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Longitudinal Associations of Hypersomnolence and Depression in the Wisconsin Sleep Cohort Study

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Abstract

Background—Hypersomnolence is common in depression, however longitudinal associations of excessive daytime sleepiness (EDS), long habitual sleep duration, and objective sleep propensity with depressive symptomatology are not well established.

Methods—Data from adults participating in the Wisconsin Sleep Cohort Study who had multiple assessments at 4-year intervals were utilized in analyses. Conditional (intrasubject) logistic regression estimated the likelihood of development of depression and three primary hypersomnolence measures: subjective EDS [Epworth Sleepiness Scale (ESS) > 10], habitual sleep duration ≥9 hours/day, and increased physiological sleep propensity [multiple sleep latency test (MSLT) mean sleep latency < 8 minutes].

Results—After adjusting for all covariates, the odds for development of depression were significantly increased 1.67-fold (95% CI 1.02-2.73, p=0.04) in participants who also developed subjective EDS. However, development of increased physiological sleep propensity on the MSLT was associated with a trend towards reduced odds for development of depression (odds ratio 0.50, 95% CI 0.24-1.06, p=0.07). No significant longitudinal association between excessive sleep duration and depression was observed.

Limitations—Depression was not verified by psychiatric interview and an objective measure of sleep duration was not utilized.

Conclusions—Our results demonstrate a significant longitudinal association between increased subjective EDS and depression. However, increased physiological sleep propensity on the MSLT was paradoxically marginally protective against the development of depression. Further research is indicated to determine the mechanism underling divergent effects of various aspects of hypersomnolence on the course of mood disorders.

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Keywords

depression; hypersomnolence; longitudinal; multiple sleep latency test; sleepiness; cohort

Introduction

Sleep disturbance plays a significant role in the assessment, pathogenesis, and treatment of mood disorders (Reynolds, 2011). The bidirectional relationship between insomnia, defined as difficulty initiating and/or maintaining sleep, and major depressive disorder is well established (Krystal, 2012). However, far less research has examined the relationships between hypersomnolence, defined as excessive daytime sleepiness and/or sleep duration, and depression, despite the fact that hypersomnolence has been associated with treatment resistance, symptomatic relapse, increased risk of suicide, and functional impairment (Fitzgerald et al., 2011; Goldstein et al., 2008; Kaplan et al., 2011; Kaplan and Harvey, 2009; Worthington et al., 1995; Zimmerman et al., 2005), underscoring the need for further investigation in this area.

The majority of investigations that have examined hypersomnolence in mood disorders have been cross-sectional, with myriad studies demonstrating that both EDS and long sleep duration are associated with depressive symptoms (Bixler et al., 2005; Breslau et al., 1997; Chellappa and Araújo, 2006; Hayley et al., 2013; Hublin et al., 1996; Krueger and Friedman, 2009; Ohayon et al., 1997; Tanaka et al., 2011; van Mill et al., 2010; Vashum et al., 2015). Fewer studies have examined the longitudinal relationships between hypersomnolence and depression, particularly in community-based samples, and those that have been conducted employed varying methodologies, which complicate comparison and generalizability of results.

Ford and Kamerow, utilizing data from the National Institute of Mental Health Epidemiologic Catchment Area study, first reported a significant longitudinal association between excessive sleep duration and major depressive disorder at one-year follow-up among 7954 respondents (Ford and Kamerow, 1989). Similar findings were demonstrated at 3.5 year follow-up by Breslau, et al. using a sample drawn from a large health maintenance organization (n=1007), though associations were no longer significant when severity of prior depressive symptoms were included as covariates in the analysis (Breslau et al., 1996). A more recent investigation that utilized data from 2510 older men participating in the Osteoporotic Fractures in Men (MrOS) Study demonstrated that long sleep duration, measured objectively by actigraphy as >8 hours per day, was not associated with increased odds of depression at mean 3.4 year follow-up assessment (Paudel et al., 2013).

