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Sleep architecture and mental health among community-dwelling older men

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Sleep architecture and mental health among community-dwelling older men

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Abstract

Objectives: To investigate the association of mood and anxiety symptoms with sleep architecture (the distribution of sleep stages) in community-dwelling older men.

Method: We used in-home unattended polysomnography to measure sleep architecture in older men. Men were categorized into four groups: (1) significant depressive symptoms only (DEP+ only, Geriatric Depression Scale>=6), (2) significant anxiety symptoms only (ANX+ only, Goldberg Anxiety Scale>=5), (3) significant depressive and anxiety symptoms (DEP+/ANX+), or (4) no significant depressive or anxiety symptoms (DEP-/ANX-).

Results: Compared to men without clinically significant symptomology, men with depressive symptoms spent a higher percentage of time in stage 2 sleep (65.42% DEP+ only vs. 62.47% DEP-/ANX-, p = .003), and a lower percentage of time in REM sleep (17.05% DEP+ only vs. 19.44% DEP-/ANX-, p = 0.0005). These differences persisted after adjustment for demographic/lifestyle characteristics, medical conditions, medications, and sleep disturbances, and after excluding participants using psychotropic medications. The sleep architecture of ANX+ men did not differ from men without clinically significant symptomology.

Discussion: Depressed mood in older adults may be associated with accelerated age-related changes in sleep architecture. Longitudinal community-based studies using diagnostic measures are needed to further clarify relationships among common mental disorders, aging, and sleep.

Abstract word count: 197 words

Keywords: aging, anxiety, depression, epidemiology, sleep architecture

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Sleep architecture and mental health among community dwelling older men

Sleep architecture refers to the distribution electrophysiologically distinct sleep states that occur in cycles throughout the night. In adulthood, sleep is entered through stage 1, or light sleep, which is characterized by a low arousal threshold. Next, during stage 2 sleep electrophysiology more intense stimuli are needed for arousal. Following stage 2 is slow wave sleep (SWS), sometimes also referred to as deep sleep. Stages 1, 2, and SWS constitute the phases of non-rapid eye movement sleep (N-REM), which alternates with rapid eye movement (REM) sleep throughout the night. In REM sleep,   brain electrical activity actually somewhat resembles waking electrophysiology. The exact function of these sleep stages remains unknown.

Research has described changes in sleep architecture that occur throughout the lifespan. With aging the percentage of both SWS and REM sleep decrease (Ohayon, Carskadon, Guilleminault, & Vitiello, 2004; Redline et al., 2004). Research has also linked altered sleep architecture with psychiatric disorders, including major depressive disorder (MDD) and generalized anxiety disorder (GAD). Patients with MDD spend a lesser percentage of sleep time in SWS, and a greater percentage of sleep time in REM sleep compared to healthy controls (Kupfer & Foster, 1972). Sleep architecture in MDD is also characterized by shorter times from sleep onset to the first REM sleep period (shortened REM sleep latency) and prolongation of the first REM sleep periods (Peterson, 2011). Within MDD patients, changes in sleep architecture have also been noted during treatment (Reynolds et al., 1991) and after recovery from depressive episodes (Lee et al., 1993), suggesting that such changes may represent traits and/or scars of depressive illness.

Anxiety disorders have been less consistently associated with alterations in sleep architecture. Some studies of GAD have reported decreases in the percentage of time spent in

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REM sleep (Fuller, Waters, Binks, & Anderson, 1997), and increases in the percentage of time

spent in lighter sleep (Fuller et al., 1997; Papadimitriou & Linkowski, 2005). In a review

including six studies of GAD and sleep architecture (Monti & Monti, 2000), all of the examined

studies showed non-significant decreases in the amount of REM sleep in GAD patients

compared to healthy controls. Only one study found statistically significant differences in levels

of REM sleep; these authors also noted that in half of the studies reviewed, the percentage of

time GAD patients spent in SWS was decreased.

While sleep architecture research has primarily examined middle aged adults, in the

1990's research in late-life depression replicated the characteristic sleep architecture changes

found among younger adults (Lee et al., 1993; Reynolds et al., 1991). The effect of MDD on

sleep architecture is independent of age (Gillin et al., 1981) but appears to be more pronounced

as age increases (Knowles & MacLean, 1990). Although sleep disturbances are common among

elderly individuals with clinically significant anxiety (Kostka & Jachimowicz, 2010), to our

knowledge, no information exists regarding the sleep architecture of anxious older persons.

