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SCIENTIFIC INVESTIGATIONS

The association between sleep microarchitecture and cognitive function in middle-aged and older men: a community-based cohort study

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Study Objectives: Sleep microarchitecture parameters determined by quantitative power spectral analysis of electroencephalograms have been proposed as potential brain-specific markers of cognitive dysfunction. However, data from community samples remain limited. This study examined cross-sectional associations between sleep microarchitecture and cognitive dysfunction in community-dwelling men.

Methods: Florey Adelaide Male Ageing Study participants (n = 477) underwent home-based polysomnography (2010–2011). All-night electroencephalogram recordings were processed using quantitative power spectral analysis following artifact exclusion. Cognitive testing (2007–2010) included the inspection time task, Trail-Making Tests A and B, and Fuld object memory evaluation. Complete case cognition, polysomnography, and covariate data were available in 366 men. Multivariable linear regression models controlling for demographic, biomedical, and behavioral confounders determined cross-sectional associations between sleep microarchitecture and cognitive dysfunction overall and by age-stratified subgroups.

Results: In the overall sample, worse Trail-Making Test A performance was associated with higher rapid eye movement (REM) theta and alpha and non-REM theta but lower delta power (all $P < .05$). In men ≥ 65 years, worse Trail-Making Test A performance was associated with lower non-REM delta but higher non-REM and REM theta and alpha power (all $P < .05$). Furthermore, in men ≥ 65 years, worse Trail-Making Test B performance was associated with lower REM delta but higher theta and alpha power (all $P < .05$).

Conclusions: Sleep microarchitecture parameters may represent important brain-specific markers of cognitive dysfunction, particularly in older community-dwelling men. Therefore, this study extends the emerging community-based cohort literature on a potentially important link between sleep microarchitecture and cognitive dysfunction. The utility of sleep microarchitecture for predicting prospective cognitive dysfunction and decline warrants further investigation.

Keywords: obstructive sleep apnea, quantitative EEG, sleep microarchitecture, power spectral analysis, community, impairment, prospective

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BRIEF SUMMARY

Current Knowledge/Study Rationale: Preliminary evidence predominantly derived from small clinical and case-controlled studies suggests sleep microarchitecture determined by quantitative power spectral analysis of electroencephalograms may represent an important brain-specific marker of cognitive dysfunction. However, previous small studies have not controlled for potential confounders, leaving the nature of this association unclear.

Study Impact: This cross-sectional study is one of the first to report that in a community sample worse focused attention and processing speed (Trail-Making Test A performance) and executive function (Trail-Making Test B performance) are independently associated with sleep microarchitecture in older community-dwelling men (≥ 65 years). These data extend the emerging community-based cohort literature and provide further evidence suggesting sleep microarchitecture may represent an important brain-specific marker of cognitive dysfunction.

INTRODUCTION

Cognitive dysfunction affects a considerable proportion of the general population and is particularly prevalent among older adults.[1,2] Insufficient sleep and sleep disorders are similarly associated with cognitive dysfunction.[3] Emerging evidence, predominantly derived from small samples, suggests sleep microarchitecture may be associated with daytime cognitive dysfunction.[4] However, evidence from community samples controlling for potential confounders remains scarce, leaving the nature of this association unclear.

Sleep microarchitecture parameters determined by quantitative power spectral analysis of electroencephalograms (EEGs) may represent important brain-specific markers of cognitive dysfunction.[4] However, as reviewed by D'Rozario et al,[2] the emerging evidence is inconsistent. Three small case-controlled

studies previously examined sleep microarchitecture in patients with mild cognitive impairment (MCI) compared to age-matched controls.[5–7] Westerberg et al[5] identified that patients with amnestic MCI (aMCI) (n = 18) showed lower rapid eye movement (REM) sleep theta activity and low-frequency non-REM (NREM) sleep delta and theta activity compared to controls (n = 10). Brayet et al[7] identified that patients with aMCI (n = 22) showed greater REM EEG slowing (ratio of slow to fast EEG frequencies) compared to controls (n = 33). Gorgoni et al[6] identified that patients with aMCI showed lower NREM fast spindle density (number/minute of ~13- to 16-Hz EEG bursts, ≥ 0.5 and ≤ 3 seconds) compared to controls (both n = 15). In a population-based case-controlled study, the Study of Osteoporotic Fractures (n = 85 MCI cases and n = 85 age-matched controls), Djonlagic et al[8] reported that community-dwelling women ≥ 65 years who had developed MCI 5 years after a baseline sleep study exhibited higher NREM alpha and theta activity and REM alpha and sigma activity compared to controls. In a similarly sized study, Waser et al[9] reported that men with cognitive decline from early to late adulthood showed greater NREM EEG slowing compared to men without cognitive decline. Although previous case-controlled studies have investigated differences in sleep microarchitecture parameters between patients with MCI or cognitive decline and controls, these have not thoroughly examined associations between sleep microarchitecture and cognitive dysfunction.

Ageing is associated with an increase in sleep disorders such as obstructive sleep apnea (OSA), which is characterized by repeated complete (apnea) or partial (hypopnea) pharyngeal upper airway collapse.[10] These nocturnal events lead to intermittent hypoxemia and hypercapnia, augmented breathing, sleep fragmentation, and blood pressure surges associated with frequent arousals.[11] Sleep microarchitecture has also been impaired in patients with OSA relative to matched controls.[4,12–14] Reported abnormalities include lower NREM delta activity,[14–16] higher fast-frequency beta activity,[15,16] decreased spindle frequency and occurrence,[17] reduced K-complex density (number/minute of < 1-Hz EEG bursts),[18] and greater REM EEG slowing.[12,13]

A community-based cohort study (n = 664) reported that increased intermittent hypoxemia was independently associated with greater REM EEG slowing and higher NREM fast-frequency beta activity.[19] Another community-based cohort study (n = 3,819) that recruited late middle-aged and older participants from 2 independent community-based cohorts, the Multi-Ethnic Study of Atherosclerosis and Osteoporotic Fractures in Men Study, found lower NREM delta activity was associated with worse executive function while accounting for OSA and other potential confounders.[20] However, no additional community-based cohort studies have investigated potential links between sleep microarchitecture and cognitive dysfunction while accounting for OSA and other potential confounders. Furthermore, no community-based cohort studies have determined whether sleep microarchitecture parameters are differentially associated with cognitive dysfunction among early to middle-aged vs older community-dwelling participants.

The primary aim of the present study was to extend the emerging community-based cohort literature by examining cross-sectional associations between sleep microarchitecture and cognitive dysfunction in community-dwelling men. A secondary aim was to examine cross-sectional associations between sleep microarchitecture and cognitive dysfunction in early to middle-aged (< 65 years) and older (≥ 65 years) men to determine whether sleep microarchitecture is differentially associated with cognitive dysfunction among early to middle-aged vs older community-dwelling men. It was hypothesized that lower NREM delta power, higher power in faster-frequency EEG bands during NREM sleep, and greater REM EEG slowing would be independently associated with worse cognitive function.

METHODS

Study participants

The Men Androgen Inflammation Lifestyle Environment and Stress (MAILES) study comprises 2,569 unselected urban community-dwelling men harmonized from 2 independent prospective population-based cohorts; all participants of the Florey Adelaide Male Ageing Study (FAMAS) and male participants of the North West Adelaide Health Study.[21] The present study includes FAMAS participants (n = 1,195) aged 35–80 years at baseline (2002) and living in the northern and western regions of Adelaide, South Australia.[22,23]

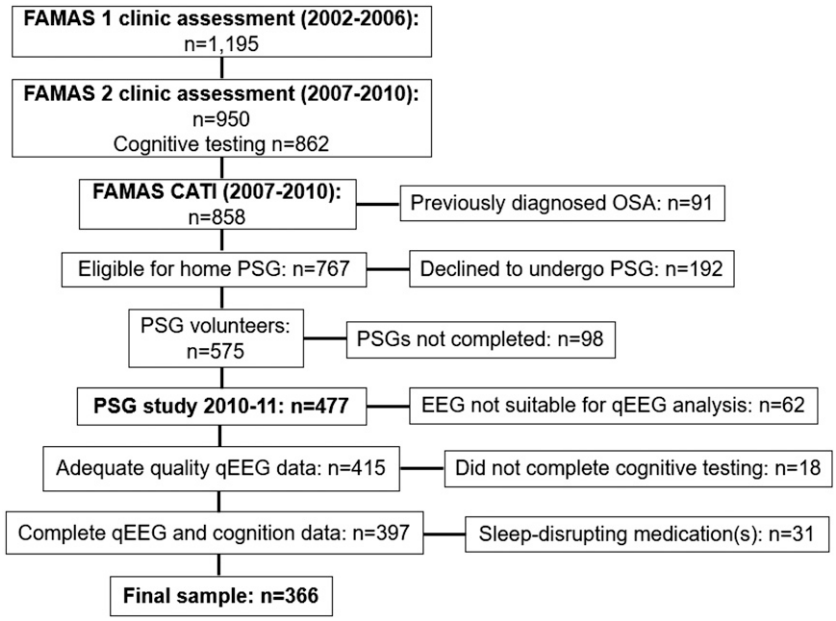
During a computer-assisted telephone interview follow-up in 2010 (n = 858), FAMAS participants who reported no previous OSA diagnosis (n = 767) were invited to undergo unattended home-based 8-channel polysomnography (PSG) (2010–2011) as part of a substudy of the MAILES study.[21,24] Approximately 75% of eligible participants (n = 575) agreed to undergo PSG. However, 98 PSGs were not completed due to time and budget constraints leading to a final PSG sample of 477 (**Figure 1**). As previously described, there was minor healthy volunteer responder bias with participants who underwent PSG.[25] Participants who underwent PSG were on average younger, less obese, and less commonly reported poor general health compared to participants who did not undergo PSG.[25] FAMAS was conducted in accordance with the Declaration of Helsinki and approved by the Royal Adelaide Hospital Human Research Ethics Committee (approval number: 020305). All participants provided written informed consent.