Data from this same cohort also failed to demonstrate a longitudinal association between self-reported EDS and depression in elderly men (Paudel et al., 2013). These negative results were similar to a prior, smaller study of young adults (n=591) participating in the Zurich Cohort Study (Hasler et al., 2005). However, in the largest study to examine longitudinal relationships between EDS and depression to date, Jaussent et al., using data from the French Three-City Study, demonstrated a significantly increased odds of incident depression at 4-year follow-up in a large cohort of older women and men (n=3824) (Jaussent et al.,

2011). Notably, the longitudinal association of EDS with depression in this investigation was independent from and of greater magnitude than that associated with insomnia, and the risk of incident depressive episode increased with frequency of EDS in a dose-dependent manner (Jaussent et al., 2011).

Other studies have also suggested longitudinal connections between excessive sleepiness and depression. Using data from 1137 participants in the Penn State Cohort, Lagrotte and colleagues demonstrated subjective EDS to be significantly associated with increased risk of incident depression at 7-year follow-up (LaGrotte et al., 2016). Data from the same cohort has also demonstrated a bidirectional relationship between depression and sleepiness, with depression significantly associated with incident EDS (Fernandez-Mendoza et al., 2015). Interestingly, the ability to fall asleep at night demonstrated divergent relationships with depression and EDS in this investigation, with increased sleep onset latency associated with incident EDS among those with depression, but reduced latency to nocturnal sleep associated with incident EDS in those without depression (Fernandez-Mendoza et al., 2015). Similarly, anxiety and/or depression has also been associated with incident EDS in the Sleep and HEalth in women (“SHE”) cohort, which examined incident EDS after 10 years in a subsample of 4322 women without sleepiness at baseline (Theorell-Haglöw et al., 2015).

Although there are potential limitations of prior investigations, such as inadequate sample size or cohort makeup, as well as variable ability to control for medical disorders related to hypersomnolence and/or depression, that may have affected findings on a study-by-study basis, the use of standard incidence models to explore connections between hypersomnolence and depression may also have significant limitations to quantify the timewise relationship between these variables. Such studies typically exclude patients at baseline who have either depression or sleepiness and reevaluate them after several years, and thus may fail to capture how these variables more acutely travel with each other longitudinally. This issue is particularly salient for studies that examine the longitudinal relationships between depression and hypersomnolence, which are phenomena that may come and go over shorter time frames than typically sampled in epidemiological studies, and may explain some of the inconsistencies in the prior literature. In addition, a universal limitation of all prior studies has been reliance on self-report measures to assess EDS. The absence of objective measures of daytime sleepiness, such as the multiple sleep latency test (MSLT), is particularly important because the relationship between objectively quantified sleep propensity and subjective sleepiness is relatively modest (Punjabi et al., 2003), and prior cross-sectional analyses from our group have demonstrated that objective and subjective hypersomnolence measures have divergent associations with depression (Plante et al., 2016). Thus, this current study utilized data from the Wisconsin Sleep Cohort (WSC) Study to examine longitudinal associations of both subjective and objective hypersomnolence measures with depression using conditional logistic regression analyses. Based on prior cross-sectional data (Plante et al., 2016), we hypothesized that self-reported excessive daytime sleepiness and sleep duration would be associated with increased odds of depression longitudinally, and that increased physiological sleep propensity, as quantified by the MSLT, would be inversely related to development of depression.

Methods

Participants

All data were derived from persons participating WSC Study, the methodology of which is detailed elsewhere (Goldbart et al., 2014; Peppard et al., 2006; Young, 2009). Briefly, beginning in 1988, a cohort of 1,545 state workers from south central Wisconsin underwent baseline overnight polysomnography (PSG) and were invited for longitudinal follow-up inclusive of repeat PSG every 4 years. All WSC Study procedures have been approved by the University of Wisconsin-Madison Health Sciences Institutional Review Board and all participants provided written informed consent. Due to the addition/removal of protocols during the course of the WSC Study, participant samples used in these analyses varied depending on the availability of data. Subjective measures of hypersomnolence were collected from participants at study visits from 1998-2014 (n=1287 participants). Multiple sleep latency testing was performed on a subsample of participants from 1989-2011 (n=1155 participants). The goal of our analysis was to examine if the development of hypersomnolence was closely concurrent to the development of depression across time. For this reason, participants had to have hypersomnolence and depression measures assessed at ≥2 time-points for inclusion, resulting in 891 and 680 participants available for evaluation of subjective and objective hypersomnolence measures, respectively.