Of importance, however, both MDD and GAD research has almost exclusively relied on

clinical samples of treatment-seeking individuals who attend in-laboratory sleep studies. To our

knowledge one small case control   study   of non-treatment seeking older adults with MDD

was unable to reproduce the changes or differences in sleep architecture documented in the

literature; these authors concluded that sleep architecture alterations in MDD found in previous

studies may have been related to characteristics of treatment-seeking behavior (Vitiello et al.,

1990). To our knowledge no research has examined anxiety and sleep architecture in

community-based sample.

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An important role of epidemiology is completing the clinical picture (Morris, 1957), and population-based research is needed to determine whether the associations of mood and anxiety with sleep architecture found in a clinical setting are also present in the community (or whether they are only present among the portion of the patient population found in the clinic). Subjects seeking treatment are likely very different than a broad population based sample of community dwelling men. We report here the sleep architecture of older community dwelling men with and without clinically significant depression and anxiety symptoms. Based on previous literature, we hypothesized that individuals with depressive symptoms would spend less of their sleep time in SWS, have shorter REM latencies, and spend a greater percentage of sleep time in REM sleep. We also hypothesized that anxiety symptoms would be related to lower amounts of both REM and SWS.

Methods

   Participants

From March 2000 to April 2002, the parent Osteoporotic Fractures in Men Study (MrOS) recruited 5,994 community-dwelling men who were ≥65 years of age at six clinical centers in the United States (Birmingham, Alabama; Minneapolis, Minnesota; Palo Alto, California; Monongahela Valley near Pittsburgh, Pennsylvania; Portland, Oregon; and San Diego, California)(Blank et al., 2005; Orwoll et al., 2005). To be eligible to participate, individuals must have been without bilateral hip replacements and able to walk without assistance.

The ancillary MrOS Sleep Study was conducted between December 2003 and March 2005, and included 3,135 participants, which exceeded the target recruitment number of 3,000 men from the parent MrOS Study. Men excluded from this sleep study were: 150 treated for sleep apnea or snoring (use of positive airway pressure therapy, a dental appliance, or oxygen);

349 who had died; 39 who withdrew from participation; 1997 who refused for diverse personal

reasons; and 324 because MrOS Sleep Study recruitment goals had already been met.

Of the 3,135 men who participated in the Sleep Visit, 2,911 have polysomnography

(PSG) data. Of these, 2,861 have data for the sleep architecture outcomes. Eight men are missing

data on depressive symptoms or anxiety, leaving 2,853 men in this analysis subset. The

institutional review boards at each clinic site approved the study, and written informed consent

was obtained from all participants.

Measures

Polysomnography

In-home sleep studies using unattended PSG (Safiro, Compumedics, Inc., Melbourne,

Australia) were performed. Participants were examined for one night in their own homes to

minimize burden. PSG records electrical activity at the scalp which can be analyzed to

determine sleep staging. The recording montage was as follows: C_3/A_2 and C_4/A_1

electroencephalograms (EEG), bilateral electrooculograms and a bipolar submental

electromyogram to determine sleep status; thoracic and abdominal respiratory inductance

plethysmography to determine respiratory effort; airflow (by nasal-oral thermocouple and nasal

pressure cannula); finger pulse oximetry; lead I EKG; body position (mercury switch sensor);

and bilateral tibialis leg movements (piezoelectric sensors). Centrally trained and certified staff

members performed home visits for setup of the PSG units. After sensors were placed and

calibrated, signal quality and impedance were checked; sensors were repositioned as needed to

improve signal quality, replacing electrodes if impedances were greater than 5000 ohms, using

approaches similar to those in the Sleep Health Heart Study (Redline et al., 1998). Staff returned

the next morning to collect the equipment and download the data to the Central Sleep Reading

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Center (Cleveland, OH) to be scored by certified research polysomnologists. PSG data quality

was excellent, with a failure rate of less than 4% and with more than 70% of studies graded as

being of excellent or outstanding quality.

Sleep stages (REM, stages 1, 2, and SWS) were scored using standard criteria

(Rechtschaffen A, 1968) and included the percentage of sleep time spent in: stage 1, stage 2,

SWS, and REM sleep. Also included was REM latency, which was defined as the number of

minutes from sleep onset to the first REM period. The reliability of these measures, determined

by rescoring studies over time, indicates that the inter-scorer reliability (ICC) for the percent of

sleep time spent in sleep stages 1, 2, slow wave sleep, and REM were .60, .91, .96, and .94

respectively. Similar, although higher levels of intra-scorer reliability were also documented.

