Predictors of Objective Sleep Tendency in the General Population

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Study Objectives: Daytime sleepiness is a pervasive problem that is associated with a significant public-health burden. Although self-reported measures of daytime sleepiness may be useful in identifying at-risk individuals, there is significant controversy because there are no population-based data relating subjective and objective measures of daytime sleep tendency. The aims of this study were to examine the associations between the Multiple Sleep Latency Test (MSLT), an objective measure of daytime sleep tendency, and self-reported information on the Epworth Sleepiness Scale (ESS) and nighttime sleep duration in the general population.

Design: Cross-sectional study.

Setting and Participants: Population-based sample of 261 women and 371 men, mean age of 50.8 years, enrolled in the Wisconsin Sleep Cohort Study.

Measurements: MSLT, ESS, and self-reported sleep duration prior to the MSLT.

Results: Using survival analysis to model the time to sleep onset during the MSLT, we found that individuals with an intermediate (6-11) and high (≥12) ESS score had a 30% and 69% increase in risk for sleep onset during the MSLT, respectively, compared to individuals with a low ESS score (≤5). A dose-response relationship between self-reported duration of nighttime sleep and objective sleep tendency was also observed. Compared to individuals reporting more than 7.50 hours of sleep (highest tertile), individuals reporting 6.75 to 7.50 hours and less than 6.75 hours (lowest tertile) had a 27% and 73% increase in risk for sleep onset during the MSLT, respectively.

Conclusions: Subjective reports of daytime sleep tendency on the ESS and the duration of nighttime sleep are associated with the results of the MSLT in the general population.

Key Words: daytime sleepiness, Epworth Sleepiness Scale, Multiple Sleep Latency Test, sleep duration.

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INTRODUCTION

EXCESSIVE DAYTIME SLEEPINESS IS A PERVASIVE PROBLEM WITH PREVALENCE ESTIMATES IN THE RANGE OF 12% TO 15% IN INDUSTRIALIZED COUNTRIES.[1,2] It is well established that daytime sleepiness is associated with decrements in psychomotor vigilance,[3] diminished performance at work,[4] and increased risk of occupational injury.[5] Empiric data also indicate that daytime sleepiness is a major contributor to motor vehicle crashes, with an estimated 1% to 3% of all crashes in the United States due to driver sleepiness.[6] The societal burden of drowsy driving is also evident in numerous reports, which indicate that up to 25% of long-distance truck drivers report falling asleep at the wheel in the past year.[7] Data from population-based studies also suggest that daytime sleepiness is associated with an increased risk of cardiovascular events and all-cause mortality.[8,9]

As public awareness of the consequences associated with daytime sleepiness has increased, so has the awareness of the predisposing factors. Voluntary sleep restriction is one of the most important contributors to the development of daytime sleepiness. Surveys of self-reported sleep habits in large samples of the general population demonstrate that the average duration of nocturnal sleep on weekdays is 6.7 hours[10] and that 29% of adults sleep less than 6 hours per night.[2] The high prevalence of daytime sleepiness is further fueled by the increasing prevalence of sleep-disordered breathing,[11] a common condition that causes sleep fragmentation and daytime sleepiness. In light of the potential dangers imposed by daytime sleepiness, identification of at-risk individuals could substantially diminish the associated public-health burden.

The evaluation of daytime sleep tendency includes a number of objective and subjective tests. One of the most commonly used tests to objectively measure daytime sleep tendency is the Multiple Sleep Latency Test (MSLT). The MSLT is a physiologic test of daytime sleep tendency that is performed in the sleep laboratory under standardized conditions and consists of four nap opportunities that are equally spaced at 2-hour intervals.[12,13] With each nap, the latency between "lights-out" and sleep onset is determined and used to quantify the severity of daytime sleep tendency. Subjective methods for assessing sleep tendency include self-administered questionnaires, such as the Epworth Sleepiness Scale (ESS), that inquire about the likelihood of falling asleep in different situations.[14] Although the ESS represents a simple method for reporting sleep tendency, several studies have shown a poor correlation between the ESS and the results of the MSLT.[15-20] The lack of strong association may be due to the relatively small sample sizes or the use of clinic-based samples in the available studies. Currently, there are no population-based data on the relationship between the ESS and the results of the MSLT. Moreover, while it is generally accepted that the duration of nighttime sleep predicts sleep tendency on the following day, little is known about the effect of sleep duration in the general population on the MSLT results. Thus, the aims of the current study were to determine whether self-reported information on the ESS and the duration of nighttime sleep were associated with MSLT-defined sleep tendency in a representative sample from the general population. It was hypothesized that sleep tendency on the ESS and self-reported duration of nighttime sleep would be associated with objective sleep tendency.