Measures of Somnolence and Sleep Duration

The primary instrument used to quantify subjective EDS was the Epworth Sleepiness Scale (ESS) (Johns, 1991). This validated scale asks the respondent to rate his/her likelihood of dozing (0-3) in eight real-life situations, with the overall score equaling the sum of responses (range 0-24). Participants with ESS scores >10 were characterized as having EDS, consistent with clinically relevant excessive sleepiness (Johns, 1991).

In addition to the ESS, two ancillary measures of subjective sleepiness were included in these analyses. The urge to sleep was assessed using the question, “Many people have periods of low energy or fatigue, but, during a typical day do you experience excessive sleepiness when it is difficult to fight an uncontrollable urge to fall asleep?”. Additionally, the frequency of EDS was elicited by asking participants, “Do you have feelings of excessive daytime sleepiness?” with response options that included: never, rarely (once per month), sometimes (2 to 4 times per month), often (5 to 15 times per month), or almost always (16 to 30 times per month). These secondary measures are referred to as EDS-urge and EDS-frequency, respectively.

Habitual sleep duration was estimated using the following questions: “how many hours of sleep do you usually get in (1) a workday night? (2) a weekend or non-work night?” Daily average sleep duration was calculated as (5 × workday sleep + 2 × weekend sleep)/7. Usual sleep time greater than or equal to 9 hours per night was utilized as the primary measure of excessive sleep duration, consistent with recent population-based estimates of habitual sleep time and nosological standards for excessive sleep duration (American Psychiatric Association, 2013; Ohayon et al., 2013).

The MSLT, widely considered the gold standard objective measure of daytime sleepiness, was utilized as the primary objective measure of physiological daytime sleep propensity. MSLT in the WSC was conducted using two protocols, both of which were in accordance with standard parameters and utilize sleep defined by electroencephalographic criteria (Carskadon et al., 1986; Littner et al., 2005). The primary difference between the two protocols was that the clinical MSLT protocol took place the night after in-laboratory polysomnography, while the research MSLT protocol took place on average 3 weeks after polysomnography. In both protocols, participants went to bed at their usual bedtime on the night prior to testing. Participants also completed sleep logs prior to their MSLT that were used to calculate total sleep time on the 2 nights preceding testing, for use as a covariate due to the possibility of sleep restriction in the vicinity of MSLT testing altering findings.

For all MSLT recordings, four to five daytime nap opportunities were conducted at 2-h intervals, beginning in the morning. Sleep onset latency (SOL) for each nap was defined as the time from the beginning of the recording to the initial 30-second epoch scored as any stage of sleep. In the research protocol, participants were awoken immediately after sleep onset was established, with the nap trial ending at that juncture. In the clinical protocol, participants were allowed to sleep for 15 min after sleep onset during naps to assess for sleep onset rapid eye movement (REM) periods. Because prior cross-sectional analyses have demonstrated nearly identical associations between mean SOL on MSLT and depressive symptoms using either protocol, as well as previous reports that have shown preceding polysomnography has minimal effects on mean SOL on MSLT, results from both protocols were combined for these analyses (Plante et al., 2016; Wichniak et al., 2002). Mean SOL below 8 minutes averaged across the first four nap opportunities defined objective EDS in these analyses, consistent with current nosology (American Academy of Sleep Medicine, 2014).

Outcome: Depression

Participants completed the Zung Self-Rating Depression Scale on the evening of in-laboratory PSG (Zung, 1965; Zung et al., 1965). Scores on this instrument range from 25 to 100, with scores 50 to 59 suggestive of mild depression, and 60 or above indicative of moderate or worse depression. For these analyses, two items related to sleep (“I have trouble sleeping through the night” and “I get tired for no reason”) were removed to avoid the possibility of a built-in association between sleep related symptoms and depression. The modified Zung score was rescaled to have a range that was consistent with the original scale (25-100). Antidepressant medication (selective serotonin reuptake inhibitors, tricyclic antidepressants, and monoamine oxidase inhibitors) use was evaluated via interview and questionnaires. Consistent with prior studies, a score of 50 or greater on the modified Zung scale or the use of antidepressant medication was utilized as the operational definition of depression for our analyses (Peppard et al., 2006; Plante et al., 2016).