Mental health

The Geriatric Depression Scale – 15 (GDS), a validated short form (Aikman & Oehlert,

2001; Almeida & Almeida, 1999; Sheikh & Yesavage, 1986) to screen for MDD among older

persons (Yesavage et al., 1982) was administered to all participants. The standard cut point of $\geq$

6 was used to define clinically significant depressive symptoms. A cutoff of $\geq$ 6 yields a

sensitivity of 90.9% and specificity of 64.5% compared to a DSM-IV diagnosis of MDD

(Almeida & Almeida, 1999). The Goldberg Anxiety Scale was used with a cut-off of $\geq$ 5 to

determine the presence of clinically significant anxiety symptoms. This was originally validated

with a sensitivity and specificity of 86% and 91%, respectively (Goldberg, Bridges, Duncan-

Jones, & Grayson, 1988).

We combined these depression and anxiety scales to create four mutually exclusive

categories: significant depressive symptoms only (DEP+), significant anxiety symptoms only

(ANX+), both depressive and anxiety symptoms (DEP+/ANX+), or no significant depressive or anxiety symptoms (DEP-/ANX-).

Covariates

Demographic/lifestyle and chronic disease/medication use covariates were identified *a priori* based on their potential relationships with mental health or sleep architecture. Sleep disturbances were also considered as potential covariates to determine whether associations of sleep architecture and mental health were independent of sleep disturbances known to occur more frequently among men with depressed mood (Paudel et al., 2008).

Demographic/lifestyle: At the Sleep Visit, information on age, study site, race/ethnicity, education, alcohol consumption, and smoking status was obtained. Measurements of body weight and height were gathered, and body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters. Physical activity was measured with the Physical Activity Scale for the Elderly (PASE) Scale (Washburn, Smith, Jette, & Janney, 1993).

Chronic disease/Medication use: Previous research with our sample has demonstrated associations between chronic diseases and psychoactive medications with sleep architecture (Blackwell, Yaffe, et al., 2011; Rao et al., 2009), and these variables were considered covariates in our analysis. A history of chronic medical conditions was also obtained by self-report, including: stroke, Parkinson's, diabetes mellitus, chronic obstructive pulmonary disease (COPD), hypertension, congestive heart failure (CHF), myocardial infarction (MI), and arthritis (osteoarthritis, OA and rheumatoid arthritis, RU). Cognitive impairment was defined as Modified Mini-Mental State examination (3MS) score < 80 (Teng & Chui, 1987). Participants were asked to bring in all current medications used within the preceding 30 days. All prescription and nonprescription medications were entered into an electronic database and each medication was

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matched to its ingredient(s) based on the Iowa Drug Information Service (IDIS) Drug

Vocabulary (College of Pharmacy, University of Iowa, Iowa City, IA) (Pahor et al., 1994). The

use of medication known to affect sleep architecture were considered (antidepressants,

benzodiazepines, and non-benzodiazepine, non-barbiturate sedative hypnotics).

Sleep covariates: Covariates of sleep disordered breathing (SDB) and nocturnal

hypoxemia included the apnea-hypopnea index (AHI) and the percent of time during sleep in

which arterial oxygen saturation was below 90% (% of sleep time with $SaO_2<90\%$). Apnea was

defined as complete or near complete cessation of airflow for >10 seconds, and hypopneas were

scored if clear reductions in breathing amplitude (at least 30% below baseline breathing)

occurred, and lasted >10 seconds (Berry et al., 2012). In these analyses, only apneas and

hypopneas that were each associated with a 3% or greater desaturation were included. AHI was

calculated as the total number of apneas and hypopneas per hour of sleep.

While sleep architecture (primary outcome) and SDB (covariate) can be measured

directly only using PSG, for increased reliability other sleep covariates were measured using

wrist actigraphy (Ambulatory Monitoring, Inc., Ardsley, NY). Actigraphy devices contain an

accelerometer which records motion and can determine sleep activity patterns when worn over

several days (Ancoli-Israel et al., 2003). Participants were instructed to wear the actigraph

continuously for 5 nights/6 days, removing it only for bathing. They were also asked to keep a

sleep log used to aid in editing the actigraph data. Actigraphy data was collected for an average

of 5.2 (± 0.9) 24-hour periods. Actigraphy data were analyzed with ActionW- 2 software

(Ambulatory Monitoring, Inc., Ardsley, NY). Details of the actigraphy scoring algorithms used

in this study have been published elsewhere (Blackwell, Ancoli-Israel, Redline, Stone, &

Osteoporotic Fractures in Men Study). Actigraphy-based sleep estimates used in this analysis

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are total sleep time (total hours slept while in bed), sleep efficiency (percentage of time

participant was sleeping while in bed), and sleep latency (amount of time until onset of sleep,

defined as when participant achieved sleep for 20 continuous minutes after getting into bed).