Disclosure Statement

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METHODS

Sample Population

The Wisconsin Sleep Cohort Study[11] is a prospective population-based study of sleep-disordered breathing initiated in 1989. Using a two-stage stratified sampling scheme, men and women in the age range of 30 to 60 years were recruited. The first stage entailed mailing a questionnaire on sleep habits, health history, and demographic information to a probability sample of 6,947 state employees identified from payroll records in south central Wisconsin. Eighty percent of those sampled completed the questionnaire. A stratified random sample of questionnaire respondents was then invited to participate in overnight sleep studies. Persons reporting habitual snoring or disturbed breathing during sleep were slightly oversampled in order to increase variability in sleep-disordered breathing. Where appropriate, weighting to account for the oversampling of the cohort is used in the reported analyses. Exclusionary criteria included unstable or decompensated cardiopulmonary disease, recent upper airway surgery, airway cancers, and pregnancy. The participation rate for the baseline examination was 52% (n=1,189) and is in line with other epidemiologic studies with a significant participant burden. The most common reason for refusal was the inconvenience of sleeping away from home. For both sampling stages, participants were compared to nonparticipants on data available from state records and the study questionnaire. Although participants reported a lower frequency of health-related conditions, had higher education and income, and reported slightly more fatigue than nonparticipants, these differences were not statistically significant.

Data Collection

The study protocol, which included overnight polysomnography and other assessments, required follow-up visits at 4-year intervals. The MSLT was added to the study protocol in 1999, and the ESS was included on a 4-year follow-up questionnaire sent to individuals who responded to the baseline questionnaire. For this investigation, all participants who underwent an MSLT within 6 months of completing the ESS were selected (N=632). Participants were asked to document their sleep and wake times in a sleep diary for 5 days before their MSLT. To measure usual sleep tendency, participants were instructed to maintain their usual routine and slept at home. Participants arrived at the sleep laboratory between 8:00 AM and 8:30 AM for the MSLT. Height and weight data were measured with standard anthropometric methods[21] in the sleep laboratory at the time of the MSLT.

A research MSLT was undertaken in accordance with published guidelines.[12,13] It consisted of four 20-minute nap trials at 2-hour intervals starting at 9:00 AM. The recording montage during the MSLT consisted of continuous physiologic recordings of right and left electrooculographic leads, submental surface electromyogram, two electroencephalographic leads (C_3A_2, C_4A_1), and one electrocardiographic lead. Each nap trial lasted 20 minutes if sleep did not occur. If sleep onset occurred within 20 minutes, the nap trial was terminated 90 seconds after sleep onset. Between naps, subjects were instructed not to sleep and were monitored by trained technicians. Sleep-stage scoring was performed on 30-second intervals of the polysomnographic record according to standard criteria.[22] The sleep latency for each nap trial was defined as the time to the first 30-second epoch composed of at least 15 seconds of any stage of sleep.

Statistical Methods

Techniques of survival analysis were used to examine predictors of sleep onset during the MSLT. Descriptive methods of survival analysis include examining the survivorship function as proposed by Kaplan and Meier.[23] An important feature of the MSLT is that all individuals were observed for the entire period of observation (20 minutes). Therefore, there is no interim censoring, and the Kaplan-Meier survivorship function is merely the proportion of individuals who remain awake at each time t for t of 20 minutes or less. For the current analyses, the Kaplan-Meier survival curve was determined for the entire 20-minute duration of the MSLT.