Statistics

All data were analyzed using SAS software (SAS Institute Inc., Cary, NC), with two-sided p values of less than 0.05 considered to indicate statistical significance.

Longitudinal models of intra-subject change in depression status were fit using conditional logistic regression to estimate the increased likelihood of development of depression associated with hypersomnolence. The conditional models use data only from individuals who transition from depressed to not depressed status or vice versa and implicitly control for fixed within-person characteristics such as sex, race, and pleiotropic genetic factors that may affect both hypersomnolence and depression (Palta, 2003). The associations of change of status for depression and hypersomnolence can be interpreted in two directions (i.e., the odds of developing depression and becoming sleepy, as well as the odds of becoming not-depressed and not sleepy), but by convention we refer to the former interpretation of the odds ratio. The conditional approach is particularly appropriate for measurement of associations between conditions with labile metrics that have a causal component with a relatively “acute” time frame. That is, we are assuming that the (putative) effect of hypersomnolence on depressed mood operates on a shorter time scale than may be detectable by an approach that followed non-depressed (at baseline) subjects for years to observe incident depression. If hypersomnolence is casually related to depression, and if the affect is relatively acute, precisely those subjects most susceptible to developing depression due, in part, to hypersomnolence, would be excluded from an incidence analysis (because subjects depressed at baseline—for whatever reason, including prevalent hypersomnolence —are excluded in a study examining incident depression).

All models included age, sex, body mass index (BMI; kg/m^2), chronic medical disorders (congestive heart failure, coronary artery disease, hypertension, angina, cerebrovascular accident, diabetes, emphysema, asthma, thyroid condition, epilepsy, arthritis, or back pain), caffeine consumption (0, 1-2, 3-4, or >5 caffeinated beverages per day), tobacco use (current, past, or never), alcohol consumption (≥2 standard drinks of beer, wine, or hard liquor per day versus less), sedative hypnotic medication use, and insomnia (reporting at least one of four insomnia complaints at least five times per month: difficulty falling asleep, waking repeatedly, waking too early in the morning, waking at night and inability to go back to sleep) as potential confounders. Additionally, sleep-disordered breathing was included as a covariate, with the mean number of apneas plus hypopneas per hour (apnea-hypopnea index; AHI) utilized to define severity according to standard cut-offs [absent (AHI < 5), mild (AHI 5 ≤ 15), or moderate or worse (AHI ≥ 15)] (Szklo-Coxe et al., 2010). Habitual sleep duration was also included as a covariate for subjective measures of daytime somnolence. Self-reported sleep duration (assessed by sleep diaries) two nights prior to testing was included as a covariate for MSLT data.

Since there are well-established relationships between insomnia and depressive symptoms (Baglioni et al., 2011), insomnia has been associated with daytime sleepiness in epidemiologic studies (Wilsmore et al., 2013), and patients with insomnia may experience sleepiness as a consequence of their sleep disturbance (American Academy of Sleep Medicine, 2014), interactions between hypersomnolence measures and insomnia were also examined for statistical significance.

Results

Descriptive data for subjective and objective hypersomnolence samples are presented in Tables 1 and 2, respectively. For the analysis of subjective measures, we used data from 891 participants with cumulative 2877 observations, among which 221 participants (752 observations) demonstrated change in depression status across time in an individual. For the analysis of MSLT data, we utilized data from 680 participants with cumulative 1691 observations, among which 123 participants (313 observations) demonstrated longitudinal change in depression status.

A change from ESS≤10 to ESS>10 (i.e. from no subjective sleepiness to sleepiness) was associated with a roughly 1.67-fold (95% CI 1.02-2.73, p=0.04) increased odds for development of depression compared to no change in ESS in the fully adjusted model (Table 3). Similarly, a change in EDS-urge from “no” to “yes” was associated with a 2.30-fold (95% CI 1.42-3.71, p=0.0007) increased odds for development of depression compared to no change in EDS-urge in the fully adjusted model. Also, EDS-frequency transitioning from “rarely” to “often” was associated with a 2.84-fold (95% CI 1.31-6.20, p=0.009) increased odds of depression, with a similar trend for transitioning from “rarely” to “almost always” (OR 2.77, 95% confidence interval 0.86-8.97, p=0.09) in fully adjusted models (Table 3).