Sleep study assessment

Participants underwent home-based 8-channel ambulatory PSG (Embletta X100; Embla Systems, Thornton, CO), which recorded electrical brain activity (EEG, F4-M1) and left electrooculography (EOG) with a 12-bit signal resolution, a sampling rate of 200 Hz, and band-pass filters (0.3–35 Hz) along with submental electromyography (EMG), nasal cannula pressure, thoracic and abdominal motion, finger pulse oximetry, and body position. Before PSG set-up, trained staff obtained anthropometric measurements (height, weight, and body mass index [BMI, kg/m^2]).

A single experienced sleep technician manually scored all PSG measures according to 2007 American Academy of Sleep Medicine (AASM) *alternative* scoring criteria,[26] which was recommended by an expert panel of the Australasian Sleep Association for use in prospective epidemiological studies.[27] OSA was identified by an apnea-hypopnea index (AHI) ≥10 events/h and further categorized as mild (10–19 events/h), moderate (20–29 events/h),

Figure 1—Clinical and sleep study assessments and cognitive function testing.



CATI = computer-assisted telephone interview, EEG = electroencephalography, FAMAS = Florey Adelaide Male Ageing Study, OSA = obstructive sleep apnea, PSG = polysomnography, qEEG = quantitative electroencephalography.

or severe (AHI ≥ 30 events/h). Ruehland et al have shown that an AHI of 5 events/h used to define sleep-disordered breathing by the AASM 2007 *recommended* criteria is approximately equivalent to 10 events/h using the *alternative* criteria and 15 events/h using the older 1999 *Chicago* criteria.[26] Therefore, an AHI cut-off of 10 events/h was chosen to maintain comparability with previous work. Apnea was defined as complete or near-complete airflow cessation (≥ 90%) measured using nasal cannula pressure excursions with breathing lasting ≥ 10 seconds. Hypopnea was defined as a ≥ 50% decrease in nasal cannula pressure excursions along with an associated ≥ 3% oxygen desaturation or EEG arousal.[26] Sleep hypoxemia was assessed from the percentage of total sleep time with oxygen saturation < 90%.[26] Sleep studies were considered acceptable with ≥ 3.5 hours of sleep and ≥ 5.5 hours of total-recorded study time with technically acceptable respiratory and EEG signal quality for the majority of the recording.

EEG data processing

A detailed description of quantitative EEG (qEEG) analysis used in this study has been previously described.[28,29] Synchronized European Data Format and sleep stage files were generated using Embla REMLogic PSG Software (Natus Medical, Inc., Pleasanton, California). Of the 477 men who underwent sleep studies, PSG data were of adequate quality for qEEG analysis in 415. An algorithm identified artifactual EEG data over consecutive nonoverlapping 5-second epochs based on previously validated artifact detection amplitude threshold parameters.[28] Contaminated 5-second epochs, including arousals where EEG traces went outside the amplitude boundaries, were subsequently excluded from qEEG analysis.

Manual verification of automated artifact scoring accuracy

Automated artifact scoring accuracy was verified by manual review in 10% of randomly selected PSGs (n = 36). Four agreement measures were calculated, including accuracy, sensitivity, specificity, and Cohen's kappa (k). Consistent with the original artifact detection validation study,[28] our algorithm displayed excellent accuracy (mean ± standard deviation) (96.6% ± 4.4%) and specificity (99.9% ± 28.1%) and good to moderate sensitivity (59.1% ± 0.1%) and agreement (k = 0.68 ± 0.26).

EEG power spectral analysis

After rejecting artifactual epochs, power spectra were obtained using a standard fast Fourier transform algorithm with a rectangular weighting window for each nonoverlapping 5-second epoch of EEG. Absolute spectral power (μV^2) was calculated in the delta, theta, alpha, sigma, and beta frequency bands and was defined as EEG activity of 0.5–4.5, 4.5–8, 8–12, 12–15, and 15–32 Hz, respectively, during NREM and REM sleep. The EEG power for each sleep-staged 30-second epoch was calculated by averaging data from 6 artifact-free 5-second epochs that made up each 30-second recording segment. The weighted average spectral power or spectral variance over the frequency interval within the defined frequency bands was computed for NREM (N2 and N3) and REM sleep. Weighted average spectral power is a weighted average, based on sleep stage or type, that was calculated by averaging the absolute power of 30-second epochs of the EEG. Relative spectral power for each frequency band during NREM and REM sleep (eg, delta/delta + theta + alpha + sigma + beta) was calculated. A global measure of NREM and

REM EEG slowing (ie, a ratio of slow to fast EEG frequencies ([delta + theta]/[alpha + sigma + beta]) was also calculated.

Cognitive assessments

Participants completed 4 standardized, validated, and well-established cognitive tests outlined below during the 2007–2010 follow-up as previously described in greater detail.[30] The average time lag between cognitive and PSG testing was 26 (range, 3–51) months. Health Study participants completed PSG testing, only FAMAS participants completed both the cognitive and PSG assessments, thus comprising the sample included in all analyses.

Inspection time task

This inspection time task measured visual processing speed determined as the average duration in milliseconds that a stimulus was presented to participants before they correctly identified which of 2 vertical lines displayed on a screen was longer on ≥ 75% of trials.[31] As a measure of the early stage of information processing, inspection time was associated with cognitive ageing.[32] Impairments in inspection time have also been associated with the severity of Alzheimer's disease.[33]

Trail-Making Test

The Trail-Making Test (TMT) assesses visual search, scanning, processing speed, mental flexibility, focused attention, and executive function.[34,35] The test consisted of 2 parts requiring participants to map out a sequential path. TMT-A is a focused-attention measure requiring participants to connect encircled numbers (1–25) in sequence.[36] TMT-B was an executive function measure requiring participants to connect circles containing numbers with the corresponding letters in the appropriate sequence (1–A, 2–B, 3–C, etc).[36] The time, in seconds, needed to complete each path was scored.

Fuld object memory evaluation

The Fuld object memory evaluation (FOME) test utilizes multiple sensory pathways (tactile, visual, and verbal) to assess working memory performance.[37] This multisensory method evaluates encoding, storage, and retrieval of unrelated objects. The maximum possible score is 10, with higher scores representing intact memory and lower scores impaired memory. The FOME test helps identify memory decline, and low scores may indicate dementia.[38]

Covariate assessments

Self-completed questionnaires determined demographic (age, financial stress [spends > earns vs saves a little/lot], highest educational attainment [≥diploma, certificate, trade, bachelor's degree or higher vs ≤ high school], and marital status [married/partner vs other]) and other health-related (current smoking status, alcohol intake, and physical activity [low/moderate/vigorous vs sedentary behavior]) risk factors and quality of life (the 36-item short-form survey instrument [SF-36]). BMI was categorized according to international criteria from the World Health Organization (< 25 [underweight/normal], 25 to < 30 [overweight], and ≥ 30 kg/m^2 [obese]).[39] Relative social disadvantage, based on participants' residential postcode, was determined with the Australian Bureau of Statistics' Socio-Economic Indexes for Areas (SEIFA) Index of Relative Socio-Economic Disadvantage.[40] Clinic assessment (2007–2010) included anthropometry (BMI and waist circumference), seated sphygmomanometer blood pressure, and a fasting blood sample to assess blood glucose.[22] Composite cardiovascular disease (self-reported, doctor-diagnosed myocardial infarction, angina, transient ischemic attack, or stroke) and diabetes mellitus (self-reported, doctor-diagnosed, fasting plasma glucose ≥ 7.0 mmol/L [126 mg/dL], hemoglobin A1C [≥ 6.5%], or reported antidiabetic medication use [oral hypoglycemic agents and/or insulin]) were also determined. Men were classified as having insomnia symptoms if they reported difficulty initiating or maintaining sleep occurring at least 3 nights per week (Pittsburgh Sleep Quality Index dimensions) and significant daytime fatigue defined as an SF-36 Vitality Scale score 1 standard deviation below the mean.[41] Hypertension was defined as systolic blood pressure ≥ 140 mm Hg and/or diastolic blood pressure ≥ 90 mm Hg or reported antihypertensive medication use.[42]

Statistical analysis methodology

Complete case cognition, PSG, and covariate data were available in 366 men. Data were analyzed using IBM SPSS version 25.0 (IBM Corporation, Armonk, New York). Descriptive statistics for NREM and REM relative spectral powers, cognitive test scores, and continuous covariates are reported as mean standard deviation. NREM and REM EEG slowing ratio is reported as median due to nonnormality. For descriptive analyses, dichotomous and categorical risk factor covariates are reported as percentages (proportion).

For analysis of cognitive function in relation to demographic, biomedical, and behavioral risk factors, 1-way analyses of variance and independent samples *t* tests were performed. Mann-Whitney *U* tests were used to test for differences in NREM and REM EEG slowing ratio between middle-aged (< 65 years) and older (≥ 65 years) men. Moreover, independent samples *t* tests were used to test for differences in NREM and REM relative spectral powers between middle-aged and older men. Pearson's chi-squared tests were used to examine differences in demographic, biomedical, and behavioral risk factors between middle-aged and older men.

Univariable and multivariable linear regression models determined cross-sectional associations of cognitive dysfunction with NREM and REM relative spectral powers and logarithmically (10-base) transformed EEG slowing ratio. Unstandardized beta (*B*) coefficients (95% confidence interval [CI]) and adjusted R^2 values are reported. For each sleep microarchitecture metric, 3 covariate-adjusted regression models were constructed. Model 1 was adjusted for age and OSA; model 2 was additionally adjusted for demographic (financial stress, education, socioeconomic disadvantage, and marital status) risk factors; and model 3 was additionally adjusted for total sleep time and biomedical and behavioral (BMI, alcohol risk, current smoking status, cardiovascular disease, diabetes mellitus, blood glucose, insomnia, and hypertension) risk factors. Age, BMI, blood glucose, and total sleep time were treated continuously, with all other covariates treated dichotomously or categorically.

