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Short and long sleep duration and risk of drowsy driving and the role of subjective sleep insufficiency

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ABSTRACT

Experimental sleep restriction increases sleepiness and impairs driving performance. However, it is unclear whether short sleep duration in the general population is associated with drowsy driving. The goal of the present study was to evaluate whether individuals in the general population who obtained sleep of 6 h or less are more likely to report drowsy driving, and evaluate the role of perceived sleep sufficiency. Data exploring whether subgroups of short sleepers (those who report the most or least unmet sleep need) show different risk profiles for drowsy driving are limited. From the 2009 Behavioral Risk Factor Surveillance System (N = 31,522), we obtained the following self-reported data: (1) sleep duration ($\leq$5, 6, 7, 8, 9, or $\geq$10 h/night); (2) number of days/week of perceived insufficient sleep; (3) among drivers, yes/no response to: "During the past 30 days, have you ever nodded off or fallen asleep, even just for a brief moment, while driving?" (4) demographics, physical/mental health. Using 7 h/night as reference, logistic regression analyses evaluated whether self-reported sleep duration was associated with drowsy driving. Overall, 3.6% reported drowsy driving. Self-identified short-sleepers reported drowsy driving more often, and long sleepers, less often. Among those who perceived sleep as always insufficient, drowsy driving was reported more often when sleep duration was $\leq$5 h, 6 h, or $\geq$10 h. Among those who perceived sleep as always sufficient, drowsy driving was reported more often among $\leq$5 h and 6 h sleepers. Overall, drowsy driving was common, particularly in self-identified short-sleepers as a whole, as well as subgroups based on sleep insufficiency.

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1. Introduction

Crashes related to drowsy driving may be more likely to result in injury or death, since they are not typically preceded by avoidance maneuvers, such as braking or swerving (Strohl et al., 1998; NHTSA, 2011). While estimating the number of accidents due to drowsy driving is methodologically difficult, federal data suggest that approximately 15–33% of fatal crashes may be due to drowsy driving. Results from the National Sleep Foundation's "Sleep in America" poll estimated that more than half of drivers admitted to drowsy driving and 17% reported falling asleep at the wheel within the past year (Drobnich, 2005; Powell and Chau, 2011), and the Centers for Disease Control and Prevention found that >4% of drivers reported driving while drowsy in the previous month (McKnight-Eily et al., 2011).

A number of investigations have linked insufficient sleep with impaired driving ability. In a study of simulated driving performance in shift workers with and without a full night's sleep, prior sleep loss coincided with increased sleepiness levels at the wheel (operationally defined as an increase in eye closure duration and lateral variability) (Anund et al., 2009). Another study, which restricted an experimental group to 5 h of sleep, found that, overall, sleep deprivation resulted in driving impairment (through lane shifting events) and, furthermore, younger men were more vulnerable to this effect (Filtness et al., 2012). An increase in break reaction time after a night of insufficient sleep has also been indicated through simulated driving studies (Miyata et al., 2010).

These studies are limited by their ability to effectively measure real-life driving scenarios. Some studies have examined less precise but more ecologically valid measures. For example, night-time driving, which coincided with an increase in sleepiness, was found to be associated with an increase in lateral variability and reduced speed while driving (Sandberg et al., 2011). In a review of California Department of Motor Vehicles driving records and reports, one study found that short sleepers are not at a higher risk for accidents or other violations (Kripke and Rex, 2002). This study is

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strengthened by its use of objective events as outcome and objective sleep measures, but is limited by potential underreporting of single-car accidents, near-misses, and other problems that may be associated with drowsy driving.