To determine whether MSLT-defined sleep tendency was associated with the ESS and self-reported duration of nighttime sleep, Kaplan-Meier curves were constructed for categories based on specific percentile cut-points for these variables. The log-rank test was used to assess differences in the Kaplan-Meier survival curves across categories of each predictor.[24] To quantify the associations between the primary predictor (eg, ESS score and reported sleep duration) and the distribution of survival times, proportional hazards regression was used.[25] For the MSLT, the proportional hazards model was first applied separately to each MSLT nap to determine whether the primary predictor was associated with an increased risk of sleep onset. In addition to modeling each nap separately, the association between the average sleep latency based on all four naps and the primary predictor was also examined. Covariates such age, sex, and body mass index (BMI) were then included in a multivariable proportional hazards model to determine the adjusted hazard ratio for sleep onset during the MSLT. In the development of the multivariable proportional hazards regression model, the 20-minute time point (ie, end of the nap trial) was used for censoring those individuals who did not experience sleep onset.

Several extensions of the proportional hazards regression model have been proposed to handle multiple event or recurrent time-to-event data.[26-29] As with regression analyses, the issue of multiple events (eg, four nap trials) presents the problem of dependence among observations. Analyzing the events without accounting for this correlation would lead to biased estimates of standard errors. A popular approach to analyze such multivariate survival data has been to obtain regression coefficients using proportional hazards models that ignore the correlation and then adjust the standard errors to account for the correlation. The regression coefficients obtained from such "naïve" proportional hazards regression are asymptotically accurate, and the adjustment corrects their precision (or standard errors) by using a robust variance-covariance matrix.[29]

To examine the association between an explanatory variable and the time to sleep onset during the MSLT, the multivariate proportional hazards model was parameterized as follows:

$$h_i(t \mid x_i) = h_{0(j)}(t)e^{\beta_i x_i} \quad (1)$$

In the above equation, $h_{0(j)}$ represents the baseline hazard function, which can vary across the four nap trials (j=1 to 4). The vector x_i is a set of explanatory variables and the vector β_i is a set of corresponding regression coefficients that describes the effect of the explanatory variables on daytime sleep latency. Plots of the log cumulative baseline hazard function for each nap trial were used to determine whether the four naps differed in the baseline hazard for sleep onset. These plots showed that, although the cumulative hazard functions were different for the four naps, there was no evidence of an interaction with time.

Based on the finding that the baseline hazard functions were proportionately different across naps, initial analyses focused on using these differences to quantify daytime variability in sleep onset. To determine the adjusted hazard ratio for falling asleep at different times of the day (ie, different nap trial), equation 1 was reparameterized to describe nap-wise hazard function differences proportionally:

$$h(t \mid x_i) = h_0(t)e^{\beta_i x_i + \beta_j nap(j)} \quad (2)$$

The hazard ratios for sleep onset during the second through fourth naps were determined compared to the first nap after adjusting for age, sex, and BMI. Further analyses included modeling the associations between the MSLT results and self-reported duration of nighttime sleep and the ESS score. Multivariable models were constructed with the addition of covariates (ie, age, sex, BMI) to the primary predictor, which was categorized into tertiles or quartiles. Statistical significance of all hazard

ratios was determined by the two-sided test of the β coefficient.

Although categorization of the exposure variable simplifies the interpretation of its effects, it assumes a step function for the effect of exposure on the outcome. To determine the dose-response relationship between sleep latency and the covariates of interest, the approach of piecewise quadratic spline regression was used.[30,31] The linear predictor ($\beta_i x_i$) in the proportional hazards regression (equation 2) was parameterized to include second-order polynomial terms for the predictor. Knots for the quadratic splines were placed at tertiles or quartiles of the covariates. All statistical analyses were weighted to determine unbiased estimates and appropriate standard errors in order to account for the stratified sampling of the cohort using the SAS 9.0 statistical software (SAS Institute Inc., Cary, NC).

Table 1—Descriptive statistics* for the study sample

Variable	Mean	(SE)	Median (Interquartile Range)
Age, years	50.8	(0.38)	50.8 (44.7-56.4)
BMI, kg/m²	29.9	(0.32)	28.6 (25.2-33.5)
Sleep duration, h	7.1	(0.05)	7.00 (6.50-7.75)
Epworth Sleepiness Scale score	8.7	(0.19)	8 (6-11)
Sleep latency, min			
Nap 1	12.0	(0.31)	11.0 (6.0-.0)
Nap 2	10.2	(0.30)	8.8 (5.0-15.3)
Nap 3	8.7	(0.29)	7.0 (4.0-11.8)
Nap 4	9.5	(0.30)	8.0 (4.5-13.5)

