# CHANGES IN PERIODIC AND APERIODIC SPECTRAL FEATURES DURING SLEEP REFLECT ADVANCING STAGES OF ALZHEIMER'S DISEASE CONTINUUM

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## INTRODUCTION

- Alzheimer's disease (AD) is the leading cause of dementia. It is estimated that 39 million people globally live with AD [1].
- Sleep disturbances are a known symptom of AD that have been reported in early stages of the disease, therefore possibly preceding clinical signs of the disease (Figure 1) [2].
- One of these disturbances is the loss of sleep spindles, burst-like signals in EEG occurring in the sigma (11 – 16 Hz) frequency band and most prevalent in N2 sleep (Figure 2) [3]. Studies have shown there is a bidirectional relationship between the loss of sleep spindles and the progression of AD [4]. Fast spindles (13-16 Hz) have been suggested to play a stronger role in memory consolidation and may be more sensitive to AD-related cognitive decline than slow spindles (11-13 Hz) [5].
- Additionally, the aperiodic exponent, believed to partially reflect the neuronal excitation/inhibition balance, has been shown to be altered in AD during wakefulness [6, 9]. However, aperiodic activity during sleep has not yet been extensively studied in this population.
- The goal of this exploratory study is to quantify these sleep disturbances through quantitative EEG (qEEG) measures in the AD continuum, using periodic and aperiodic spectral features.

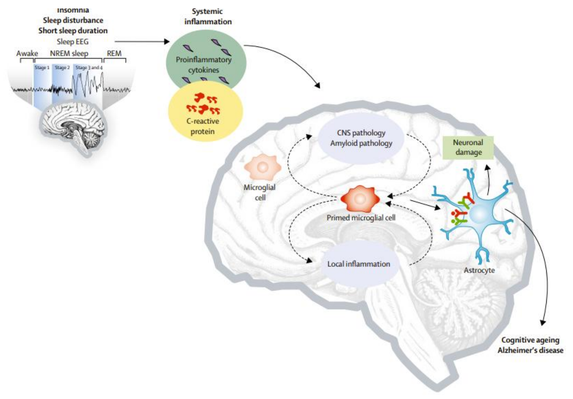


**Figure 1:** Hypothetical model linking sleep disturbances, inflammation, and risk of AD, figure adapted from [7].

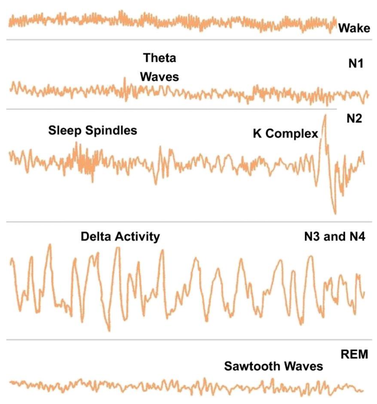


**Figure 2:** EEG patterns in the different sleep stages. Sleep spindles are detected in N2 sleep, figure adapted from [8].

## METHODS

- Overnight 24-channel, 24-hour EEG recordings of healthy controls (**HC**, n = 14), subjects with preclinical AD (**preclAD**, n = 7), mild cognitive impairment due to AD (**MCI**, n = 20) and AD dementia (**ADD**, n = 6) from the University Hospital Brussels were analyzed retrospectively.
- For each recording, **automatic sleep staging** was performed and 10 minutes of N2 and N3 sleep were selected based on automatically computed **signal quality metrics** [10].
- The extracted segments were band-pass filtered between 0.5 and 100 Hz, with a 50 Hz notch filter applied to suppress line noise. Signals were re-referenced to the common average, and eye-movement artefacts were removed using independent component analysis (ICA).
- The **power spectral density** (PSD) was computed using Welch's method with 6 s epochs and subsegments of 3 s with a 2 s overlap.
- The FOOOF algorithm was used to decompose the power spectrum into a periodic and an aperiodic component (Figure 3). The periodic (oscillatory) power was computed in the sigma (11-16 Hz) frequency band and the aperiodic exponent was computed from the aperiodic component [9]. Both **periodic sigma power** and the **aperiodic exponent** were computed from the PSD in **N2** and **N3 sleep**.