One of the key questions that remain to be addressed is whether the association between sleep and driving generalizes to the population level, beyond small studies of restricted cohorts. Also, since many studies examined driving impairment as a result of forced sleep deprivation under experimental conditions, questions remain regarding the effects of habitual short sleep on driving quality. Accordingly, the present study examined the 2009 Behavioral Risk Factor Surveillance System national survey to determine: (1) whether short-sleepers (6 h or less) were more likely to report drowsy driving than average-duration sleepers and, (2) if perception of insufficient sleep (as either always sufficient or always insufficient) modified the self-reporting of drowsy driving and/or this association. These analyses were carried out using a large, highly generalizable sample (with weighted data representing ~21 million American adults from 6 states).

2. Methods

2.1. Data source

Data from the 2009 Behavioral Risk Factor Surveillance System (BRFSS) were used (Centers for Disease Control, 2009b). The BRFSS is an annual, state-based, random-digit telephone interview survey of United States adults aged ≥18 years. It is conducted by the Centers for Disease Control and Prevention and it is designed to monitor health-related behaviors in the general population. Since not all states are administered all questions, we restricted analyses to states that were asked both sleep and driving survey items. These included 6 states, representing states from the West (Hawaii and Wyoming), South (Georgia and Louisiana), and Midwest (Illinois and Minnesota); no states from the Northeast provided data. Response rates ranged from 45.6% (Hawaii) to 59.7% (Minnesota), and cooperation rates ranged from 68.9% (Hawaii) to 83.9% (Georgia) (Centers for Disease Control, 2009a). All analyses are adjusted to remove bias in the sample. To do this, BRFSS assigns a weight to each participant to account for differences in selection probability, lack of coverage or response, number of residential telephone lines in the home of each participant, and number of adults in the household. This increases generalizability of results by accounting for factors of location and accessibility, and characteristics such as age, sex, and ethnicity. A more detailed description can be located within BRFSS documentation (Centers for Disease Control, 2009a).

2.2. Measures

Drowsy driving. Drowsy driving was assessed using the item, "During the past 30 days, have you ever nodded off or fallen asleep, even just for a brief moment, while driving?" Responses were coded as Yes or No. Those who did not answer, did not have a license, or do not drive were excluded.

Sleep duration. Self-reported habitual sleep duration was assessed using the question, "On average, how many hours of sleep do you get in a twenty-four hour period? Think about the time you actually spend sleeping or napping, not just the amount of sleep you think you should get". Hours of sleep were entered in whole numbers. Responses were categorized as <5, 5–6, 7 [reference], 8–9, and ≥10 h.

Insufficient sleep. Perceived sleep insufficiency was assessed using the question, "During the past thirty days, for about how many days have you felt you did not get enough rest or sleep?" Responses were transformed to number of days per week (by dividing by 4.285) for improved clarity in interpretation, with 0 days/week defined as "always sufficient" and 7 days/week defined as "always insufficient".

Covariates. Covariates included in analyses were age, sex, race/ethnicity (White, Black/African–American, Hispanic/Latino, Asian/Other, Multiracial), education (less than high school, high school graduate, some college, college graduate), and income (<$10,000, $10,000–$15,000, $15,000–$20,000, $20,000–$25,000, $25,000–$35,000, $35,000–$50,000, $50,000–$75,000, and ≥$75,000). Physical health was assessed as days of poor physical health in the past 30 days, and mental health was assessed as days of poor mental health in the past 30 days. These variables were chosen a priori, as previous studies have found that these variables were related to sleep (Buxton and Marcelli, 2010; Grandner et al., 2010a).

2.3. Statistical analyses

Complete case analysis was implemented for both sleep duration and sleep insufficiency, such that only participants who provided complete data were included for each analysis. Categorical variables were expressed as percentages while continuous variables were expressed in terms of mean (±SD). To assess unadjusted associations between each dependent variable and all covariates, Rao-Scott Chi-square and binary logistic regression were used. For the dependent outcome (drowsy driving), two separate models were subsequently built as follows; (1) sleep duration alone; (2) sleep duration plus covariates. This was conducted for the entire sample, as well as separately for those reporting 0 and 7 nights/week of sleep insufficiency.

This large sample of >30,000 individuals represents a population of ~21 million. As a result, we have the power to detect significance for relatively small effect sizes.