Statistical analysis

The percentages of time spent in each sleep stage were first summarized across

demographic/lifestyle categories as mean +/- SD, and compared using T-Tests or ANOVA. In

the main analysis, we used linear regression equations to compare the percentage of sleep time

spent in each sleep stage by mental health (MH) status, with DEP-/ANX- as the reference group.

All linear regression comparisons were made first in unadjusted models (Model 1), then after

adjustment for demographic, medical, and medication covariates (Model 2), and in the final

model, after adjusting for other sleep measures (Model 3) in order to determine if associations of

mental health with sleep architecture were independent of these covariates. Results were

presented as adjusted means and 95% confidence intervals.

Several sensitivity analyses were conducted to rule out alternative explanations of

associations between MH and sleep architecture. Analyses were repeated after excluding

individuals using medications (n = 352) that could affect sleep architecture (antidepressants,

benzodiazepines, and non-benzodiazepine, non-barbiturate sedative hypnotics). Participants

with severe SDB (AHI ≥ 30, n = 497) were excluded because SDB is also known to affect sleep

architecture (Redline et al., 2004). We also substituted the GDS definition of depression with a

proxy of diagnosis, specifically use of any antidepressant medication (n = 216 or 7.57%); this

analysis was designed to examine if men being treated pharmacologically for depression had the

same sleep architecture patterns found in men with GDS determined depressed mood overall.

A *post-hoc* follow-up analysis was also conducted to confirm that depression results would be

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sustained with a more stringent GDS threshold which yields higher specificity (GDS $\geq$ 9, n = 65

or 2.28%). (Marc, Raue, & Bruce, 2008). All p-values reported were two-sided and all analyses

were conducted using SAS version 9.2 (SAS Institute Inc, Cary, NC). P-values less than 0.05

were considered statistically significant.

Results

The analysis sample was 90.61% white with an average age of 76.38 (s.d. 5.54) years. In

total 94 (3.29%) participants met the criteria for only DEP+, 165 (5.78%) met criteria for only

ANX+, and 89 (3.12%) met criteria for both DEP+ and ANX+, with the rest of the sample (n =

2505, 87.80%) meeting neither criteria (DEP-/ANX-). On average, the men spent 6.82 +/-

4.28% of sleep time in Stage 1, 62.64 +/- 9.59% in Stage 2, 11.25 +/- 8.99% in SWS and 19.29

+/- 6.56% in REM. On average, it took the men 74.62 +/- 43.46 minutes to the first onset of

REM sleep.

Associations of covariates with sleep architecture

There were statistically significant associations with age (in quartiles) across all sleep

architecture outcomes except SWS and REM latency (Table 1), with older men spending a

greater percentage of sleep time in stage 1 (p < 0.0001) and stage 2 sleep (p = 0.005) and a lesser

percentage of in REM sleep (p < 0.0001). Other demographic/lifestyle factors were also

associated with sleep architecture and can be seen in Table 1, for example, higher physical

activity scores (PASE) were associated with a greater percentage of sleep time spent in REM (p

= 0.0001) and lower REM latencies (p = 0.0117).

Main findings: Mental Health and Sleep Architecture

Multivariable linear regression analysis revealed significant independent associations of

depressive symptoms (DEP+) with sleep architecture, while no statistically significant

associations of sleep architecture and anxiety symptoms (ANX+) or comorbid depressive and anxiety symptoms (DEP+/ANX+) were present after adjustment for covariates (Table 2).

Compared to men without clinically significant depressive or anxiety symptoms, men with clinically significant depressive symptoms spent greater percentage of sleep time in stage 2 sleep (on average, 62.47% DEP-/ANX- vs. 65.42% DEP+) and a smaller percentage of sleep time in REM sleep (on average, 19.44% DEP-/ANX- vs. 17.05% DEP+). The association of depressive symptoms with stage 2 and REM sleep remained statistically significant after adjustments for demographic/lifestyle factors, chronic diseases, and medication use (Model 2), as well as after adjustments for sleep disturbances (Model 3). This pattern of findings was unaltered when repeating analyses excluding individuals using psychoactive medications (antidepressants, benzodiazepines, and non-benzodiazepine, non-barbiturate sedative hypnotics). When excluding participants with severe SDB, the association of DEP+ with the percentage of time spent in stage 2 sleep was no longer significant in the fully adjusted model (Model 3: 63.50% DEP+ vs. 61.87% DEP-/ANX-, p = 0.1505), while DEP+ was still significantly associated with a lesser percentage of time spent in REM sleep (Model 3: 18.12% DEP+ vs. 19.92% DEP-/ANX-, p = 0.0181).