Moderator analysis was performed using age × qEEG as an interaction term to determine if age significantly moderated observed fully adjusted associations between sleep microarchitecture and cognitive dysfunction. After identifying significant

moderation, age-stratified (< 65 vs ≥ 65 years) linear regression analyses were performed to determine if sleep microarchitecture parameters were differentially associated with cognitive dysfunction among early to middle-aged vs older community-dwelling men.

For age-stratified multivariable linear regression analyses, the purposeful-selection-of-covariates procedure proposed by Hosmer and Lemeshow[43] was applied to construct a robust multivariable model. Accordingly, unadjusted analyses were first performed to examine crude associations between covariates and cognitive outcomes, with covariates returning P-values < 0.25 selected as potential candidates for adjustment. Nonsignificant covariates were gradually removed until only significant covariates remained. Covariates not initially selected as potential candidates for adjustment were then gradually re-added with the significant covariates retained earlier to identify which of these covariates were important in the presence of initially selected covariates. This purposeful covariate selection procedure reduced the final multivariable model to 8 covariates, including age, AHI, financial stress, socioeconomic disadvantage, marital status, education, total sleep time, and cardio-metabolic conditions (including 1 or more of diabetes, hypertension, or cardiovascular disease).

Assumptions of linear regression modeling, including linearity, independence, homoscedasticity, and normality, were met. Furthermore, all variance inflation factor values were near 1, indicating absence of multicollinearity. For all analyses, a 2-sided $P < .05$ was considered statistically significant. No multiple comparison adjustments were performed.[44,45]

RESULTS

Of the 477 men who underwent PSG, 397 had adequate quality sleep microarchitecture and cognition data available for analysis. In total, 366 men were included in the analysis after excluding 31 (7.8%) who reported regularly using psychoactive medication(s), including opiates, antipsychotics, antiepileptics, antidepressants, or benzodiazepines, which may potentially disrupt sleep microarchitecture.

Participant characteristics

Participant characteristics, overall and stratified by age, are reported in **Table 1**. Of the men included in the analysis, 52.5% had at least mild OSA (AHI ≥ 10 events/h), and 12.9% had severe OSA (AHI ≥ 30 events/h). Approximately one-third (31.7%) were obese (BMI ≥ 30 kg/m^2). Higher age, lower education, diabetes, and presence of 1 or more cardio-metabolic conditions were associated with worse cognitive function (**Table S1** in the supplemental material).

Men ≥ 65 years (n = 109) had more severe OSA and a higher incidence of cardiovascular disease, diabetes, hypertension, and 1 or more cardio-metabolic conditions compared to men < 65 years (n = 257). Men ≥ 65 years also showed lower total sleep time compared to men < 65 years. Furthermore, men ≥ 65 years showed higher NREM theta power compared to men < 65 years. However, there were no other age group differences in sleep microarchitecture.

Associations of NREM and REM sleep microarchitecture parameters with cognitive dysfunction in the overall sample

The reported unstandardized beta coefficients represent the change in cognitive test scores corresponding to a 1% increase in relative EEG power and a 1-unit increase in logarithmically (10-base) transformed EEG slowing ratio. In the overall sample, worse TMT-A performance was associated with lower NREM and REM delta power, higher NREM and REM theta power, and higher REM alpha power in unadjusted models (**Table 2**). These associations persisted after adjusting for age and OSA (model 1) and demographic factors (model 2) and in fully adjusted models (model 3). Worse TMT-B performance was only associated with higher NREM theta power in an unadjusted model, attenuating after covariate adjustment. Associations of worse TMT-B performance with higher REM theta power were only evident after adjusting for age and OSA and in a fully adjusted model. Associations of worse TMT-B performance with higher REM alpha power were observed in an unadjusted and fully adjusted model (**Table 3**). There were no associations of inspection time (**Table 4**) or FOME performance (**Table S2** in the supplemental material) with NREM or REM sleep microarchitecture in the overall sample.

Effect moderator analysis

Interaction terms of age × qEEG were included to determine if age moderated significant fully adjusted associations between sleep microarchitecture and cognitive function. Age significantly moderated fully adjusted associations of lower NREM delta power (B = 1.31, 95% CI [–1.93, –0.70], $P < .001$), lower REM delta power (B = –0.74, 95% CI [–1.36, –0.11], $P = .021$), higher NREM theta power (B = 1.56, 95% CI [0.96, 2.15], $P < .001$), higher REM theta power (B = 0.85, 95% CI [0.26, 1.44], $P = .005$), and higher REM alpha power (B = 1.03, 95% CI [0.36, 1.71], $P = .003$) with worse TMT-A performance. Age also significantly moderated fully adjusted associations of higher REM theta power (B = 6.35, 95% CI [3.46, 9.24], $P < .001$) and higher REM alpha power (B = 7 .20, 95% CI [3.89, 10.5], $P < .001$) with worse TMT-B performance.

Associations of NREM and REM sleep microarchitecture parameters with cognitive dysfunction in men < 65 years

In men < 65 years, worse TMT-A performance was associated only with higher REM alpha power in an unadjusted model. Slower inspection time was only associated with lower NREM sigma power after adjustment for demographic factors. There were no other associations of cognitive function with sleep microarchitecture in men < 65 years.

Associations of NREM and REM sleep microarchitecture parameters with cognitive dysfunction in men ≥ 65 years

In men ≥ 65 years, worse TMT-A performance was associated with lower NREM delta power but higher NREM theta and alpha power in unadjusted and all 3 adjusted models. Worse TMT-A performance was only associated with higher NREM

Table 1—Participant characteristics (relative spectral powers, EEG slowing ratio, OSA parameters, and demographic and other risk factors).

Participant Characteristics	Overall Sample (n = 366)	< 65 Years (n = 257)	≥ 65 Years (n = 109)
Demographic risk factors			
Age (years), mean (SD)	59.0 (10.4)	53.5 (6.4)	71.9 (5.3)*
Financial stress, % (n)			
Spends > earns	15.3 (56)	14.4 (37)	17.4 (19)
Saves a little/lot	84.7 (310)	85.6 (220)	82.6 (90)
Highest educational attainment, % (n)			
Diploma, certificate, trade, bachelor's degree or higher	71.3 (261)	73.2 (188)	67.0 (73)
SEIFA IRSD, % (n)			
Quintile 1 (highest disadvantage)	21.6 (79)	24.9 (64)	13.8 (15)†
Quintile 2	10.7 (39)	11.7 (30)	8.3 (9)
Quintile 3	29.0 (106)	32.3 (83)	21.1 (23)†
Quintile 4	26.0 (95)	22.6 (58)	33.9 (37)†
Quintile 5 (lowest disadvantage)	12.8 (47)	8.6 (22)	22.9 (25)†
Married/partner, % (n)	85.0 (311)	85.6 (220)	83.5 (91)
Relative spectral powers, mean (SD)			
NREM			
Delta power (0.5–4.5 Hz), %	81.3 (6.9)	81.5 (6.9)	80.8 (6.6)
Theta power (4–8 Hz), %	8.1 (2.7)	7.9 (2.7)	8.5 (2.7)*
Alpha power (8–12 Hz), %	5.3 (2.4)	5.3 (2.5)	5.3 (2.4)
Sigma power (12–15 Hz), %	2.0 (1.0)	2.1 (1.0)	1.9 (1.0)
Beta power (15–32 Hz), %	3.3 (2.0)	3.3 (2.1)	3.5 (1.9)
REM			
Delta power (0.5–4.5 Hz), %	70.1 (9.6)	70 (9.5)	70.3 (10)
Theta power (4.5–8 Hz), %	11.8 (4.1)	11.9 (4.0)	11.6 (4.4)
Alpha power (8–12 Hz), %	6.8 (2.5)	6.8 (2.5)	6.9 (2.7)
Sigma power (12–15 Hz), %	2.9 (1.1)	2.9 (1.1)	2.9 (1.1)
Beta power (15–32 Hz), %	8.4 (3.9)	8.4 (3.9)	8.3 (4.0)
EEG slowing ratios, median (IQR)			
NREM slowing ratio	9.0 (6.8, 12.4)	9.0 (6.7, 12.5)	8.8 (6.8, 12.2)
REM slowing ratio	4.5 (3.4, 6.4)	4.5 (3.4, 6.2)	4.5 (3.2, 6.6)
OSA severity categories (AHI), % (n)			
< 10 events/h	47.5 (162)	50.6 (130)	43.1 (47)†
10–19 events/h	26.7 (91)	28 (72)	22.0 (24)†
20–29 events/h	12.9 (44)	11.3 (29)	18.3 (20)†
≥ 30 events/h	12.9 (44)	10.1 (26)	16.5 (18)†
Other risk factors			
Medium–very high alcohol risk, % (n)	5.2 (19)	6.6 (17)	1.8 (2)†
Low/moderate/vigorous physical activity, % (n)	77.3 (283)	75.1 (193)	82.6 (90)†
BMI (kg/m^2), % (n)			
< 25 (underweight/normal)	19.9 (73)	20.6 (53)	18.3 (20)
25 to < 30 (overweight)	48.4 (177)	48.2 (124)	48.6 (53)
≥ 30 (obese)	31.7 (116)	31.1 (80)	33.0 (36)
Current smokers, % (n)	16.9 (62)	20.2 (52)	9.2 (10)†
Cardiovascular disease, % (n)	6.8 (25)	3.1 (8)	15.6 (17)†
Insomnia, % (n)	12.8 (47)	13.2 (34)	11.9 (13)

(continued on following page)

Table 1—Participant characteristics (relative spectral powers, EEG slowing ratio, OSA parameters, and demographic and other risk factors). (*Continued*)

Participant Characteristics	Overall Sample (n = 366)	< 65 Years (n = 257)	≥ 65 Years (n = 109)
Diabetes mellitus, % (n)	17.2 (63)	13.6 (35)	25.7 (28)†
Hypertension, % (n)	47.0 (172)	40.5 (104)	62.4 (68)†
Cardiometabolic conditions, % (n)	56.6 (204)	48.2 (124)	73.4 (80)†
Total sleep time < 360 minutes, % (n)	36.9 (135)	34.6 (89)	42.2 (46)†