We considered a two-tailed *P*-value of <0.05 as significant. All statistical calculations were performed using STATA/SE version 11.1 (STATA Corp., College Station, TX).

3. Results

3.1. Sample characteristics

Characteristics of the sample are reported in Table 1. All cases were weighted, resulting in a sample that was nationally representative. Sleep duration categories were, however, differentially distributed across sociodemographic, socioeconomic, and health variables, justifying their inclusion as covariates. Overall, from a sample $N = 31{,}522$, 3.6% ($N = 1197$) reported drowsy driving. Of the total sample, 10.9% reported sleep as always insufficient, and 29.1% as always sufficient. A total of 8.5% that reported sleep duration ≥10 h reported that sleep was always insufficient. Frequency distributions of sleep duration in the complete study sample, as well as sub-groups that report always insufficient and always sufficient sleep are displayed in Fig. 1.

3.2. Drowsy driving and sleep duration

Table 2 shows the logistic regression results for falling asleep at the wheel as associated with sleep duration for the complete sample. Both before and after adjustment for covariates, short duration sleepers (6 h or less) were more likely to report drowsy driving. The unadjusted data shows that very short sleepers (≤5 h) were 3.8 times as likely to report drowsy driving (OR = 3.816, $p < .0001$), and that short sleepers (6 h) were twice as likely to report drowsy driving (OR = 2.004, $p < .0001$). After adjustment for covariates, the increase in reported drowsy driving in short

Table 1
Characteristics of the sample, stratified by sleep duration category.

Variable	Description	Overall sample	Stratification by sleep duration groups						
			≤5 h	6 h	7 h	8 h	9 h	≥10 h	*p*
Age	Mean ± SD	46.047 ± 17.336	46.081 ± 16.223	44.016 ± 15.854	44.484 ± 15.271	48.444 ± 19.148	45.385 ± 20.694	46.762 ± 23.311	<0.0001
Sex	Female	51.478%	49.332%	52.048%	49.472%	54.609%	56.468%	51.182%	0.0006
Race/ethnicity	Non-Hispanic White	68.214%	74.581%	55.899%	66.561%	70.125%	66.026%	53.615%	<0.0001
	Black/African–American	16.080%	11.216%	25.458%	17.803%	14.781%	14.922%	27.761%	
	Hispanic/Latino	7.041%	5.934%	7.746%	6.802%	7.358%	9.082%	10.154%	
	Asian/Other	6.586%	6.631%	7.104%	6.602%	6.357%	7.119%	5.285%	
	Multiracial	2.079%	1.639%	3.793%	2.231%	1.378%	2.851%	3.185%	
Education	Less than high school	7.552%	4.951%	11.257%	5.864%	8.847%	8.521%	18.646%	<0.0001
	High school	27.381%	22.897%	32.372%	26.934%	28.414%	31.481%	38.721%	
	Some college	27.924%	27.256%	30.198%	30.372%	25.674%	28.899%	24.368%	
	College graduate	37.143%	44.897%	26.173%	36.830%	37.065%	31.099%	18.265%	
Income	<$10,000	3.831%	2.084%	8.714%	3.199%	3.403%	4.045%	10.894%	<0.0001
	$10,000–$15,000	4.010%	2.011%	6.045%	4.057%	4.452%	5.937%	8.366%	
	$15,000–$20,000	6.300%	4.720%	8.438%	6.750%	6.024%	4.578%	15.187%	
	$20,000–$25,000	8.325%	6.843%	9.583%	7.592%	9.133%	10.985%	12.292%	
	$25,000–$35,000	10.039%	7.997%	12.691%	9.654%	10.596%	14.306%	11.017%	
	$35,000–$50,000	14.457%	14.819%	13.094%	14.894%	14.720%	14.124%	11.155%	
	$50,000–$75,000	17.227%	18.636%	15.653%	17.127%	17.613%	15.232%	11.125%	
	>$75,000	35.812%	42.890%	25.783%	36.726%	34.059%	30.794%	19.964%	
Physical health	Mean ± SD	59.902 ± 38.078	62.415 ± 37.309	53.083 ± 37.979	57.488 ± 37.502	62.885 ± 38.605	60.576 ± 37.736	53.864 ± 39.736	<0.0001
Mental health	Mean ± SD	62.325 ± 37.205	65.378 ± 36.048	53.708 ± 37.393	58.614 ± 36.796	66.802 ± 36.974	60.479 ± 38.604	59.580 ± 39.053	<0.0001
Fell asleep driving		3.573%	2.434%	8.693%	4.762%	2.242%	1.374%	2.969%	<0.0001
7 Days/week insufficient sleep		10.878%	5.028%	36.589%	15.618%	4.570%	2.537%	8.501%	<0.0001
0 Days/week insufficient sleep		29.072%	27.465%	8.960%	15.399%	45.543%	50.550%	44.298%	<0.0001