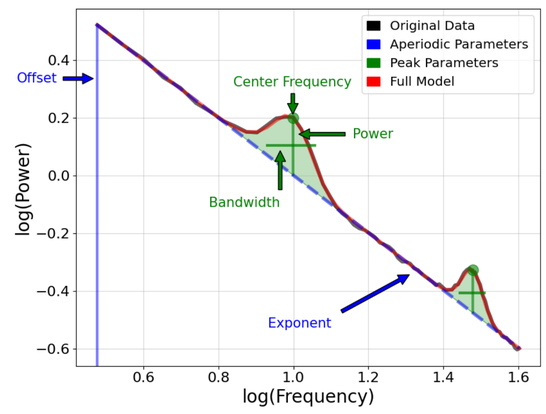


**Figure 3:** Decomposition of neural power spectra into aperiodic and oscillatory components, figure adapted from [9].

## RESULTS

### 1 – Decrease in N2 periodic sigma power in ADD

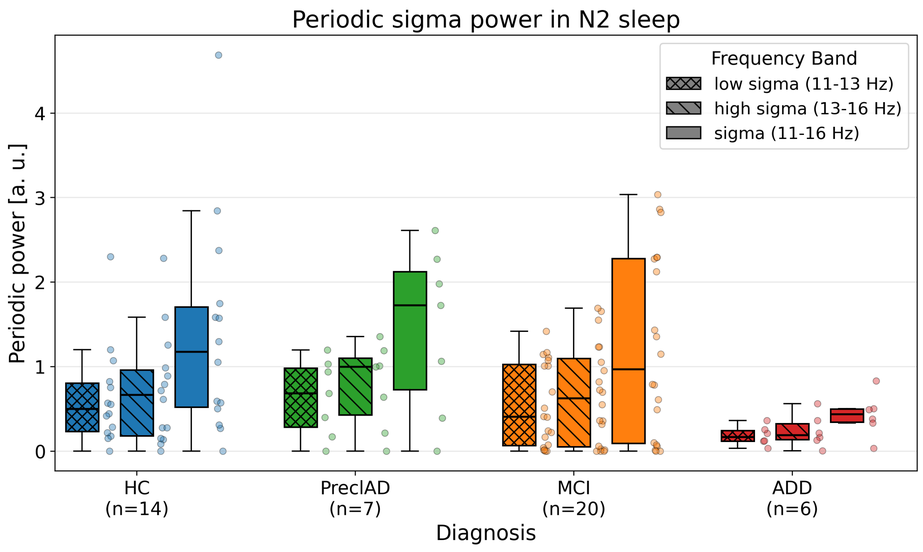


**Figure 4:** Periodic low, high and total sigma power in the four diagnostic groups.

- A large decrease in periodic sigma power was observed in subjects with ADD compared to HC.
- No clear differences in periodic sigma power were observed between subjects with PreClAD, MCI and HC.
- Low sigma (11-13 Hz) and high sigma (13-16 Hz) power followed a similar trend across the AD continuum.
- This trend was not observed in N3 sleep.

### 2 – Gradual decrease in N2 and N3 aperiodic exponent along AD continuum

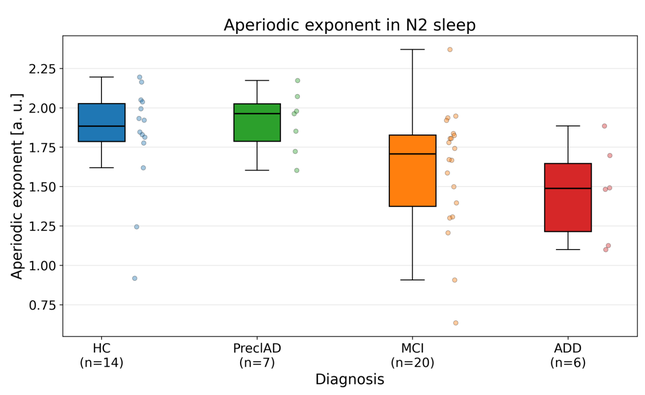


**Figure 5:** Aperiodic exponent in N2 sleep in the four diagnostic groups.

- A gradual decrease in aperiodic exponent was observed in N2 sleep across the AD continuum.
- On average, subjects with ADD exhibited the lowest values of aperiodic exponent.

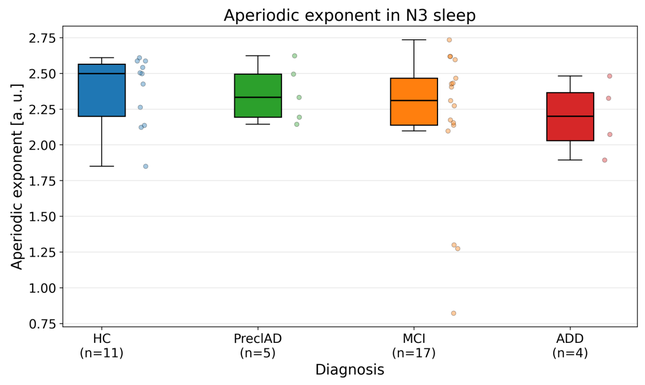


**Figure 6:** Aperiodic exponent in N3 sleep in the four diagnostic groups.

- As in N2, a similar gradual decrease was observed in the N3 aperiodic exponent across the AD continuum.
- Compared to N2, the observed decrease in the aperiodic exponent is attenuated.

## CONCLUSION

- Reduced periodic sigma power in subjects with ADD compared to HC suggests loss of sleep spindles, which could reflect impaired memory consolidation and intellectual ability [5].
- A reduced aperiodic exponent in N2 and N3 sleep for subjects with MCI and ADD could reflect an excitation/inhibition (E/I) imbalance favoring excitation. Several E/I imbalances have previously been described in sleep in AD, such as subclinical epileptiform discharges [11] and disrupted slow-wave activity [12]. Future research should investigate if the identified change in aperiodic exponent is reflective of any of these mechanisms.
- This exploratory study shows that periodic and aperiodic spectral features of overnight EEG recordings offer complementary insights into neurophysiological changes across the AD continuum. These preliminary results should be confirmed in a larger sample size.

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