There was no significant association between a change to excessive sleep duration from normal sleep duration (i.e. <9 hours to ≥9 hours) and development of depression in fully adjusted models (OR 1.18, 95% CI 0.53-2.61, p=0.69) (Table 3).

On the MSLT, a change in mean SOL from ≥8 minutes to <8 minutes (i.e. from no increased physiological sleep propensity to objective tendency to fall asleep) was associated with a trend towards reduced odds for development of depression in the fully adjusted model (OR 0.50, 95% CI 0.24-1.06, p=0.07) (Table 3).

There were no significant interactions between insomnia and subjective or objective hypersomnolence measures for any model. Exploratory analyses using an alternate definition of depression that considered only Zung score≥50 irrespective of antidepressant medication use did not substantially alter results. Additional analyses examining men and women separately, workday and weekend sleep duration separately, as well as controlling for trait anxiety (defined by use of anxiolytic agents or a Trait Anxiety Score≥39 on the State-Trait Anxiety inventory (Speilburger 1983), which represents the cutpoint for the 75th percentile among participants in the WSC), demonstrated similar findings compared to those derived from primary analyses. There was a significant, but weak correlation between subjective sleepiness and MSLT sleep latency in our sample (ESS vs. MSLT SOL: Spearman’s $\rho = -0.25$, $p<0.001$).

Discussion

Our findings demonstrate that subjective excessive daytime sleepiness is longitudinally associated with the development of depression in the WSC Study, consistent with prior reports that suggest a longitudinal and bidirectional relationship between EDS and depression (Fernandez-Mendoza, et al. 2015; Jaussent et al., 2011; Theorell-Haglöw et al,

2015). Moreover, objectively measured daytime sleep propensity, as assessed by the MSLT, is not associated with depression longitudinally, and in fact, may even be marginally negatively associated with the development of depression. Strengths of our investigation include well-characterized participants which allowed for adjustment for a wide range of covariates, analysis of multiple subjective sleepiness measures to provide convergent validity, and the use of the MSLT as an objective measure of daytime sleep propensity. Our results underscore the complexity of the relationships between hypersomnlence and depression, as well as the limitations of the MSLT as a measure of sleepiness in psychiatric disorders.

Although considered a gold-standard measure of daytime sleepiness, the MSLT has limited utility in the assessment of hypersomnolence in mood disorders. Recent meta-analysis has shown that psychiatric patients with clinical complaints of hypersomnolence demonstrate mean sleep latency values on the MSLT that are similar to population norms (Plante, 2016). In this context, it is not surprising that the MSLT as a measure of sleepiness is not significantly associated with the longitudinal development of depression. In fact, in prior cross-sectional analyses of data from the WSC Study, shortened sleep latency on the MSLT has been associated with significantly decreased odds of depression, despite increased odds of depression using subjective measures of sleepiness (Plante et al., 2016). These findings highlight the frequently paradoxical relationship between MSLT-derived sleep propensity and self-assessed EDS in mood disorders.

The MSLT is a measure of “sleepability” (Harrison and Horne, 1996), as it quantifies a person’s capacity to fall asleep on multiple repeated nap opportunities. As a measure of sleep propensity, the MSLT does not measure other aspects of sleepiness such as drowsiness or the ability to maintain vigilance (Mullington et al., 2011; Sangal et al., 1992). Similar to results observed in this study, sleep latency on the MSLT significantly, but marginally correlates with subjective measures of sleepiness such as the ESS (Chervin et al., 1997). In this context, it is possible that the divergent longitudinal associations between depression and self-reported versus MSLT-derived sleepiness in our study occurred because a different aspect of sleepiness (drowsiness, ability to maintain wakefulness, etc.), that was not quantified by the MSLT, is a more salient measure of sleepiness in mood disorders.

Another plausible explanation for our results is that patients with depression misperceive fatigue, defined as low energy and/or exhaustion, as sleepiness. However, difficulties segregating sleepiness and fatigue are unlikely to be unique to mood disorders, as significant correlations between fatigue and sleepiness have been reported in both healthy and sleep-disordered individuals, with reports of fatigue more common than complaints of sleepiness even in patients with objective sleepiness quantified by the MSLT (Chervin, 2000; Valko et al., 2008). Thus, future research that employs longitudinal assessments of depression in concert with multiple objective measures of sleepiness that measure different facets of sleepiness not quantified by the MSLT, for example using the maintenance of wakefulness test, may help clarify the mechanism responsible for our observed results.