sleepers became slightly less pronounced for ≤5 h: (OR = 3.573, $p < .001$), and for 6 h: (OR = 1.894, $p < .0001$). After adjustment, the 9-h sleepers showed a decreased likelihood to report drowsy driving (OR = 0.329, $p = .0057$).

3.3. Drowsy driving and perceived sleep insufficiency

Table 2 also shows the logistic regression results for drowsy driving and sleep duration for those who reported 7 days/week of insufficient sleep (always insufficient) and 0 days/week of insufficient sleep (always sufficient). Among those who reported sleep that was always insufficient, there was an increased probability of self-reported drowsy-driving in both very short sleepers (≤5 h) and short sleepers (6 h) when compared to 7 h sleepers. Long sleepers (≥10 h) that also rated their sleep as always insufficient were also more likely to report drowsy driving. After adjustment for covariates, the relationship remained for ≤5 h, 6 h and ≥10 h. For those who reported 0 days/week of insufficient sleep (always sufficient), very short and short-sleeper subgroups were again more likely to report drowsy driving both before and after adjustment.

4. Discussion

We found that "very short" and "short" sleep durations, defined as ≤5 and 6 h, respectively, were associated with drowsy driving in main and adjusted analyses. Very short sleepers were 3.6–3.8 times more likely to report drowsy driving than 7-h sleepers, and short sleepers were 1.9–2.0 times more likely. Members of these sleep duration categories rated themselves as having always sufficient or always insufficient sleep, defined as number of days of perceived insufficient sleep in the past 30 days. The main finding, that short sleep duration is associated with drowsy driving, was independent of perceived sufficiency. Said another way, short sleepers and very short sleepers experienced drowsy driving, regardless of whether or not they rated their sleep as always sufficient – this relationship persisted even in cases where subjects reported no insufficient sleep at all in the past month. The second key finding was that a subgroup of long sleepers (≥10 h) who also experienced sleep quality as "always insufficient" also had increased risk of drowsy driving.

Our findings are consistent with previously reported data (Van Dongen et al., 2004) regarding self-rated sleepiness in response to acute and chronic sleep deprivation. While subjects are able to perceive sleepiness in conditions of acute sleep deprivation, such ability reaches a plateau during sustained periods of chronic sleep insufficiency, and the ability to perceive performance deficits becomes impaired. On the other hand, objective assessments continue to show cumulative deficits in neurocognitive performance under conditions of chronic sleep deprivation. One such measure is the psychomotor vigilance test (PVT) (Rupp et al., 2004; Lim and Dinges, 2008, 2010), which measures vigilance and response time, both of which are critical during on-the-road driving performance. These data suggest that short or very short self-reported sleep duration is a robust predictor of drowsy driving, rather than the self-rating of sleep as always sufficient or always insufficient.