Men with DEP+/ANX+ spent a smaller percentage of sleep time in REM sleep than DEP-/ANX- men (Model 1), however this result failed to retain significance after adjustment for demographic/lifestyle factors, chronic diseases, and medication use (Model 2). Compared to their counterparts without clinically significant symptoms, all three mental health groups had significantly longer REM latencies (Model 1); however these differences were no longer statistically significant after adjustments in Model 2.

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Repeating the analyses with use of an antidepressant medication as a proxy for MDD

diagnosis yielded similar results; however, using this measure of depression additionally yielded

a significantly longer REM latency (Model 3: 111.62 minutes in anti-depressant users without

anxiety vs. 71.53 minutes in non-anti-depressant users without anxiety, $p < 0.0001$). Those using

antidepressants with anxiety also had longer REM latency than those nonusers of antidepressants

(Model 3: 101.64 minutes vs. 71.53 minutes, respectively, $p < 0.0001$). In a *post-hoc* sensitivity

analysis, a more stringent cut-off was used for the GDS (≥ 9) in order to increase specificity

compared to a full MDD diagnosis above 90% (Marc et al., 2008). This criterion yielded 26

(0.91%) DEP+/ANX-, 215 (7.54%) DEP-/ANX+, and 39 (1.37%) DEP+/ANX+ participants. In

the fully adjusted model the pattern of results was altered so that there were no longer significant

associations of the percentage of time spent in stage 2 sleep with any MH category compared to

DEP-/ANX-, although men with DEP+/ANX- compared to DEP-/ANX- still spent a smaller

percentage of time in REM sleep ($p = .034$).

Discussion

In this first large-scale population based study of sleep architecture among community

dwelling older menwe found that participants with depressed mood spent a greater percentage of

their sleep time in lighter (stage 2) sleep. We found that depressed mood was associated with a

lower percentage of time spent in REM sleep and with trends towards longer latency from sleep

onset to the first REM period. We found no statistically significant associations between sleep

architecture and anxiety symptoms.

Our findings differ from previous studies of in-patient sleep patients and this difference

may be interpreted in several ways. First, the biological signatures documented in previous sleep

architecture studies may be related to some disease processes highly correlated with treatment

seeking behavior. However, when examining those being treated pharmacologically for

depression, our findings were reproduced indicating that an absence of treatment-seeking does

not explain differing community and clinic-based findings. It is likely that clinical samples

include more severely depressed individuals than our population based sample, however use of a

more extreme cut point for depressive symptoms did not alter our finding that DEP+ men had a

lower percentage of sleep time in REM.

We had no information on the duration of mood disturbances. Since prior research has

demonstrated differences in sleep architecture coinciding with episode duration (Dew et al.,

1996), duration of depressive illness may explain this discrepancy between clinical and

community settings. In addition, we relied solely on depressive symptom count and do not have

full diagnostic measures (including the duration criteria required for an MDD diagnosis).

Nevertheless, studying depressive symptoms among older adults is important in its own right

because they are common among (Blazer, 2003),and contribute to poor physical health

(Jaconelli, Stephan, Canada, & Chapman, 2012; Turiano et al., 2012), physical disability

(Michael, Berkman, Colditz, & Kawachi, 2001), and reduced quality of life (Terracciano,

Lockenhoff, Zonderman, Ferrucci, & Costa, 2008).

Our results demonstrate associations between depressed mood and sleep architecture

(increases in the percentages of stage 2 and decreases in the percentage of REM sleep) that

parallel changes occurring across age groups (see Table 1). Redline et al. (2004), comparing

participants 37-54 years of age compared to 70+, noted a 5.1% increase in the percentage of time

spent in stage 2 sleep, and a 1.7% decrease in the percentage of time slept in REM sleep.

Comparing these age-related differences in sleep architecture to our adjusted findings in men

with depressed mood (2.43% more spent in stage 2 and 1.74% less spent in REM sleep) gives

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context to assess the magnitude of these effects, and indicates that depressed mood may be associated with an acceleration of age-related changes to sleep.