All PSG measures were scored according to AASM 2007 *alternative* scoring criteria in which an AHI of 10 events/h is approximately equivalent to an AHI of 5 events/h used to define sleep-disordered breathing by the AASM 2007 *recommended* scoring criteria. SEIFA IRSD: Socio-Economic Indexes for Areas Index of Relative Socio-Economic Disadvantage; BMI: body mass index categorized according to international criteria from the World Health Organization (< 25 [underweight/normal], 25 to < 30 [overweight], and ≥ 30 kg/m^2 [obese]). Cardiovascular disease: self-reported, doctor-diagnosed myocardial infarction, angina, transient ischemic attack, or stroke. Insomnia: at least 1 of 2 Pittsburgh Sleep Quality Index dimensions (difficulty initiating or maintaining sleep) and significant daytime fatigue defined as an SF-36 Vitality Scale score 1 SD below the mean. Hypertension: systolic blood pressure ≥ 140 mm Hg and/or diastolic blood pressure ≥ 90 mm Hg or reported antihypertensive medication use. Cardiometabolic conditions: a combined variable including 1 or more of diabetes, hypertension, or cardiovascular disease. Mann-Whitney U tests were performed to examine between groups differences in EEG slowing ratio only. However, the differences were no statistically significant. As such, please remove "#Mann-Whitney U test $P < .05$ compared with men <65 years". *Independent samples *t* test $P < .05$ compared with men < 65 years. #Mann-Whitney *U* test $P < .05$ compared with men < 65 years. †Pearson's chi-square test, $P < .05$ compared with men < 65 years. AASM = American Academy of Sleep Medicine, AHI = apnea-hypopnea index, BMI = body mass index, EEG = electroencephalography, FOME = Fuld object memory evaluation, IQR = interquartile range, NREM = non–rapid eye movement, OSA = obstructive sleep apnea, REM = rapid eye movement, SD = standard deviation, SEIFA = Socio-Economic Indexes for Areas, TMT-A = Trail-Making Test A, TMT-B = Trail-Making Test B.

sigma power but lower EEG slowing ratio after adjusting for demographic factors.

Regarding REM sleep microarchitecture parameters, worse TMT-A performance was associated with higher REM theta power in an unadjusted and all 3 adjusted models but higher REM alpha power in an unadjusted model only. Worse TMT-B performance was associated with higher REM theta and alpha power but lower delta power in unadjusted and all 3 adjusted models. However, worse TMT-B performance was only associated with higher REM sigma power after adjustment for demographic factors.

DISCUSSION

This community-based cohort study is 1 of the first to examine cross-sectional associations between qEEG sleep microarchitecture and cognitive dysfunction while accounting for OSA and other potential confounders. In this sample of community-dwelling middle-aged and older men (n = 366), worse focused attention and processing speed (TMT-A performance) was associated with higher NREM theta and REM theta and alpha but lower delta power the overall sample and men ≥ 65 years. Moreover, worse executive function (TMT-B performance) was also associated with higher REM theta and alpha power in the overall sample and men ≥ 65 years. These results contribute to and strengthen the emerging community-based cohort literature suggesting that sleep microarchitecture may represent an important brain-specific marker of cognitive dysfunction.

Previous literature has documented that sleep microarchitecture parameters are associated with neurocognitive disorders. For example, analysis of sleep microarchitecture has been applied in clinical settings to diagnose epilepsy, stroke, traumatic brain injury, depression, learning and attention disorders, and Alzheimer's disease.[2,46–48] Furthermore, several small case-controlled studies have examined differences in NREM and REM sleep microarchitecture parameters between older patients with MCI and matched controls. Reported findings include higher NREM delta and theta power,[5] greater REM EEG slowing ratio,[7] and slower NREM parietal spindle density[6] in patients with MCI compared to matched controls. However, case-controlled studies have not thoroughly examined associations between sleep microarchitecture and cognitive dysfunction.

A recent community-based cohort study[20] investigated the link between sleep architecture and cognitive dysfunction using over 150 objectively measured sleep architecture parameters to identify 23 that were associated with cognitive function. Regarding executive function, Djonlagic et al[20] found that lower NREM delta activity was associated with worse TMT-B performance. When combined with our finding that worse focused attention and processing speed (TMT-A performance) was associated with lower NREM delta power in the overall sample and men ≥ 65 years, these results support the notion that slow-wave activity (0.5–4 Hz) is important for cognitive function.

In contrast with the findings of Djonlagic et al,[20] we did not observe any independent associations of lower NREM delta power with worse TMT-B performance. The contrasting findings may be due to electrode positioning. While Djonlagic et al[20] used multiple electrode sites with statistical adjustment, we used only 1 frontal EEG derivation (F4-M1). The multiple electrode sites used by Djonlagic et al[20] may partly explain their reported association between lower NREM delta power and worse TMT-B performance. Their findings that contrast with our study could also reflect the inclusion of women participants from the Multi-Ethnic Study of Atherosclerosis cohort. Nevertheless, the present and Djonlagic et al[20] studies provide evidence that NREM sleep microarchitecture is independently associated with worse executive function, particularly in older community-dwelling men.

Previous case-controlled studies report greater frontal REM EEG slowing in patients with MCI compared to matched controls.[2] A similar pattern of frontal REM EEG slowing has been

Table 2—Unadjusted and adjusted associations of TMT-A performance with NREM and REM sleep relative powers and EEG slowing ratio.

	Unadjusted Model		Adjusted Model 1		Adjusted Model 2		Adjusted Model 3	
	B (95% CI)	*P*	*B* (95% CI)	*P*	*B* (95% CI)	*P*	*B* (95% CI)	*P*
Overall Sample								
NREM Sleep								
Delta	–0.14 (–0.24, –0.04)	.008	–0.11 (–0.20, –0.02)	.021	–0.11 (–0.20, –0.02)	.022	–0.11 (–0.20, –0.02)	.023
Adjusted R^2	0.02		0.23		0.27		0.28	
Theta	0.53 (0.27, 0.77)	< .001	0.36 (0.14, 0.59)	.002	0.34 (0.12, 0.57)	.003	0.36 (0.14, 0.59)	.002
Adjusted R^2	0.04		0.24		0.28		0.29	
Alpha	0.28 (–0.02, 0.57)	.064	0.23 (–0.03, 0.49)	.081	0.23 (–0.04, 0.49)	.089	0.22 (–0.05, 0.48)	.10
Adjusted R^2	0.007		0.23		0.26		0.27	
Sigma	–0.08 (–0.80, 0.65)	.84	0.34 (–0.31, 0.99)	.31	0.42 (–0.22, 1.06)	.20	0.48 (–0.17, 1.13)	.15
Adjusted R^2	0.003		0.22		0.26		0.27	
Beta	0.22 (–0.13, 0.56)	.23	0.15 (–0.16, 0.46)	.35	0.16 (–0.15, 0.46)	.32	0.13 (–0.18, 0.44)	.42
Adjusted R^2	0.001		0.22		0.26		0.27	
Slowing ratio	–2.46 (–5.85, 0.92)	.15	–2.08 (–5.08, 0.92)	.17	–2.25 (–5.23, 0.73)	.14	–2.12 (–5.13, 0.88)	.17
Adjusted R^2	0.003		0.22		0.26		0.27	
REM Sleep								
Delta	–0.07 (–0.14, 0.008)	.081	–0.07 (–0.13, –0.03)	.041	–0.07 (–0.13, –0.003)	.042	–0.08 (–0.14, –0.009)	.026
Adjusted R^2	0.006		0.23		0.27		0.28	
Theta	0.17 (0.01, 0.35)	.037	0.18 (0.03, 0.33)	.017	0.17 (0.03, 0.32)	.021	0.21 (0.06, 0.36)	.006
Adjusted R^2	0.01		0.23		0.27		0.28	
Alpha	0.35 (0.07, 0.63)	.013	0.28 (0.03, 0.53)	.027	0.29 (0.04, 0.53)	.021	0.34 (0.08, 0.59)	.009
Adjusted R^2	0.02		0.23		0.27		0.28	
Sigma	0.27 (–0.38, 0.91)	.42	0.35 (–0.23, 0.92)	.23	0.37 (–0.21, 0.95)	.21	0.45 (–0.16, 1.05)	.14
Adjusted R^2	0.001		0.22		0.26		0.27	
Beta	0.02 (–0.16, 0.21)	.80	0.06 (–0.10, 0.22)	.47	0.06 (–0.11, 0.22)	.49	0.04 (–0.13, 0.20)	.67
Adjusted R^2	0.003		0.22		0.26		0.27	
Slowing ratio	–0.09 (–0.22, 0.04)	.18	–0.07 (–0.19, 0.05)	.24	–0.08 (–0.19, 0.04)	.18	–0.07 (–0.19, 0.04)	.22
Adjusted R^2	0.002		0.22		0.26		0.27	
Age–Stratified Sample (< 65 years)								
NREM Sleep								
Delta	–0.06 (–0.14, 0.03)	.18	–0.04 (–0.12, 0.04)	.37	–0.03 (–0.12, 0.05)	.44	–0.008 (–0.10, 0.08)	.87
Adjusted R^2	0.003		0.07		0.06		0.07	
Theta	0.19 (–0.02, 0.40)	.082	0.12 (–0.09, 0.33)	.26	0.12 (–0.10, 0.34)	.28	0.09 (–0.13, 0.31)	.42
Adjusted R^2	0.008		0.07		0.07		0.07	
Alpha	0.14 (–0.10, 0.37)	.26	0.08 (–0.15, 0.31)	.50	0.67 (–0.17, 0.31)	.59	0.03 (–0.21, 0.28)	.79
Adjusted R^2	0.001		0.07		0.06		0.07	
Sigma	0.11 (–0.46, 0.68)	.71	0.12 (–0.43, 0.68)	.66	0.08 (–0.49, 0.65)	.77	–0.07 (–0.68, 0.54)	.81
Adjusted R^2	0.003		0.07		0.06		0.07	
Beta	0.09 (–0.18, 0.36)	.51	0.07 (–0.20, 0.33)	.61	0.05 (–0.22, 0.32)	.73	–0.20 (–0.60, 0.19)	.31
Adjusted R^2	0.002		0.07		0.06		0.07	
Slowing ratio	–1.32 (–4.04, 1.41)	.34	–0.81 (–3.45, 1.84)	.55	–0.67 (–3.41, 2.08)	.63	–0.14 (–3.01, 2.72)	.92
Adjusted R^2	0.000		0.07		0.06		0.07	
REM Sleep								
Delta	–0.06 (–0.12, 0.001)	.055	–0.05 (–0.11, 0.01)	.13	–0.04 (–0.11, 0.02)	.17	–0.04 (–0.10, 0.03)	.23
Adjusted R^2	0.01		0.08		0.07		0.07	
Theta	0.13 (–0.01, 0.28)	.073	0.10 (–0.05, 0.24)	.18	0.09 (–0.05, 0.24)	.20	0.09 (–0.06, 0.24)	.23