Contrary to our hypotheses, we did not observe a significant longitudinal association between excessive sleep duration and depression, despite prior reports of cross-sectional

associations from the WSC Study, as well as other cohorts (Krueger and Friedman, 2009; Ohayon et al., 2013; Plante et al., 2016; Tanaka et al., 2011; van Mill et al., 2010). The lack of a longitudinal association between depression and long habitual sleep duration in this investigation could be a true finding, or alternatively due to inadequate statistical power in our study to assess this domain. Additionally, the lack of a longitudinal association, despite well-established cross-sectional associations, could be due to differences in the chronicity of effect of long sleep time on depression, particularly relative to EDS measures. Prior reports that longstanding excessive sleep duration is associated with higher risk of incident major depression than more acute increases in sleep duration, support this possibility (Ford and Kamerow, 1989). Additionally, long sleep duration has been independently associated with persistence of depression and anxiety in large cohorts of patients with psychiatric disorders, even after adjusting for severity of psychiatric symptoms, suggesting excessive sleep duration may have a more chronic effect on illness course than could be detected by this investigation (van Mill et al., 2014).

There are limitations of this study that merit discussion. First, our outcome of depression was based on a self-reported rating scale, which may be less accurate than structured interviews in the assessment of mood disorders. Second, we did not have an objective measure of sleep duration such as actigraphy or ad libitum polysomnography, and thus we cannot determine whether such a measure is longitudinally associated with depression. Third, the sample of repeated MSLTs was smaller than repeated subjective hypersomnolence variables, and thus power for statistical inference is lower for physiological sleep propensity. Fourth, our findings are associative in nature, and thus a cause-effect relationship between hypersomnolence and depression cannot be established from these data. In addition, our conditional logistic regression models cannot ascertain specifically whether sleepiness precedes depression or vice versa, but rather demonstrate a longitudinal association that these phenomena change in concert with one another over time. Moreover, this study is not able to establish a mechanistic cause for associations of hypersomnolence with depression that vary by type of measure. Also, because this study examined a population-based cohort, our findings cannot be extended directly to patients with CNS hypersomnias such as narcolepsy and idiopathic hypersomnia, who have by definition increased sleep propensity on the MSLT and have demonstrated increased rates of depression (Dauvilliers et al., 2013). Finally, despite efforts to control for factors that might influence results, there may have been unmeasured and/or unadjusted covariates that could have affected findings. However, detailed assessment of health-related diagnoses, activities, and habits, including polysomnography to assess for sleep disordered breathing, that were included as covariates, limits the likelihood of such confounding substantially altering results.

In conclusion, we have demonstrated significant longitudinal associations between subjective daytime sleepiness and depression among participants in the WSC Study. These associations were observed despite a trend towards a protective association of MSLT-defined increased physiological sleep propensity and depression in this cohort. These findings highlight the complex relationships between hypersomnolence and depression, and the need for further studies that probe the cause of these divergent associations, which may further inform our pathophysiological and nosological understanding of these phenomena.

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Table 1

Descriptive characteristics of the sample included in subjective hypersomnolence measures and depression.