Our finding that men with depressed mood spend more time in stage 2 sleep suggests that men with depressed mood spend more time in lighter sleep. The implications of our finding that men with depressed mood spend less time in REM sleep are less direct, but can be contextualized in view of previously documented associations of REM sleep with health outcomes. For example, increased mortality has been associated with both extreme high and low percentages of REM sleep (Dew et al., 2003). Declines in REM sleep have been also been related to brain dysfunction in the elderly (Prinz et al., 1982), and patients diagnosed with probable Alzheimer's disease show decreased REM sleep expression compared to age matched healthy controls (Reynolds et al., 1985). In rats, REM sleep deprivation contributes to a reduction in hippocampal neurogenesis (Guzman-Marin et al., 2008).

Although our data did not assess structural changes in the brain, the relationship between depressed mood and sleep architecture may relate to neurodegeneration. The "vascular hypothesis" of late-life depression suggests a distinct subtype of MDD in older adults characterized by cerebral hyperintensities (Taylor, Aizenstein, & Alexopoulos, 2013), indeed, greater levels of vascular abnormalities in the brain relate generally to faster aging-related health decline (Rosano et al., 2005). Because SDB may lead to vascular abnormalities in the brain and altered sleep architecture, we conducted a sensitivity analysis excluding participants with severe SDB. This analysis did not reproduce the finding of an independent association between depressed mood and more stage 2 sleep, indicating that the relationship between depressed mood and greater levels of stage 2 sleep may be driven in part by the increased rates of SDB found among men with mood disturbance. However, in this sensitivity analysis depressed mood was

still independently associated with less REM sleep. Future work including measures of brain structure should clarify whether neurodegeneration precedes or results from depressed mood and/or REM sleep architecture. Such future work can also investigate the roles of REM sleep and neurodegeneration in mediating the known association between depressed mood and risk of dementia (da Silva, Goncalves-Pereira, Xavier, & Mukaetova-Ladinska, 2013).

The strengths of our study include the novel examination of depression and anxiety symptoms separately in a large population based sample of older men who were not selected on the basis of mental health status or sleep disturbances. In addition, we adjusted for a wide array of medical, sleep and lifestyle confounders. Our findings are robust, and were consistent when excluding participants on relevant psychotropic medications, indicating that our findings are not a result of pharmacological treatment. These results were also similar when examining only individuals currently using antidepressant medication (used here as a proxy for diagnosis), or when examining a group of patients with more severe depressive symptoms using a higher GDS threshold.. The differences in the percentages spent in stage 2 and REM sleep were statistically significant albeit small and   their clinical implications are unclear.

There are, however, several limitations including that we did not have true diagnostic measures of MDD and GAD limiting the comparison of the current study to previous clinical findings. Additionally, although the PSG measures were recorded in-home which should afford participants more comfort than in a laboratory setting, only a single night of PSG recording was available and it is possible that differential "first night" effects bias our results; this "first night" effect, however, was not evident using in-home PSG in the Sleep Heart Health Study (Quan et al., 2002). Compared to a laboratory setting, in-home PSG lacks control over environmental conditions such as noise and light, and this may lead to bias in our results. Since this was an

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observational study, residual confounding by variables that we did not assess could occur. Our analysis was cross-sectional and as such, we cannot comment on the temporal relations of sleep architecture and mental health variables. Finally, our sample was 90.61% older white men and, our results cannot be generalized to other ethnic groups, women, and younger men.

In conclusion, in a large community-based sample of older men, depressed mood was associated with a lesser percentage of time spent in REM sleep. Our findings underscore the importance of examining community-based as well as clinical samples in seeking to understand the underlying biology and health implications of, mood disturbances. Future research is needed to further our understanding of the relationships between mood, sleep, brain and overall health throughout the process of aging.

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Table 1. Summary of Sleep Staging and Rem Latency by Demographic/Lifestyle Characteristics, mean +/- SD

Characteristic	% of Time Spent In Stage 1 Sleep	% of Time Spent In Stage 2 Sleep	% of Time Spent In Slow Wave Sleep	% of Time Spent In REM Sleep	REM latency, min
Age, years					
<72 (n = 657)	**6.02 +/- 3.23**	**62.15 +/- 8.80**	11.49 +/- 8.31	**20.33 +/- 6.05**	73.65 +/- 41.78
72 to <76 (n = 745)	**6.69 +/- 4.03**	**61.92 +/- 9.56**	11.47 +/- 8.88	**19.92 +/- 6.35**	73.60 +/- 41.23
76 to <80 (n = 650)	**6.82 +/- 4.22**	**62.91 +/- 10.10**	11.14 +/- 9.06	**19.13 +/- 6.84**	72.89 +/- 41.80
80+ (n = 801)	**7.58 +/- 5.12**	**63.49 +/- 9.77**	10.95 +/- 9.56	**17.99 +/- 6.71**	77.77 +/- 47.83
P-value	**<.0001**	**0.0052**	0.5828	**<.0001**	0.1124
BMI, kg/m2					
<20 (n =27)	**8.95 +/- 4.71**	62.12 +/- 9.51	**11.31 +/- 10.21**	17.61 +/- 6.03	**83.44 +/- 51.46**