*Weighted for the probability sampling of the cohort

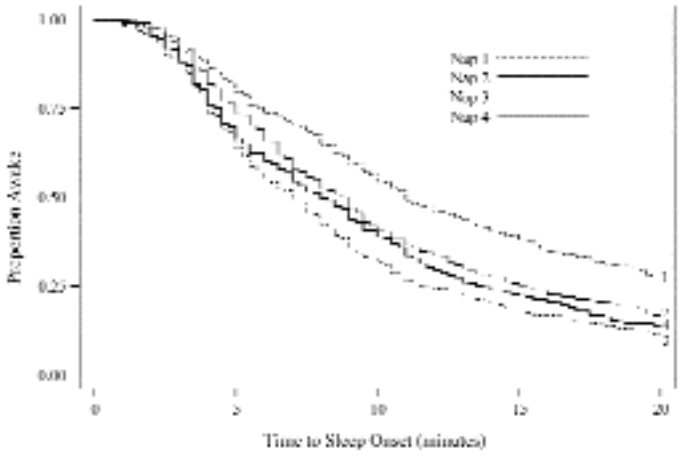

Figure 1—Kaplan-Meier survival curves for the Multiple Sleep Latency Test results by nap trial

Table 2—Adjusted* hazard ratios for sleep onset during the Multiple Sleep Latency Test as a function of the Epworth Sleepiness Scale

	Hazard ratios (95% Confidence Interval)				
Covariate	**Nap 1**	**Nap 2**	**Nap 3**	**Nap 4**	**Pooled Estimates‡**
ESS score					
≤ 5	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
6-11	1.24 (0.92-1.66)	1.27 (0.96-1.68)	1.50 (1.14-1.96)	1.17 (0.91-1.50)	1.30 (1.04-1.62)
≥ 12	1.60 (1.16-2.22)	1.71 (1.25-2.34)	2.11 (1.55-2.87)	1.36 (1.01-1.83)	1.69 (1.31-2.18)
Sex					
Female	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Male	1.26 (1.01-1.57)	1.22 (1.00-1.50)	1.22 (1.01-1.48)	1.10 (0.90-1.35)	1.19 (1.01-1.41)
BMI†, kg/m²	1.04 (1.01-1.07)	1.05 (1.02-1.08)	1.04 (1.01-1.07)	1.05 (1.02-1.08)	1.05 (1.02-1.07)

*Multivariable model with Epworth Sleepiness Scale score, age, sex, and body mass index
† Hazard ratio per 2-kg/m² increase in body mass index
‡Pooled estimates determined by combing data from all four naps and using the multivariate proportional hazards (see methods)
ESS refers to the Epworth Sleepiness Scale; BMI, body mass index.

RESULTS

The final study sample consisted of 632 individuals who underwent an MSLT and had complete data on the ESS and self-reported sleep duration. There were 261 women (41.3%) and 371 men (58.7%). Table 1 summarizes the demographic characteristics of the study sample, adjusted for the stratified sampling. Data from the MSLT revealed that objective sleep tendency varied as a function of the time of day. The longest sleep latency was during the morning nap (9:00 AM) and the shortest sleep latency was during the early afternoon (1:00 PM) nap. Figure 1 shows the Kaplan-Meier survival curves for sleep onset during each MSLT nap. The cumulative probabilities for sleep onset within 20 minutes in naps 1 through 4 were 72.5%, 83.2%, 88.6%, and 86.1%, respectively. These data indicate that approximately 72% of the study sample experienced sleep onset within 20 minutes during the first nap, whereas approximately 86% of the sample experienced sleep onset within 20 minutes in the fourth nap. To further quantify the differences in objective sleep tendency across the four naps, proportional hazards regression, as parameterized in equation 2 (see Methods), was used to estimate the hazard ratio for sleep onset during each nap after adjusting for age, sex, and BMI. Using the early morning nap as the reference, the adjusted hazard ratios of sleep onset during the second, third, and fourth MSLT naps were 1.40 (95% CI: 1.27, 1.54), 1.80 (95% CI: 1.62, 2.00), and 1.57 (95% CI: 1.41, 1.74), respectively. These hazard ratios demonstrate a diurnal pattern in objective sleep tendency, with the highest risk for sleep onset in the early to mid-afternoon.