Variable	Depression Status Over Time (2877 observations on 891 participants)			All subjects
	Consistently Not Depressed	Changed Depression Status	Consistently Depressed	
Number of participants, n (%)	537 (60)	221 (25)	133 (15)	891
Number of observations, n (%)	1731 (60)	752 (26)	394 (14)	2877
Age in years (SD)	60 (8)	58 (9) *	57 (8) *	59 (9)
Male sex, n (%)	1049 (61)	367 (49)	129 (33)	1545 (54)
Body Mass Index, kg/m^2 (SD)	31 (7)	32 (8)	33 (7) *	32 (7)
Chronic Conditions, n (%)	1033 (60)	510 (68) *	303 (77) *	1846 (64)
Insomnia, n (%)	824 (46)	386 (50)	194 (49)	1365 (47)
Apnea Hypopnea Index ≥ 15, n (%)	281 (16)	135 (18)	103 (26) *	519 (18)
More than 14 alcoholic drinks per week	101 (6)	45 (6)	12 (3)	158 (5)
Current Smoker, n (%)	120 (7)	86 (11) *	60 (15) *	266 (9)
Sedative drugs, n (%)	52 (3)	67 (9) *	73 (19) *	192 (7)
No caffeinated drinks per day, n (%)	318 (18)	124 (17)	50 (13)	492 (17)
ESS > 10, n (%)#	499 (29)	241 (32)	169 (43) *	909 (32)
EDS-Urge, Yes, n (%)#	300 (17)	160 (21)	126 (32) *	586 (20)
EDS-Frequency, Often or Almost Always, n (%)#	228 (13)	140 (19) *	106 (27) *	474 (16)
Habitual Sleep Time ≥ 9 hours, n (%)#	49 (3)	57 (8) *	40 (10) *	146 (5)

* Significantly different from Consistently Not Depressed group at $p<0.05$

Hypersomnolence measure utilized in analyses

Table 2

Descriptive characteristics of the sample included in objective sleep sleepiness and depression.

Variable	Depression Status Over Time (1691 observations on 680 participants)			All Subjects
	Consistently Not Depressed	Changed Depression Status	Consistently Depressed	
Number of participants, n (%)	438 (64)	123 (18)	119 (18)	680
Number of observations, n (%)	1103 (65)	313 (19)	275 (16)	1691
Age in years (SD)	59 (8)	58 (9)	56 (8) *	58 (8)
Male sex, n (%)	668 (60)	143 (46) *	95 (35) *	906 (54)
Body Mass Index, kg/m^2 (SD)	31 (7)	32 (8)	33 (7)	32 (7)
Chronic Conditions, n (%)	666 (60)	199 (64)	207 (75) *	1072 (63)
Insomnia, n (%)	509 (46)	158 (50)	139 (50)	806 (48)
Apnea Hypopnea Index ≥ 15, n (%)	202 (18)	49 (16)	65 (24) *	316 (19)
More than 14 alcoholic drinks per week	54 (5)	19 (6)	8 (3)	81 (5)
Current Smoker, n (%)	84 (8)	42 (13) *	36 (13) *	162 (10)
Sedative drugs, n (%)	24 (2)	21 (7) *	52 (19) *	97 (6)
No caffeinated drinks per day, n (%)	221 (20)	60 (19)	26 (9) *	307 (18)
MSLT< 8, n (%)#	322 (29)	82 (26)	69 (25)	473 (28)
Minutes of sleep night before MSLT (SD)	426 (74)	431 (67)	436 (69)	428 (65)
Minutes of sleep two nights before MSLT (SD)	443 (74)	450 (84)	463 (88) *	447 (79)

* Significantly different from Consistently Not Depressed group at p<0.05

Hypersomnolence measure utilized in analyses

Table 3

Results of longitudinal conditional logistic modeling[a] of the relationship between hypersomnolence measures and depression

Variable	Odds ratio	95% Confidence interval	p value
Subjective Daytime Sleepiness			
Epworth Sleepiness Scale[b] >10 (vs. ≤ 10)	1.67	(1.02,2.73)	0.04
EDS-frequency[b] (vs. Never)			
Rarely	0.66	(0.38,1.15)	0.14
Sometimes	1.06	(0.55,2.01)	0.87
Often	2.84	(1.31,6.20)	0.009
Almost always	2.77	(0.86,8.97)	0.09
EDS-urge[b] Yes (vs. No)	2.30	(1.42,3.71)	0.0007
Subjective Excessive Sleep Duration			
Self-report habitual sleep time ≥ 9 h (vs. < 9)	1.18	(0.53,2.61)	0.69
Objective Excessive Daytime Sleepiness			
Mean sleep latency[c] from MSLT< 8 min (vs. ≥ 8)	0.50	(0.24,1.06)	0.07

[a]Adjusted for age, sex, body mass index, smoking status, alcohol use, caffeine use, chronic medical conditions, insomnia, sedative hypnotic use, and sleep disordered breathing.

[b]Additionally adjusted for self-reported habitual sleep duration.

[c]Additionally adjusted for self-reported sleep time during 2 nights preceding MSLT.