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20 to <25 (n = 837)	**6.59 +/- 4.34**	62.20 +/- 9.49	**12.08 +/- 9.31**	19.13 +/- 6.36	**72.42 +/- 43.99**
25 to <30 (n=1411)	**6.85 +/- 4.16**	62.54 +/- 9.66	**11.04 +/- 8.76**	19.57 +/- 6.66	**74.15 +/- 42.46**
30+ (n = 576)	**6.97 +/- 4.47**	63.52 +/- 9.57	**10.61 +/- 8.95**	18.90 +/- 6.61	**78.47 +/- 44.41**
P-value	**0.0198**	0.0782	**0.0126**	0.0746	**0.0471**
Race/Ethnicity					
White (n = 2585)	6.79 +/- 4.26	**62.56 +/- 9.60**	**11.45 +/- 9.06**	**19.20 +/- 6.55**	75.00 +/- 43.28
Black (n = 97)	6.63 +/- 5.31	**65.02 +/- 10.21**	**7.84 +/- 7.73**	**20.52 +/- 7.28**	71.75 +/- 57.16
Other (n = 171)	7.33 +/- 3.93	**62.45 +/- 8.98**	**10.19 +/- 8.10**	**20.04 +/- 6.19**	70.61 +/- 36.65
P-value	0.2503	**0.045**	**0.0001**	**0.0455**	0.3555
Education					
<high school (n = 149)	**7.62 +/- 4.85**	**64.34 +/- 10.57**	10.86 +/- 10.60	**17.17 +/- 7.03**	**82.73 +/- 52.93**

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high school (n = 466)	**7.64 +/- 4.98**	**63.09 +/- 9.99**	10.52 +/- 8.44	**18.76 +/- 6.89**	**77.92 +/- 47.23**
some college or more (n = 2238)	**6.59 +/- 4.06**	**62.43 +/- 9.43**	11.43 +/- 8.98	**19.54 +/- 6.43**	**73.40 +/- 41.84**
P-value	**<.0001**	**0.0342**	0.1187	**<.0001**	**0.008**
PASE Score					
Quartile 1 (n = 711)	7.14 +/- 4.46	63.06 +/- 10.01	11.47 +/- 9.64	**18.33 +/- 6.89**	**79.12 +/- 49.10**
Quartile 2 (n = 713)	6.72 +/- 4.09	62.55 +/- 10.02	11.26 +/- 9.17	**19.47 +/- 6.51**	**74.17 +/- 45.76**
Quartile 3 (n = 715)	6.75 +/- 3.98	62.71 +/- 9.22	10.94 +/- 8.53	**19.59 +/- 6.62**	**73.22 +/- 39.41**
Quartile 4 (n = 714)	6.65 +/- 4.57	62.24 +/- 9.09	11.34 +/- 8.59	**19.77 +/- 6.12**	**72.01 +/- 38.43**
P-value	0.1301	0.4342	0.7259	**0.0001**	**0.0117**

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Alcohol use (drink/week)					
<1 (n = 1326)	6.71 +/- 4.14	62.89 +/- 9.72	11.30 +/- 9.14	19.11 +/- 6.87	74.60 +/- 44.78
1 - 13 (n = 1361)	6.88 +/- 4.37	62.48 +/- 9.42	11.24 +/- 8.88	19.4 +/- 6.26	74.50 +/- 42.72
14+ (n = 154)	7.19 +/- 4.81	61.69 +/- 10.12	11.27 +/- 8.93	19.84 +/- 6.36	75.70 +/- 39.46
P-value	0.3209	0.2526	0.9861	0.2865	0.9487
Smoking Status					
Never (n = 1127)	6.87 +/- 4.28	62.88 +/- 9.17	11.00 +/- 8.60	19.25 +/- 6.51	74.26 +/- 45.16
Past (n = 1669)	6.77 +/- 4.30	62.45 +/- 9.80	11.46 +/- 9.20	19.33 +/- 6.57	74.86 +/- 42.34
Current (n = 57)	7.23 +/- 4.12	63.56 +/- 11.47	10.31 +/- 10.09	18.9 +/- 7.39	74.93 +/- 41.93
P-value	0.6418	0.3849	0.3112	0.8631	0.9373