To examine the association between the ESS and objective sleep tendency, participants were initially categorized into quartiles of the ESS score. Because individuals in the second and third quartiles did not reveal any significant differences in survivorship functions (data not shown), these two quartiles were combined. Thus, the classification for the ESS score was as follows: 5 or less (first quartile), 6 to 11 (second and third quartiles), and 12 or greater (fourth quartile). The Kaplan-Meier survival curves showed that, for each nap trial, individuals with higher ESS scores consistently tended to have a higher tendency for sleep onset during the MSLT. The cumulative probabilities for sleep onset within 20 minutes in the first through fourth naps for individuals in the highest ESS quartile were 81.1%, 89.4%, 94.3%, and 89.0%, respectively. In contrast, the cumulative probabilities for sleep onset within 20 minutes in the first through fourth naps for individuals in the lowest ESS quartile were 64.7%, 73.8%, 78.0%, and 82.3%, respectively. Multivariable proportional hazards models were constructed for each nap with the ESS score as the primary predictor and the following covariates: age, sex, and BMI. Across all four naps (Table 2), a higher ESS score was associated with an increased tendency for sleep onset. Models that used the conventional mean sleep latency also showed that the ESS was associated with sleep tendency. Using an ESS score ≤5 as a reference, the adjusted hazard ratios for intermediate (ESS score: 6-11) and high ESS scores (ESS score ≥ 12) were 1.32 (95% CI: 1.03, 1.68) and 1.85 (95% CI: 1.42, 2.42), respectively. Given that the mean sleep latency is based on data from the four naps, it was not surprising that these odds ratios were on the same order of magnitude as those observed between the ESS and sleep-latency data from individual naps.

Given the relative homogeneity (ie, lack of statistically significant differences) across naps in the association between the ESS score and objective sleep tendency, pooled estimates for the adjusted hazard ratios for the ESS scores were determined (Table 3) by combing data from all four naps and using the multivariate proportional hazards model as parameterized in equation 2 (see Methods). Individuals with an ESS score of at least 12 had an adjusted hazard ratio of 1.69 (95% CI: 1.31, 2.18) for sleep onset during the MSLT compared to individuals with an ESS score ≤5. Individuals in the intermediate category (ESS score: 6-

11) had an adjusted hazard ratio of 1.30 (95% CI: 1.04, 1.62) for sleep onset during the MSLT compared to individuals with an ESS score of ≤5. In addition to the associations with ESS, sex and BMI were also related to objective sleep tendency. Compared to women, men were at increased risk for sleep onset during the MSLT with an adjusted hazard ratio of 1.19 (95% CI: 1.01, 1.41). Furthermore, for every 2-point increase in BMI, the adjusted hazard ratio for sleep onset during the MSLT was 1.05 (95% CI: 1.02, 1.07). Finally, no significant association was noted between age and objective sleep tendency.

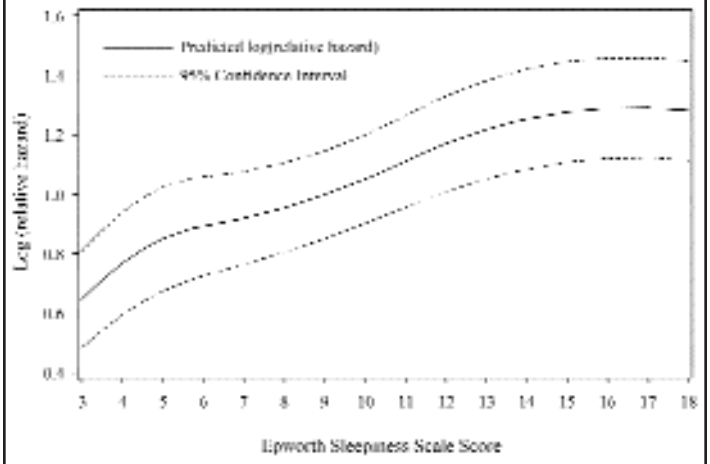

Figure 2—Predicted log (relative hazard) for sleep onset during the Multiple Sleep Latency Test as a function of the Epworth Sleepiness Scale score