(continued on following page)

Table 2—Unadjusted and adjusted associations of TMT-A performance with NREM and REM sleep relative powers and EEG slowing ratio. (*Continued*)

	Unadjusted Model		Adjusted Model 1		Adjusted Model 2		Adjusted Model 3	
	***B* (95% CI)**	***P***	***B* (95% CI)**	***P***	***B* (95% CI)**	***P***	***B* (95% CI)**	***P***
Adjusted R^2	0.009		0.08		0.07		0.07	
Alpha	0.25 (0.02, 0.49)	.036	0.17 (–0.07, 0.40)	.16	0.18 (–0.06, 0.42)	.14	0.14 (–0.10, 0.38)	.26
Adjusted R^2	0.01		0.08		0.07		0.07	
Sigma	0.47 (–0.06, 1.00)	.082	0.32 (–0.19, 0.84)	.22	0.32 (–0.23, 0.86)	.25	0.27 (–0.28, 0.82)	.33
Adjusted R^2	0.008		0.08		0.07		0.07	
Beta	0.08 (–0.08, 0.23)	.33	0.08 (–0.07, 0.22)	.31	0.06 (–0.09, 0.21)	.43	0.05 (–0.10, 0.21)	.51
Adjusted R^2	0.000		0.07		0.06		0.07	
Slowing ratio	–0.05 (–0.16, 0.05)	.32	–0.04 (–0.14, 0.07)	.50	–0.03 (–0.14, 0.07)	.55	–0.03 (–0.13, 0.08)	.63
Adjusted R^2	0.000		0.07		0.06		0.07	
Age–Stratified Sample (≥ 65 years)								
NREM Sleep								
Delta	–0.39 (–0.67, –0.11)	.007	–0.38 (–0.64, –0.12)	.004	–0.36 (–0.61, –0.12)	.004	–0.34 (–0.59, –0.08)	.011
Adjusted R^2	0.06		0.21		0.34		0.31	
Theta	1.08 (0.48, 1.68)	.001	1.00 (0.44, 1.56)	.001	0.88 (0.34, 1.42)	.002	0.84 (0.29, 1.39)	.003
Adjusted R^2	0.11		0.24		0.35		0.33	
Alpha	0.87 (0.07, 1.68)	.034	0.85 (0.10, 1.59)	.027	0.82 (0.12, 1.52)	.022	0.73 (0.009, 1.45)	.047
Adjusted R^2	0.04		0.18		0.31		0.29	
Sigma	1.10 (–1.19, 3.38)	.34	1.66 (–0.45, 3.78)	.12	2.06 (0.07, 4.04)	.043	1.81 (–0.31, 3.93)	.093
Adjusted R^2	0.001		0.16		0.30		0.28	
Beta	0.56 (–0.52, 1.64)	.31	0.60 (–0.41, 1.60)	.24	0.70 (–0.25, 1.65)	.14	0.63 (–0.59, 1.84)	.31
Adjusted R^2	0.001		0.15		0.29		0.26	
Slowing ratio	–6.86 (–16.2, 2.51)	.15	–8.20 (–16.9, 0.45)	.063	–8.24 (–16.4, –0.12)	.047	–7.07 (–15.7, 1.57)	.11
Adjusted R^2	0.01		0.17		0.30		0.28	
REM Sleep								
Delta	–0.13 (–0.31, 0.05)	.14	–0.14 (–0.30, 0.03)	.096	–0.14 (–0.29, 0.01)	.070	–0.14 (–0.30, 0.02)	.080
Adjusted R^2	0.01		0.16		0.30		0.28	
Theta	0.39 (0.005, 0.78)	.047	0.39 (0.03, 0.74)	.034	0.38 (0.04, 0.71)	.027	0.41 (0.07, 0.75)	.019
Adjusted R^2	0.03		0.17		0.31		0.30	
Alpha	0.61 (–0.05, 1.27)	.068	0.65 (0.04, 1.26)	.038	0.68 (0.11, 1.24)	.019	0.66 (0.07, 1.25)	.029
Adjusted R^2	0.02		0.17		0.32		0.29	
Sigma	0.51 (–1.18, 2.21)	.55	0.79 (–0.78, 2.36)	.32	0.98 (–0.52, 2.48)	.20	0.79 (–0.79, 2.37)	.32
Adjusted R^2	0.007		0.14		0.28		0.26	
Beta	0.008 (–0.47, 0.48)	.97	0.03 (–0.41, 0.47)	.90	0.04 (–0.39, 0.46)	.87	–0.009 (–0.46, 0.44)	.97
Adjusted R^2	0.01		0.13		0.27		0.25	
Slowing ratio	–0.18 (–0.54, 0.18)	.33	–0.28 (–0.61, 0.06)	.10	–0.24 (–0.55, 0.08)	.14	–0.20 (–0.53, 0.12)	.22
Adjusted R^2	0.000		0.16		0.29		0.27	

Multicollinearity tests displayed the acceptable variance inflation factor for all covariates; AHI was scored according to AASM 2007 *alternative* scoring criteria in which an AHI of 10 events/h is approximately equivalent to an AHI of 5 events/h used to define sleep-disordered breathing by the AASM 2007 *recommended* scoring criteria. Coefficients: unstandardized beta (B) coefficients (95% CI) from univariable and multivariable linear regression models are reported. Estimates: Estimates represent the change in cognitive test scores corresponding to a 1% increase in relative spectral power and a 1-unit increase in logarithmically (10-base) transformed EEG slowing ratio. Relative spectral powers: delta: 0.5–4 Hz, theta: 4.5–8 Hz, alpha: 8–12 Hz, sigma: 12–15 Hz, beta: 15–32 Hz. EEG slowing ratio: calculated as a ratio of slow to fast EEG frequencies ([delta + theta]/[alpha + sigma + beta]). Adjusted Model 1: adjusted for age and AHI. Adjusted Model 2: adjusted for age, AHI, financial stress, highest educational attainment, socioeconomic disadvantage, and marital status. Adjusted Model 3 (overall sample): adjusted for age. Adjusted Model 3 (age-stratified samples): adjusted for age, AHI, total sleep time, financial stress, highest educational attainment, socioeconomic disadvantage, marital status, and cardio-metabolic conditions (1 or more of diabetes mellitus, hypertension, or cardiovascular disease). Significant associations are underlined. AASM = American Academy of Sleep Medicine, AHI = apnea-hypopnea index, CI = confidence interval, EEG = electroencephalography, NREM = nonrapid eye movement, REM = rapid eye movement, TMT-A = Trail-Making Test A.

Table 3—Unadjusted and adjusted associations of TMT-B performance with NREM and REM sleep relative powers and EEG slowing ratio.

