
sub-022	F	68	A	20	24.43	11.51	7.23	0.88	-2.55
sub-023	M	60	A	16	24.06	10.33	6.38	-0.02	-3.48
sub-024	F	69	A	20	24.03	11.39	5.59	-1.40	-7.86
sub-025	F	79	A	20	23.96	10.07	9.93	0.90	-0.02
sub-026	F	61	A	18	24.27	10.77	5.30	3.35	4.44
sub-027	F	67	A	16	24.62	13.33	5.72	1.28	-0.20
sub-028	M	49	A	20	23.88	10.76	5.01	-1.59	-7.29

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Table 5 – continued from previous page

participant_id	Gender	Age	Group	MMSE	delta	theta	alpha	beta	gamma
sub-029	F	53	A	16	23.79	11.56	5.30	-0.81	-5.02
sub-030	F	56	A	20	25.42	14.04	7.99	1.68	-0.83
sub-031	F	67	A	22	24.33	9.94	7.29	-0.25	-3.50
sub-032	F	59	A	20	24.12	13.13	8.64	2.52	-2.97
sub-033	F	72	A	20	23.77	9.64	6.29	0.98	-3.52
sub-034	F	75	A	18	24.03	10.00	4.23	-1.69	-7.52
sub-035	F	57	A	22	23.74	10.08	4.76	-1.55	-5.44
sub-036	F	58	A	9	23.38	10.39	9.77	3.22	-5.64

Table 6 Extracted spectral power values for the HC group

participant_id	Gender	Age	Group	MMSE	delta	theta	alpha	beta	gamma
sub-037	M	57	C	30	24.30	10.64	10.84	-0.67	-6.87
sub-038	M	62	C	30	23.53	9.34	6.58	-0.31	-6.76
sub-039	M	70	C	30	23.72	10.38	13.40	0.81	-4.99
sub-040	M	61	C	30	25.01	9.86	9.52	-0.34	-4.76
sub-041	F	77	C	30	24.06	9.29	6.79	0.34	-3.17
sub-042	M	74	C	30	24.00	9.54	8.84	0.23	-5.80
sub-043	M	72	C	30	23.82	9.50	4.93	-1.45	-6.02
sub-044	F	64	C	30	24.30	9.85	10.67	-0.19	-7.62
sub-045	F	70	C	30	24.10	10.00	5.52	-0.67	-6.49
sub-046	M	63	C	30	24.08	10.92	10.47	2.48	-4.66
sub-047	F	70	C	30	23.99	10.08	9.23	0.14	-5.49
sub-048	M	65	C	30	24.40	10.10	8.72	0.55	-2.04
sub-049	F	62	C	30	24.02	9.92	9.78	0.28	-5.39
sub-050	M	68	C	30	24.50	10.24	7.43	-0.43	-2.80
sub-051	F	75	C	30	24.59	9.69	6.69	-0.65	-4.58
sub-052	F	73	C	30	23.82	10.01	8.62	0.70	-4.55
sub-053	M	70	C	30	24.52	10.71	10.16	0.81	-2.48
sub-054	M	78	C	30	24.00	10.41	10.55	0.73	-6.00
sub-055	M	67	C	30	24.14	9.77	8.63	2.10	

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Table 6 – continued from previous page

participant_id	Gender	Age	Group	MMSE	delta	theta	alpha	beta	gamma
-6.04									
sub-056	F	64	C	30	24.36	15.54	13.99	7.66	
3.59									
sub-057	M	64	C	30	23.95	9.63	8.15	-0.31	
-6.10									
sub-058	M	62	C	30	23.86	9.71	9.03	0.85	
-4.23									
sub-059	M	77	C	30	24.07	9.53	4.60	-1.09	
-6.40									
sub-060	F	71	C	30	24.36	9.62	4.31	-0.15	
-6.21									
sub-061	F	63	C	30	24.28	9.35	6.70	-1.94	
-4.87									
sub-062	M	67	C	30	24.50	9.86	10.92	-0.68	
-6.56									
sub-063	M	66	C	30	23.42	9.44	5.76	-0.95	
-6.01									
sub-064	M	66	C	30	24.51	10.57	14.51	2.68	
-4.18									
sub-065	F	71	C	30	24.12	9.39	5.39	-0.69	
-5.21									

Table 7 Extracted Spectral Power Values for the FTD group

participant_id	Gender	Age	Group	MMSE	delta	theta	alpha	beta	gamma
sub-066	M	73	F	20	24.14774209	11.04331802	6.900788402	-0.9258666636	
-4.110691749									
sub-067	M	66	F	24	23.45611039	9.442973001	7.176935579	6.170911153	
5.0924709									
sub-068	M	78	F	25	23.81099327	9.311606871	6.252365546	-1.723475601	
-6.86910703									
sub-069	M	70	F	22	23.12282062	13.89857615	9.90937427	0.7338068264	
-4.761770184									
sub-070	F	67	F	22	23.43000875	9.17261665	4.454434391	-0.77370417	
-4.779553962									
sub-071	M	62	F	20	23.29541308	9.547319017	7.076945335	0.7521041546	
-2.56831203									
sub-072	M	65	F	18	23.97732846	10.86750574	5.05667544	-1.217306405	
-6.196453323									
sub-073	F	57	F	22	24.0003933	9.471702306	5.805955263	-2.283632118	
-7.483540579									
sub-074	F	53	F	20	24.40435903	10.64997804	6.710669368	-1.242773384	
-5.185254692									
sub-075	F	71	F	22	24.11371921	10.13954175	9.418118056	2.638016969	
0.484459442									
sub-076	M	44	F	24	23.8789562	10.28709925	5.178378257	0.959992796	
-2.107749567									
sub-077	M	61	F	22	24.42659577	9.34567672	4.260910774	-1.061401714	
-3.471761127									
sub-078	M	62	F	22	24.58945543	9.516747086	4.326592923	-0.8451392884	
-5.005469201									
sub-079	F	60	F	18	23.90105209	9.450616497	6.969539884	1.652430495	
-0.8004358647									
sub-080	F	71	F	20	23.86265358	9.752226118	11.30617092	0.6052493531	
-4.710157783									
sub-081	F	61	F	18	23.94479488	9.756725072	4.695618432	-2.49932706	
-8.586834583									

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Table 7 – continued from previous page

participant_id	Gender	Age	Group	MMSE	delta	theta	alpha	beta	gamma
sub-082	M	63	F	27	24.17141465	9.674243111	7.029324007	-1.19173046	-4.988300678
sub-083	F	68	F	20	24.00278676	9.454667747	3.854587601	-2.094592227	-6.121895277
sub-084	F	71	F	24	22.40793211	9.927376755	4.25377631	-1.339743065	-5.684278318