Table 3—Adjusted* hazard ratios for sleep onset during the Multiple Sleep Latency Test as a function of reported sleep duration

	Hazard ratios (95% Confidence Interval)				
Covariate	**Nap 1**	**Nap 2**	**Nap 3**	**Nap 4**	**Pooled Estimates**
Total Sleep Time					
> 7.50, h	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
6.75-7.50, h	1.32 (1.00-1.75)	1.16 (0.88-1.53)	1.11 (0.86-1.42)	1.55 (1.19-2.02)	1.27 (1.02-1.57)
< 6.75, h	1.80 (1.35-2.40)	1.64 (1.26-2.12)	1.59 (1.24-2.03)	1.97 (1.51-2.56)	1.73 (1.40-2.15)
Sex					
Female	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
Male	1.22 (0.98-1.53)	1.18 (0.96-1.44)	1.19 (0.97-1.45)	1.02 (0.84-1.25)	1.15 (0.97-1.35)
BMI†, kg/m²	1.04 (1.01-1.07)	1.05 (1.02-1.08)	1.04 (1.02-1.07)	1.05 (1.02-1.08)	1.05 (1.02-1.07)

*Multivariable model with total sleep time, sex, body mass index, and age
† Hazard ratio per 2-kg/m² increase in body mass index
‡Pooled estimates determined by combing data from all 4 naps and using the multivariate proportional hazards (see methods)
BMI refers to body mass index

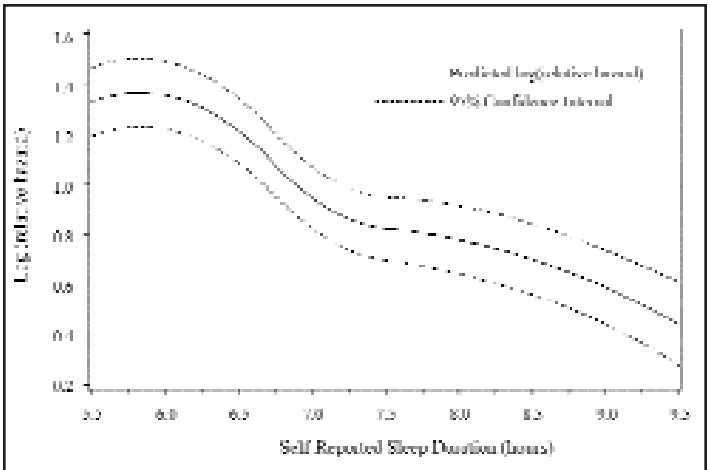

Figure 3—Predicted log (relative hazard) for sleep onset during the Multiple Sleep Latency Test as a function of self-reported sleep duration

The shape of the relationship between the ESS and objective sleep tendency was examined using the technique of quadratic spline regression. Knots for spline regression analysis were placed at the 25th and 75th percentile of the ESS score. Alternative cut-points were also examined and did not significantly alter the overall shape of the relationship shown in Figure 2. In this figure, the *y* axis represents the term log $[h_j(t|x_i)/h_0(t)]$ from equation 2 and is a measure of risk for sleep onset during the MSLT. Although a quadratic spline model was specified with knots placed at an ESS score of 6 and 11, the association between the degree of self-reported daytime tendency and the log (relative hazard) for sleep onset during the MSLT was relatively linear.