	Unadjusted Model		Adjusted Model 1		Adjusted Model 2		Adjusted Model 3	
	B (95% CI)	*P*	*B* (95% CI)	*P*	*B* (95% CI)	*P*	*B* (95% CI)	*P*
Overall Sample								
NREM Sleep								
Delta	–0.51 (–1.03, 0.007)	.053	–0.35 (–0.81, 0.11)	.14	–0.28 (–0.74, 0.19)	.24	–0.31 (–0.77, 0.16)	.19
Adjusted R^2	0.008		0.22		0.26		0.27	
Theta	1.95 (0.68, 3.21)	.003	1.12 (–0.02, 2.26)	.054	0.83 (–0.31, 1.97)	.15	0.90 (–0.25, 2.05)	.13
Adjusted R^2	0.02		0.22		0.26		0.27	
Alpha	0.69 (–0.79, 2.17)	.36	0.44 (–0.87, 1.76)	.51	0.23 (–1.08, 1.53)	.73	0.32 (–0.99, 1.64)	.63
Adjusted R^2	0.000		0.22		0.25		0.26	
Sigma	–1.06 (–4.66, 2.54)	.56	0.90 (–2.32, 4.12)	.58	0.99 (–2.20, 4.20)	.54	1.50 (–1.77, 4.77)	.37
Adjusted R^2	0.002		0.22		0.26		0.27	
Beta	1.40 (–0.33, 3.12)	.11	1.05 (–0.48, 2.59)	.18	0.97 (–0.54, 2.48)	.21	1.01 (–0.54, 2.56)	.20
Adjusted R^2	0.004		0.22		0.26		0.27	
Slowing ratio	–7.54 (–24.4, 9.34)	.38	–5.38 (–20.4, 9.59)	.48	–4.45 (–19.3, 10.4)	.56	–4.79 (–19.8, 10.3)	.53
Adjusted R^2	0.001		0.22		0.26		0.26	
REM Sleep								
Delta	–0.23 (–0.60, 0.13)	.20	–0.24 (–0.56, 0.09)	.15	–0.24 (–0.56, 0.08)	.14	–0.29 (–0.62, 0.05)	.091
Adjusted R^2	0.002		0.22		0.26		0.27	
Theta	0.75 (–0.08, 1.59)	.076	0.75 (0.02, 1.49)	.045	0.68 (–0.04, 1.41)	.064	0.80 (0.04, 1.55)	.039
Adjusted R^2	0.006		0.22		0.26		0.27	
Alpha	1.43 (0.04, 2.83)	.044	1.04 (–0.20, 2.28)	.10	1.09 (–0.14, 2.31)	.082	1.43 (0.15, 2.70)	.028
Adjusted R^2	0.009		0.22		0.26		0.27	
Sigma	0.66 (–2.57, 3.90)	.69	0.96 (–1.90, 3.82)	.51	1.14 (–1.75, 4.02)	.44	1.74 (–1.29, 4.77)	.26
Adjusted R^2	0.002		0.22		0.26		0.27	
Beta	–0.08 (–1.00, 0.84)	.86	0.06 (–0.75, 0.88)	.88	0.12 (–0.69, 0.92)	.78	0.09 (–0.73, 0.91)	.83
Adjusted R^2	0.08		0.22		0.25		0.26	
Slowing ratio	–0.23 (–0.89, 0.42)	.48	–0.13 (–0.71, 0.45)	.65	–0.11 (–0.69, 0.46)	.69	–0.09 (–0.67, 0.48)	.75
Adjusted R^2	0.001		0.22		0.25		0.26	
Age–Stratified Sample (< 65 years)								
NREM Sleep								
Delta	–0.26 (–0.71, 0.20)	.27	–0.13 (–0.57, 0.30)	.54	–0.06 (–0.51, 0.39)	.80	0.14 (–0.34, 0.62)	.57
Adjusted R^2	0.001		0.09		0.09		0.09	
Theta	0.41 (–0.75, 1.58)	.48	–0.008 (–1.13, 1.11)	.99	–0.17 (–1.33, 0.99)	.77	–0.35 (–1.50, 0.80)	.55
Adjusted R^2	0.002		0.09		0.09		0.09	
Alpha	0.39 (–0.90, 1.67)	.56	0.06 (–1.18, 1.29)	.93	–0.16 (–1.43, 1.11)	.80	–0.33 (–1.62, 0.96)	.62
Adjusted R^2	0.003		0.09		0.09		0.09	
Sigma	0.70 (–2.35, 3.75)	.65	0.68 (–2.24, 3.60)	.65	0.26 (–2.73, 3.26)	.86	–0.83 (–4.03, 2.37)	.61
Adjusted R^2	0.003		0.09		0.09		0.09	
Beta	1.36 (–0.09, 2.81)	.065	1.18 (–0.21, 2.57)	.096	1.00 (–0.42, 2.42)	.17	–0.22 (–2.29, 1.84)	.83
Adjusted R^2	0.01		0.10		0.10		0.09	
Slowing ratio	–5.97 (–20.6, 8.64)	.42	–2.69 (–16.7, 11.3)	.71	–0.36 (–14.8, 14.1)	.96	3.55 (–11.5, 18.6)	.64
Adjusted R^2	0.001		0.09		0.09		0.09	
REM Sleep								
Delta	–0.03 (–0.36, 0.30)	.86	0.05 (–0.27, 0.37)	.75	0.09 (–0.24, 0.42)	.60	0.08 (–0.26, 0.41)	.65
Adjusted R^2	0.004		0.09		0.09		0.09	
Theta	0.14 (–0.65, 0.92)	.73	–0.06 (–0.81, 0.68)	.87	–0.13 (–0.89, 0.64)	.74	–0.10 (–0.86, 0.67)	.80
Adjusted R^2	0.004		0.09		0.09		0.09	

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Table 3—Unadjusted and adjusted associations of TMT-B performance with NREM and REM sleep relative powers and EEG slowing ratio. (*Continued*)

	Unadjusted Model		Adjusted Model 1		Adjusted Model 2		Adjusted Model 3	
	***B* (95% CI)**	***P***	***B* (95% CI)**	***P***	***B* (95% CI)**	***P***	***B* (95% CI)**	***P***
Alpha	0.51 (–0.77, 1.80)	.43	0.006 (–1.23, 1.25)	.99	–0.05 (–1.31, 1.22)	.95	–0.06 (–1.33, 1.22)	.93
Adjusted R^2	0.002		0.09		0.09		0.09	
Sigma	0.26 (–2.61, 3.12)	.86	–0.60 (–3.35, 2.15)	.67	–0.98 (–3.84, 1.89)	.50	–0.96 (–3.83, 1.92)	.51
Adjusted R^2	0.004		0.09		0.09		0.09	
Beta	–0.20 (–1.02, 0.62)	.63	–0.20 (–0.98, 0.58)	.62	–0.29 (–1.09, 0.51)	.48	–0.25 (–1.06, 0.56)	.54
Adjusted R^2	0.003		0.09		0.09		0.09	
Slowing ratio	–0.10 (–0.67, 0.47)	.73	0.02 (–0.52, 0.56)	.94	0.10 (–0.46, 0.65)	.74	0.14 (–0.42, 0.70)	.62
Adjusted R^2	0.004		0.09		0.09		0.06	
Age–Stratified Sample (≥ 65 years)								
NREM Sleep								
Delta	–1.17 (–2.53, 0.19)	.092	–1.08 (–2.39, 0.22)	.10	–1.03 (–2.25, 0.20)	.10	–0.98 (–2.22, 0.27)	.12
Adjusted R^2	0.02		0.11		0.25		0.27	
Theta	4.18 (1.28, 7.09)	.005	3.79 (0.99, 6.58)	.008	3.29 (0.60, 5.99)	.017	3.13 (0.50, 5.77)	.020
Adjusted R^2	0.07		0.15		0.27		0.30	
Alpha	2.02 (–1.87, 5.90)	.31	1.72 (–2.00, 5.44)	.36	1.72 (–1.77, 5.22)	.33	1.42 (–2.03, 4.88)	.42
Adjusted R^2	0.001		0.09		0.23		0.26	
Sigma	0.37 (–10.45, 11.2)	.95	2.48 (–7.92, 12.9)	.64	4.17 (–5.69, 14.0)	.40	2.73 (–7.39, 12.8)	.59
Adjusted R^2	0.01		0.08		0.23		0.25	
Beta	0.48 (–4.64, 5.60)	.85	0.57 (–4.32, 5.46)	.82	1.18 (–3.48, 5.85)	.62	1.48 (–4.26, 7.22)	.61
Adjusted R^2	0.01		0.08		0.22		0.25	
Slowing ratio	–13.2 (–58.1, 31.6)	.56	–17.0 (–59.8, 25.9)	.43	–17.0 (–57.4, 23.3)	.40	–12.6 (–53.8, 28.6)	.55
Adjusted R^2	0.007		0.09		0.23		0.25	
REM Sleep								
Delta	–0.95 (–1.78, –0.12)	.026	–0.97 (1.76, –0.17)	.017	–0.94 (–1.67, –0.21)	.012	–0.86 (–1.60, –0.11)	.024
Adjusted R^2	0.04		0.13		0.28		0.29	
Theta	2.51 (0.73, 4.30)	.006	2.51 (0.81, 4.21)	.004	2.32 (0.72, 3.92)	.005	2.17 (0.59, 3.75)	.008
Adjusted R^2	0.07		0.16		0.29		0.31	
Alpha	3.49 (0.37, 6.61)	.029	3.53 (0.56, 6.51)	.021	3.65 (0.92, 6.39)	.009	3.56 (0.82, 6.31)	.012
Adjusted R^2	0.04		0.13		0.28		0.31	
Sigma	5.39 (–2.65, 13.4)	.19	6.64 (–1.02, 14.3)	.089	7.80 (0.53, 15.1)	.036	5.51 (–1.87, 12.9)	.14
Adjusted R^2	0.008		0.11		0.26		0.27	
Beta	0.75 (–1.50, 3.00)	.51	0.76 (–1.39, 2.91)	.48	0.90 (–1.15, 2.94)	.39	0.57 (–1.54, 2.68)	.59
Adjusted R^2	0.006		0.08		0.23		0.25	
Slowing ratio	–0.47 (–2.19, 1.25)	.59	–0.80 (–2.45, 0.85)	.34	–0.56 (–2.11, 1.00)	.48	–0.31 (–1.87, 1.24)	.69
Adjusted R^2	0.007		0.09		0.23		0.25	

Multicollinearity tests displayed acceptable variance inflation factor for all covariates; AHI was scored according to AASM 2007 *alternative* scoring criteria in which an AHI of 10 events/h is approximately equivalent to an AHI of 5 events/h used to define sleep-disordered breathing by the AASM 2007 *recommended* scoring criteria. Coefficients: unstandardized beta (B) coefficients (95% CI) from univariable and multivariable linear regression models are reported. Estimates: estimates represent the change in cognitive test scores corresponding to a 1% increase in relative spectral power and a 1-unit increase in logarithmically (10-base) transformed EEG slowing ratio. Relative spectral powers: delta: 0.5–4 Hz, theta: 4.5–8 Hz, alpha: 8–12 Hz, sigma: 12–15 Hz, beta: 15–32 Hz. EEG slowing ratio: calculated as a ratio of slow to fast EEG frequencies [(delta + theta)/(alpha + sigma + beta)]. Adjusted Model 1: adjusted for age and AHI. Adjusted Model 2: adjusted for age, AHI, financial stress, highest educational attainment, socioeconomic disadvantage, and marital status. Adjusted Model 3 (overall sample): adjusted for age, AHI, total sleep time, household financial stress, highest educational attainment, socioeconomic disadvantage, marital status, alcohol risk, BMI, current smoking status, physical activity level, cardiovascular disease, diabetes mellitus, blood glucose, insomnia, and hypertension. Adjusted Model 3 (age-stratified samples): adjusted for age, AHI, total sleep time, financial stress, highest educational attainment, socioeconomic disadvantage, marital status, and cardiometabolic conditions (1 or more of diabetes mellitus, hypertension, or cardiovascular disease). Significant associations are underlined. AASM = American Academy of Sleep Medicine, AHI = apnea-hypopnea index, CI = confidence interval, EEG = electroencephalography, NREM = nonrapid eye movement, REM = rapid eye movement, TMT-B = Trail-Making Test B.