PASE – Physical Activity Scale for the Elderly; *P*-value from ANOVA. **BOLD = p<0.05.**

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Table 2: Adjusted means (95% confidence interval) of Sleep Staging Parameters by Mental Health Status

	Neither depressive nor anxiety symptoms (DEP-/ANX-)	P	Depressive symptoms only (DEP+)	P	Anxiety symptoms only (ANX+)	P	Both depressive and anxiety symptoms (DEP+/ANX+)	P
Sleep Measures (%)								
% time stage 1								
Model 1	6.81 (6.65, 6.98)	Reference	6.26 (5.40, 7.13)	0.2219	6.93 (6.27, 7.58)	0.7426	7.29 (6.40, 8.18)	0.2974
Model 2*	6.82 (6.65, 6.98)	Reference	6.10 (5.23, 6.97)	0.2219	6.97 (6.32, 7.63)	0.6549	7.28 (6.36, 8.20)	0.3389

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Model 3**	6.81 (6.65, 6.97)	Reference	6.10 (5.26, 6.93)	0.1008	6.91 (6.28, 7.54)	0.7629	7.18 (6.30, 8.07)	0.423
% time stage 2								
Model 1	62.47 (62.10, 62.85)	Reference	**65.42 (63.49, 67.36)**	**0.003**	63.00 (61.54, 64.46)	0.4932	63.75 (61.76, 65.74)	0.2164
Model 2*	62.56 (62.19, 62.93)	Reference	**65.08 (63.15, 67.01)**	**0.012**	62.36 (60.90, 63.82)	0.7945	62.07 (60.02, 64.12)	0.6483
Model 3**	62.57 (62.19, 62.94)	Reference	**65.00 (63.07, 66.93)**	**0.015**	62.26 (60.81, 63.71)	0.6905	62.06 (60.03, 64.10)	0.635
% time SWS								
Model 1	11.28 (10.93, 11.63)	Reference	11.28 (9.46, 13.09)	0.9977	10.78 (9.41, 12.15)	0.4904	11.44 (9.57, 13.31)	0.8674
Model 2*	11.26 (10.91,	Reference	11.09 (9.26,	0.8574	11.09 (9.71,	0.8171	12.30 (10.36,	0.304

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	11.61)		12.92)		12.47)		14.24)	
Model 3**	11.25 (10.90, 11.60)	Reference	11.28 (9.46, 13.11)	0.9746	11.00 (9.62, 12.38)	0.729	12.42 (10.49, 14.34)	0.2467
% time REM								
Model 1	19.44 (19.18, 19.69)	Reference	**17.05 (15.72, 18.37)**	**0.0005**	19.30 (18.3, 20.30)	0.7908	**17.52 (16.16, 18.88)**	**0.007**
Model 2*	19.36 (19.11, 19.62)	Reference	**17.73 (16.42, 19.05)**	**0.018**	19.58 (18.58, 20.57)	0.6811	18.35 (16.95, 19.75)	0.1652
Model 3**	19.37 (19.12, 19.62)	Reference	**17.63 (16.32, 18.93)**	**0.0102**	19.83 (18.85, 20.81)	0.3768	18.34 (16.96, 19.71)	0.1496
REM latency (minutes)								
Model 1	73.13 (71.44,	Reference	**87.34 (78.59,**	**0.0018**	**81.07 (74.47,**	**0.023**	**91.13 (82.15,**	**0.0001**

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	74.83)		**96.09)**		**87.67)**		**100.12)**	
Model 2*	74.31 (72.66, 75.95)	Reference	81.86 (73.35, 90.38)	0.0886	75.35 (68.92, 81.78)	0.7593	74.28 (65.25, 83.31)	0.9956
Model 3**	74.21 (72.57, 75.85)	Reference	81.40 (72.87, 89.93)	0.1059	75.09 (68.67, 81.53)	0.7942	73.51 (64.51, 82.52)	0.8817

*P-value compared to the reference category, DEP-/ANX-

Model 1: Unadjusted

Model 2: Adjusted for age, clinic, body mass index, race/ethnicity, education, physical activity, alcohol use, smoking status, cognitive impairment, hypertension, diabetes mellitus, rheumatoid arthritis, osteoarthritis, Parkinson's disease, myocardial infarction, congestive heart failure, COPD, stroke, antidepressant use, benzodiazepine use, sleep medication use.

Model 3: Model 2 + sleep efficiency, sleep duration, sleep latency, apnea-hypopnea index, and percent of sleep time with SaO2<90%.