The association between self-reported duration of nighttime sleep and objective sleep tendency during the four MSLT naps was also examined using the Kaplan-Meier method. Inferences regarding the association between self-reported sleep duration and objective sleep tendency did not significantly differ whether sleep duration from any of the five nights or the overall average from all five nights was used. Thus, the reported sleep duration from the night prior to the MSLT was used in the final analyses. Individuals with a reported sleep duration of at least 7.50 hours (highest tertile) had a cumulative probability for sleep onset within 20 minutes of 61.9%, 75.1%, 84.9%, and 74.7%, respectively, during the four naps. In contrast, individuals with reported sleep duration of less than 6.75 hours (lowest tertile) had a cumulative probability for sleep onset within 20-minutes of 81.1%, 92.8%, 94.7%, and 94.0%, respectively. Multivariable proportional hazards model for tertiles of self-reported sleep duration after adjusting for age, sex, and BMI were constructed for each MSLT nap trial (Table 3). Not surprisingly, across all four naps, shorter duration of reported nighttime sleep was associated with an increased hazard of sleep onset during the nap. Given the relative homogeneity (ie, lack of statistically significant differences) in the effects of reported sleep duration on objective sleep tendency across naps, pooled estimates for the hazard ratios associated with reported sleep duration were derived using data from all four naps and the multivariate proportional hazards model as described in equation 2. Compared to individuals with reported sleep duration of more than 7.50 hours, individuals with sleep duration between 6.75 and 7.50 hours had a hazard ratio of 1.27 (95% CI: 1.02, 1.57) for sleep onset during the MSLT, whereas individuals with reported sleep duration of less than 6.75 hours had a hazard ratio of 1.73 (95% CI: 1.40, 2.15). Significant associations were again noted between BMI and objective sleep tendency in models that included self-reported sleep duration. However, associations between sleep tendency and sex or age did not reach statistical significance after adjusting for self-reported total sleep time.

A quadratic spline regression model (Figure 3) was then developed to define the dose-response relationship between reported duration of nighttime sleep and objective sleep tendency. Knots for spline regression analysis were placed at the 33rd and 66th percentiles of the self-reported duration of nighttime sleep. As before, the *y* axis represents the term log $[h_j(t|x_i)/ h_0(t)]$ or log(relative hazard) and is a measure of risk for sleep onset during the MSLT. As sleep duration increased, the hazard of sleep onset during the MSLT progressively decreased (Figure 3). In particular, even after 7 hours of nighttime sleep, the hazard of sleep onset during the MSLT continued to decrease.

DISCUSSION

The primary objective of this study was to examine whether the ESS and self-reported nighttime sleep duration were associated with MSLT-defined sleep tendency in a large sample of individuals recruited from the general population. Using the techniques of multivariate survival analysis to model the MSLT results, the current study was able to

demonstrate a number of unique findings. First, the ESS was moderately associated with objective sleep tendency. Compared to individuals in the lowest ESS quartile (≤5), individuals in the intermediate (6 –11) and highest (≥12) ESS quartiles had a 30% and 69% increased risk for sleep onset during the MSLT, respectively. Second, a dose-response relationship between self-reported sleep duration and objective sleep tendency was also observed. Individuals reporting 6.75 to 7.50 hours and less than 6.75 hours of sleep the night before the MSLT had a 27% and 73% increase in risk, respectively, for sleep onset compared to individuals with more than 7.50 hours. Third, a diurnal pattern in objective sleep tendency was also demonstrated in this sample, with the highest risk for sleep onset occurring during the early to midafternoon. Finally, the present study illustrates the use of survival analysis to examine predictors of the MSLT, which is an objective test that measures the inability to maintain wakefulness and thus represents failure time data.