Table 4—Unadjusted and adjusted associations of inspection time with NREM and REM sleep relative powers and EEG slowing ratio.

	Unadjusted Model		Adjusted Model 1		Adjusted Model 2		Adjusted Model 3	
	B (95% CI)	*P*	*B* (95% CI)	*P*	*B* (95% CI)	*P*	*B* (95% CI)	*P*
Overall Sample								
NREM Sleep								
Delta	–0.01 (–0.47, 0.47)	.99	0.10 (–0.35, 0.55)	.67	0.29 (–0.17, 0.74)	.22	0.32 (–0.11, 0.76)	.15
Adjusted R^2	0.003		0.11		0.13		0.24	
Theta	0.66 (–0.50, 1.82)	.26	0.13 (–0.98, 1.24)	.82	–0.32 (–1.44, 0.80)	.57	–0.60 (–1.68, 0.48)	.28
Adjusted R^2	0.001		0.11		0.13		0.24	
Alpha	–0.58 (–1.92, 0.77)	.40	–0.72 (–1.99, 0.55)	.27	–1.22 (–2.50, 0.06)	.061	–1.16 (–2.38, 0.11)	.064
Adjusted R^2	0.001		0.11		0.14		0.24	
Sigma	–2.78 (–6.06, 0.50)	.097	–1.45 (–4.59, 1.70)	.37	–2.45 (–5.60, 0.71)	.13	–2.59 (5.66, 0.49)	.099
Adjusted R^2	0.005		0.11		0.13		0.24	
Beta	0.22 (–1.37, 1.81)	.78	0.02 (–1.49, 1.53)	.98	–0.32 (–1.82, 1.18)	.67	–0.29 (–1.76, 1.17)	.69
Adjusted R^2	0.003		0.11		0.13		0.23	
Slowing ratio	4.66 (–10.8, 20.1)	.55	5.77 (–8.81, 20.4)	.44	11.0 (–3.66, 25.6)	.14	12.1 (–1.99, 26.2)	.092
Adjusted R^2	0.002		0.11		0.13		0.24	
REM Sleep								
Delta	0.05 (–0.29, 0.38)	.78	0.04 (–0.27, 0.36)	.79	0.09 (–0.23, 0.41)	.57	0.16 (–0.15, 0.47)	.31
Adjusted R^2	0.003		0.11		0.13		0.24	
Theta	0.07 (–0.70, 0.83)	.87	0.07 (–0.66, 0.79)	.86	–0.05 (–0.77, 0.67)	.89	–0.28 (–0.99, 0.44)	.45
Adjusted R^2	0.003		0.11		0.13		0.24	
Alpha	0.34 (–0.93, 1.62)	.60	0.10 (–1.11, 1.31)	.87	–0.07 (–1.28, 1.14)	.91	–0.19 (–1.39, 1.01)	.76
Adjusted R^2	0.002		0.11		0.13		0.23	
Sigma	–0.44 (–3.39, 2.51)	.77	–0.18 (–2.96, 2.61)	.90	–0.78 (–3.62, 2.07)	.59	–1.13 (–3.98, 1.73)	.44
Adjusted R^2	0.003		0.11		0.13		0.24	
Beta	–0.49 (–1.33, 0.35)	.25	–0.38 (–1.18, 0.41)	.35	–0.43 (–1.22, 0.37)	.29	–0.49 (–1.27, 0.28)	.21
Adjusted R^2	0.001		0.11		0.13		0.24	
Slowing ratio	0.12 (–0.47, 0.72)	.69	0.18 (–0.38, 0.74)	.53	0.35 (–0.21, 0.91)	.22	0.44 (–0.10, 0.98)	.11
Adjusted R^2	0.002		0.11		0.13		0.24	
Age–Stratified Sample (< 65 years)								
NREM Sleep								
Delta	–0.09 (–0.49, 0.32)	.67	–0.02 (–0.43, 0.39)	.93	0.17 (–0.25, 0.58)	.44	0.03 (–0.39, 0.45)	.88
Adjusted R^2	0.003		0.02		0.05		0.06	
Theta	0.97 (–0.07, 2.00)	.066	0.76 (–0.28, 1.80)	.15	0.31 (–0.76, 1.38)	.57	0.75 (–0.25, 1.74)	.14
Adjusted R^2	0.01		0.03		0.05		0.07	
Alpha	–0.18 (–1.33, 0.97)	.76	–0.38 (–1.54, 0.77)	.51	–0.89 (–2.06, 0.28)	.13	–0.49 (–1.61, 0.62)	.38
Adjusted R^2	0.004		0.02		0.05		0.06	
Sigma	–1.89 (–4.65, 0.87)	.18	–1.94 (–4.68, 0.80)	.16	–2.82 (–5.57, –0.06)	.045	–2.47 (–5.26, 0.31)	.082
Adjusted R^2	0.003		0.03		0.06		0.07	
Beta	0.04 (–1.29, 1.36)	.96	–0.07 (–1.39, 1.25)	.92	–0.37 (–1.69, 0.95)	.58	–0.74 (–2.54, 1.06)	.42
Adjusted R^2	0.004		0.02		0.05		0.06	
Slowing ratio	2.17 (–11.1, 15.4)	.75	4.10 (–9.10, 17.3)	.54	9.44 (–3.93, 22.8)	.17	5.13 (–8.00, 18.3)	.44
Adjusted R^2	0.004		0.02		0.05		0.06	
REM Sleep								
Delta	–0.03 (–0.34, 0.27)	.83	0.009 (–0.29, 0.31)	.96	0.04 (–0.27, 0.34)	.80	–0.15 (–0.44, 0.14)	.32
Adjusted R^2	0.004		0.02		0.05		0.06	
Theta	0.37 (–0.33, 1.08)	.30	0.28 (–0.43, 0.98)	.44	0.15 (–0.55, 0.86)	.67	0.55 (–0.11, 1.22)	.10
Adjusted R^2	0.001		0.02		0.05		0.07	

(continued on following page)

Table 4—Unadjusted and adjusted associations of inspection time with NREM and REM sleep relative powers and EEG slowing ratio. (*Continued*)

	Unadjusted Model		Adjusted Model 1		Adjusted Model 2		Adjusted Model 3	
	***B* (95% CI)**	***P***	***B* (95% CI)**	***P***	***B* (95% CI)**	***P***	***B* (95% CI)**	***P***
Alpha	0.50 (–0.66, 1.66)	.40	0.24 (–0.92, 1.41)	.68	0.08 (–1.09, 1.26)	.89	0.78 (–0.33, 1.88)	.17
Adjusted R^2	0.001		0.02		0.05		0.07	
Sigma	–0.38 (–2.98, 2.21)	.77	–0.82 (–3.41, 1.78)	.54	–1.25 (–3.91, 1.41)	.36	0.15 (–2.36, 2.67)	.91
Adjusted R^2	0.004		0.02		0.05		0.06	
Beta	–0.39 (–1.13, 0.35)	.30	–0.38 (–1.12, 0.35)	.31	–0.34 (–1.08, 0.41)	.37	–0.07 (–0.77, 0.64)	.85
Adjusted R^2	0.001		0.02		0.05		0.06	
Slowing ratio	0.02 (–0.49, 0.53)	.94	0.09 (–0.42, 0.60)	.74	0.26 (–0.25, 0.78)	.32	0.05 (–0.44, 0.55)	.83
Adjusted R^2	0.004		0.02		0.05		0.06	
Age–Stratified Sample (≥ 65 years)								
NREM Sleep								
Delta	0.34 (–1.00, 1.68)	.62	0.41 (–0.90, 1.72)	.54	0.63 (–0.69, 1.96)	.34	0.82 (–0.52, 2.17)	.23
Adjusted R^2	0.008		0.04		0.07		0.12	
Theta	–0.93 (–3.86, 2.01)	.53	–1.27 (–4.14, 1.60)	.38	–2.21 (–5.13, 0.71)	.14	–2.15 (–5.03, 0.73)	.14
Adjusted R^2	0.006		0.05		0.09		0.13	
Alpha	–1.42 (–5.20, 2.37)	.46	1.63 (–5.32, 2.07)	.38	–2.05 (–5.78, 1.69)	.28	–2.41 (–6.09, 1.27)	.20
Adjusted R^2	0.005		0.05		0.08		0.13	
Sigma	–0.13 (–10.7, 10.4)	.98	1.46 (–8.87, 11.8)	.78	1.08 (–9.51, 11.7)	.84	–1.52 (–12.4, 9.36)	.78
Adjusted R^2	0.01		0.04		0.07		0.11	
Beta	0.43 (–4.58, 5.43)	.87	0.47 (–4.41, 5.35)	.85	0.73 (–4.29, 5.74)	.77	–0.30 (–6.47, 5.88)	.92
Adjusted R^2	0.01		0.04		0.07		0.11	
Slowing ratio	10.3 (–33.2, 53.8)	.64	7.72 (–34.9, 50.3)	.72	9.00 (–34.2, 52.2)	.68	18.7 (–25.5, 62.9)	.40
Adjusted R^2	0.008		0.04		0.07		0.12	
REM Sleep								
Delta	0.05 (–0.77, 0.87)	.91	0.05 (–0.77, 0.87)	.91	0.08 (–0.72, 0.88)	.85	0.30 (–0.52, 1.12)	.47
Adjusted R^2	0.01		0.04		0.07		0.11	
Theta	–0.16 (–1.97, 1.64)	.86	–0.18 (–1.94, 1.58)	.84	–0.32 (–2.09, 1.46)	.72	–0.51 (–2.28, 1.25)	.57
Adjusted R^2	0.01		0.04		0.07		0.11	
Alpha	0.16 (–2.93, 3.24)	.92	0.15 (–2.87, 3.18)	.92	–0.14 (–3.16, 2.88)	.93	–0.41 (–3.47, 2.65)	.79
Adjusted R^2	0.01		0.04		0.07		0.11	
Sigma	2.10 (–5.70, 9.91)	.59	2.94 (–4.69, 10.6)	.45	2.72 (–5.15, 10.6)	.49	–0.30 (–8.32, 7.73)	.94
Adjusted R^2	0.007		0.05		0.07		0.11	
Beta	–0.35 (–2.53, 1.83)	.75	–0.37 (–2.50, 1.77)	.74	–0.24 (–2.43, 1.95)	.83	–1.19 (–3.45, 1.07)	.30
Adjusted R^2	0.009		0.04		0.07		0.12	
Slowing ratio	0.52 (–1.15, 2.18)	.54	0.31 (–1.34, 1.95)	.71	0.31 (–1.35, 1.97)	.71	0.74 (–0.93, 2.40)	.38
Adjusted R^2	0.006		0.04		0.07		0.12	

Multicollinearity tests displayed acceptable variance inflation factor for all covariates; AHI was scored according to AASM 2007 *alternative* scoring criteria in which an AHI of 10 events/h is approximately equivalent to an AHI of 5 events/h used to define sleep-disordered breathing by the AASM 2007 *recommended* scoring criteria. Coefficients: unstandardized beta (B) coefficients (95% CI) from univariable and multivariable linear regression models are reported. Estimates: estimates represent the change in cognitive test scores corresponding to a 1% increase in relative spectral power and a 1-unit increase in logarithmically (10-base) transformed EEG slowing ratio. Relative spectral powers: delta: 0.5–4 Hz, theta: 4.5–8 Hz, alpha: 8–12 Hz, sigma: 12–15 Hz, beta: 15–32 Hz. EEG slowing ratio: calculated as a ratio of slow to fast EEG frequencies ([delta + theta]/[alpha + sigma + beta]). Adjusted Model 1: adjusted for age and AHI. Adjusted Model 2: adjusted for age, AHI, financial stress, highest educational attainment, socioeconomic disadvantage, and marital status. Adjusted Model 3 (overall sample): adjusted for age, AHI, total sleep time, household financial stress, highest educational attainment, socioeconomic disadvantage, marital status, alcohol risk, BMI, current smoking status, physical activity level, cardiovascular disease, diabetes mellitus, blood glucose, insomnia, and hypertension. Adjusted Model 3 (age-stratified samples): adjusted for age, AHI, total sleep time, financial stress, highest educational attainment, socioeconomic disadvantage, marital status, and cardio-metabolic conditions (1 or more of diabetes mellitus, hypertension, or cardiovascular disease). Significant associations are underlined. AASM = American Academy of Sleep Medicine, AHI = apnea-hypopnea index, CI = confidence interval, EEG = electroencephalography, NREM = nonrapid eye movement, REM = rapid eye movement.

reported in patients with mild-moderate Alzheimer's disease.[2,13] While we did not observe associations of REM EEG slowing with cognitive function, we found that worse TMT-A performance was associated with lower NREM EEG slowing in men ≥ 65 years. Although it has been reported that REM EEG slowing may be linked with worse cognitive function,[12,13] NREM EEG slowing reflects the predominance of slower vs faster EEG frequencies, which is typically associated with better cognitive function. However, Waser et al[9] identified greater NREM EEG slowing in men with cognitive decline from early to late adulthood, contrasting with our results in community-dwelling men and other small studies in participants with MCI or Alzheimer's disease.[2,49,50] These contrasting findings may be due to the different study populations and warrant further exploration in longitudinal studies.

In men ≥ 65 years in this study, worse TMT-A performance was associated with higher NREM theta power, conflicting with previous findings in older women. Women ≥ 65 years of the Study of Osteoporotic Fractures who had developed MCI 5 years after a baseline sleep study exhibited lower NREM theta power compared to age- and sex-matched controls.[8] Previous literature has reported that women typically show higher power in slower frequency bands during NREM sleep compared to age-matched men.[51] Consequently, discrepancies between our findings and the Study of Osteoporotic Fractures may be primarily driven by the difference in sex, and associations between sleep microarchitecture and cognitive function may differ in women compared to men. Therefore, as our study was only conducted in men, the generalizability of our results to women remains unknown. Furthermore, MCI reflects significantly greater and broader cognitive dysfunction compared to relatively normal performance on a single task TMT-A in our cohort of men, which may also account for the different findings. Therefore, further studies are warranted to investigate sex differences in sleep microarchitecture in relation to cognitive dysfunction.

In our study, there were no associations of memory performance (FOME test) with sleep microarchitecture, contrasting with previous small studies assessing different types of memory.[5,52] Westerberg et al[5] studied patients with aMCI and controls and assessed sleep-dependent declarative memory. The authors found correlations of higher NREM delta and theta power with better declarative memory in controls but not in patients with aMCI.[5] Moreover, Ferrarelli et al[52] found a strong correlation of higher NREM delta power with better working memory. However, previous small studies could not adjust for potential confounders, which was a key advantage of our comparatively large cohort. Therefore, our community-based cohort study provides more robust evidence suggesting that memory performance is not independently associated with sleep microarchitecture. Nevertheless, further evidence from community samples controlling for potentially important confounders remains warranted to extend our findings.

Regarding visual processing speed, we observed an association of slower inspection time with lower NREM sigma power in men < 65 years after adjusting for demographic factors. However, this significant association cannot be compared to small studies given the cognitive domains assessed. Previous small studies have not examined associations between visual processing speed and sleep microarchitecture. Thus, further studies in large samples are needed to extend our findings.

Preliminary evidence from small studies suggests sleep spindle parameters, including occurrence, frequency, density, and amplitude, may be associated with cognitive function.[53–58] Our adjusted association of worse TMT-A performance with higher NREM sigma power in men ≥ 65 years could reflect disrupted thalamocortical network integrity with advancing age. Therefore, further community-based cohort studies are warranted to determine whether spindle parameters are independently associated with cognitive function. Moreover, the non-oscillatory component of 1/f function or noise-like temporal brain activity should be considered in future studies, given the potential links with cognitive processing speed.[59] Accurate application of this EEG analysis approach requires multiple electrode derivations (frontal, temporal, and occipital),[60] and accordingly was impracticable in the present study.

The key strengths of this study are 1) the comparatively large and well-characterized sample of community-dwelling men with data available on objectively measured sleep microarchitecture parameters and multiple standardized, validated, and well-established cognitive tests,[36,61] and 2) the extensive OSA, survey, and biomedical data,[21] allowing for control of confounders that influence cortical activity and cognitive function. The main limitation of this study is its cross-sectional design from which causality cannot be inferred. Another limitation is the average time lag of 26 months between cognitive (2007–2010) and PSG (2010–2011) assessment, with potential changes in sleep microarchitecture over that period. However, we feel this is unlikely given the evidence from our team and others that sleep microarchitecture is relatively stable within individuals and represents a trait fingerprint of electrical brain activity.[62,63] Furthermore, given that cognition has been reported to decline over time, particularly in older community-dwelling participants,[30,64] assessing cognitive function before sleep microarchitecture could have underestimated the observed associations. Assessing cognitive function and sleep microarchitecture at the same time point could have increased the significance of our observed associations.

Several additional study limitations need to be acknowledged. As the EEG montage did not include recording of leg EMG signals, we could not adjust for sleep-associated movement disorders such as REM sleep behavior disorder, restless legs syndrome, and periodic limb movements of sleep, which may have introduced changes in sleep microarchitecture. However, any leg movement-related artifacts in the EEG crossing the artifact detection boundaries would have been excluded from the analysis. Also, sleep microarchitecture parameters were identified using only a single frontal EEG derivation (F4-M1); consequently, potentially important topographical differences in sleep microarchitecture parameters may have been missed.[65] Nonetheless, over 85% of EEG traces were of sufficient quality for qEEG analysis and not rejected due to artifacts by the qEEG algorithm, as having an 85% clean artifact-free EEG was the threshold for any PSG qEEG included in the analysis. Although this study comprehensively adjusted for multiple relevant potential confounders, several residual and unknown factors could have influenced the findings. Finally, this sleep substudy was conducted exclusively in men; consequently, independent associations of sleep microarchitecture parameters with cognitive dysfunction in women remain unknown.

In summary, in this sample of community-dwelling middle-aged and older men, NREM and REM sleep microarchitecture parameters derived from qEEG power spectral analysis were independently associated with cognitive dysfunction. Worse TMT-A performance was independently associated with higher NREM theta and REM theta and alpha but lower delta power in the overall sample and men ≥ 65 years. Furthermore, worse TMT-B performance was independently associated with higher REM theta and alpha power in the overall sample and men ≥ 65 years. These novel findings suggest sleep microarchitecture parameters determined by quantitative power spectral analysis of the EEG derived from routine overnight sleep studies may represent important brain-specific markers of daytime cognitive dysfunction beyond standard PSG indices of OSA and sleep timing, particularly older community-dwelling men. Prospective population-based cohort studies ideally conducted in large samples of randomly selected community-dwelling men and women are warranted to determine if sleep microarchitecture parameters in midlife are independently associated with future cognitive decline in older age.

ABBREVIATIONS

AASM, American Academy of Sleep Medicine
AHI, apnea-hypopnea index
aMCI, amnestic mild cognitive impairment
BMI, body mass index
CI, confidence interval
EEG, electroencephalography
FAMAS, Florey Adelaide Male Ageing Study
FOME, Fuld object memory evaluation
MCI, mild cognitive impairment
NREM, non–rapid eye movement
OSA, obstructive sleep apnea
PSG, polysomnography
qEEG, quantitative electroencephalography
REM, rapid eye movement
TMT, Trail-Making Test

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