The observed relationship between the ESS and objective sleep tendency in this study is in significant contrast to a number of previous reports. In the original description of the ESS, Johns noted a correlation coefficient of -0.51 between the ESS and the log-transformed daytime sleep latency.[14] Subsequent studies have found minimal or inconsistent associations between the ESS and the MSLT-defined sleep tendency.[15-19] The discrepancies across available studies have generated significant controversy on whether self-reported sleep tendency during the day has significant value in the clinical arena or in epidemiologic field surveys. The finding of a moderately strong association between the ESS and objective sleep tendency suggests that inconsistencies among previous studies may be due to the use of clinic-based samples, other methodologic limitations (including small sample size and the use of correlation and regression methods to examine the MSLT data), or a combination of these factors. Individuals who do not fall asleep during the MSLT represent censored observations and impose a problem for conventional statistical methods. Regression analyses treat censored observations as if they were continuous measurements of sleep latency and can thus introduce bias in estimating the parameters of interest. The techniques of survival analysis overcome this limitation by appropriately modeling censored observations and were first utilized by Carskadon et al[32] for the analysis of the MSLT data. In the current study, the methods of multivariate survival analysis were used, which showed that the ESS has a moderate and independent association with objective sleep tendency. However, it should be noted that there was significant variability in objective sleep tendency among individuals within the second and third ESS quartiles (ESS score: 6-11). Several factors may explain the inability of an intermediate ESS score to discriminate between individuals with varying degrees of objective sleep tendency. First, it is generally accepted that the ESS and the MSLT assess different aspects of daytime sleep tendency. The MSLT is a physiologic test that measures the electroencephalogram-defined sleep tendency under standardized conditions, which can be influenced by the duration of prior sleep, circadian rhythms, environmental factors, and subject motivation. Thus, the MSLT provides a point estimate of objective sleep tendency that encompasses not only subject-related factors, but also the conditions surrounding the test. In contrast, the ESS provides an overall assessment of sleep tendency because it requires the subject to assess the propensity for sleep onset in a number of different situations. Second, the fact that the ESS and MSLT in this study were not performed concurrently may have attenuated the strength of the relationship between the 2 measures, specifically in individuals with mild to moderate levels of sleepiness. However, understanding the agreement of subjective and objective sleep tendency over a variable interval of up to 6 months is desirable if subjective measures, such as the ESS, are to be used in future epidemiologic or screening studies. Third, the interindividual variability in estimating sleep onset in situations described on the ESS may have also diluted the relationship between subjective and objective measures. Finally, reporting the likelihood of falling asleep in specific situations, as required by the ESS, versus reporting the actual frequency of sleep onset under those circumstances may have also introduced error in the subjective assessment of sleep tendency. Regardless of the underlying cause, the lack of precision in defining objective sleep tendency in individuals with mild to moderate degrees of subjective sleepiness highlights the need for using objective measures in identifying at-risk individuals (eg, truck drivers) with equivocal subjective reports.

The finding that self-reported nighttime sleep duration was a strong predictor of objective sleep tendency is consistent with the well-established notion that curtailment of nighttime sleep is a major contributor in the putative causal pathway to increased sleep tendency during the day. However, data from population studies to substantiate this idea have been lacking. Several laboratory-based experimental studies with small sample sizes have previously shown that even a modest amount of sleep restriction (eg, 6 hours of sleep per night) can increase objective sleep tendency.[33-36] Experimental work in normal subjects demonstrates that as sleep loss is extended beyond a few days to a full week, a state of chronic sleep deprivation ensues and the propensity for sleep onset during the MSLT increases.[35] The effect of insufficient sleep on daytime sleepiness is further substantiated by a number of epidemiologic studies that also demonstrate an inverse association between the duration of nocturnal sleep and the degree of self-reported daytime sleep tendency.[1,2,10] Moreover, recent work on chronic sleep restriction in healthy young adults provides strong evidence indicating that sleep loss has a dose-response and a cumulative effect not only on subjective ratings of daytime sleepiness, but also on cognitive performance.[37] The question of whether sleep restriction, even at extreme levels (eg, less than 5 hours of sleep per night), is associated with excess risk of mortality[38] or the development of chronic medical conditions, such as type 2 diabetes mellitus,[39] is controversial and requires further study.

Although causality cannot be established due to the cross-sectional design of this study, the results presented herein also suggest that extension of nocturnal sleep, even beyond the usual 7 to 8 hours, may further decrease objective sleep tendency. In fact, sleep extension to more than 10 hours in normal individuals has previously been shown to further improve the MSLT results in individuals with low (< 6 minutes) and normal (>12 minutes) baseline levels.[40] However, the significance of increasing the MSLT results in nonsleepy individuals beyond normative levels is unknown. Clearly, further research is necessary to determine whether extension of nighttime sleep beyond 7 to 8 hours and prolongation of the daytime sleep latency have any added benefit with regard to improvement in the performance of neurobehavioral tasks, quality of life, and general health.

There are several implications of the current investigation. First, subjective measures of sleep tendency on the ESS are of value, particularly in epidemiologic field studies where conducting physiologic tests, such as the MSLT, may not be feasible. Second, the current study suggests that the use of sleep logs or diaries provides a simple means for assessing sleep habits at the population level. While there is little doubt that subjective judgments about nighttime sleep duration generally underestimate the polysomnographic or actigraphic measures, the minimal burden associated with acquiring self-reported data make this approach attractive. Finally, this study also illustrates that survival analysis should be considered in the analysis of time to sleep onset during the MSLT or in other tests where time to an event (eg, relapse during a task) is analyzed as the dependent variable.

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