In contrast, long sleepers (≥10 h) were at increased risk for drowsy driving only if they perceived their sleep as always insufficient. As suggested previously (Grandner and Patel, 2009; Grandner et al., 2010b), this group is also at higher risk for all-cause mortality. One prevailing hypothesis is that the combination of long sleep duration and perception of insufficient sleep may mark those with comorbid sleep disorders such as obstructive sleep apnea (OSA). OSA is common in the general population; prevalence

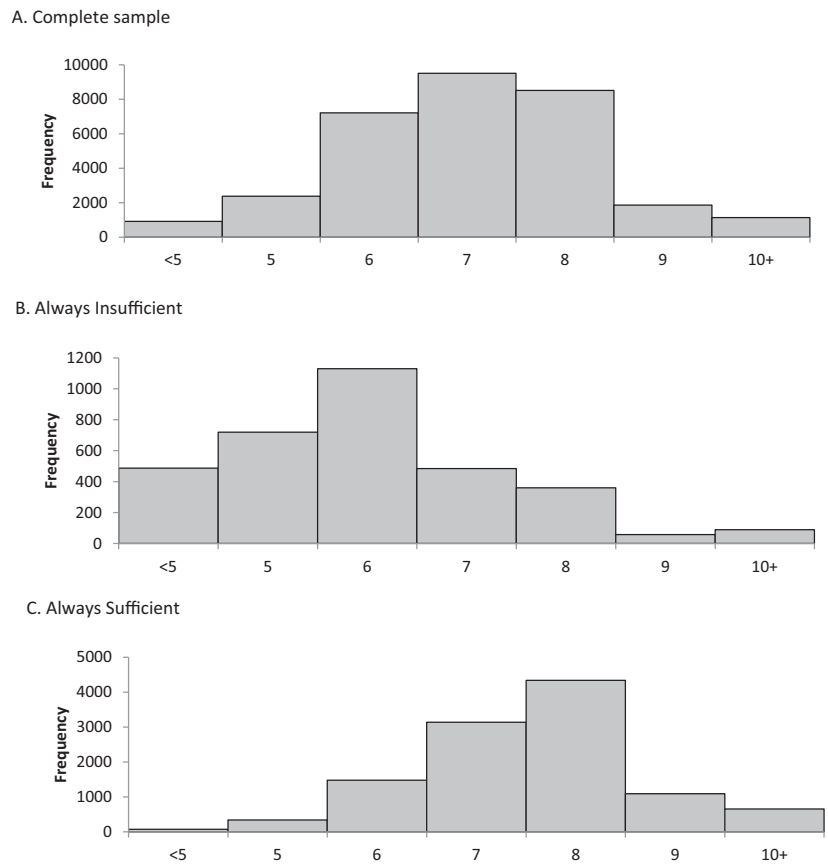

Fig. 1. Frequency distributions of sleep duration in the study sample.

estimates from 1993 suggest that OSA afflicts 4% of men and 2% of women (Young et al., 1993). This prevalence has likely risen, given the link between OSA and obesity, though more recent population prevalence data are not currently available. Despite adequate or even long sleep duration, patients with OSA may report daytime sleepiness and suffer increased risk of sleepiness-related vehicular crashes, at a rate of 1.21–4.89 compared to controls without sleep apnea (Tregear et al., 2009). Treatment of sleep apnea in these individuals has been shown to lower crash risk to baseline levels (Tregear et al., 2010). Therefore, our studies may be marking an important subgroup that deserves formal sleep evaluation to assess for sleep disorders.

Table 2
Unadjusted and adjusted logistic regression results for falling asleep at the wheel associated with sleep duration for the complete sample, those reporting 7 days/week insufficient sleep ("always insufficient"), and those reporting 0 days/week insufficient sleep ("sufficient").

Sleep duration	Unadjusted		Adjusted	
	OR (95% CI)	*p*	OR (95% CI)	*p*
Complete sample				
≤5 h	3.816 (2.829, 5.146)	<0.0001	3.573 (2.593, 4.924)	<0.0001
6 h	2.004 (1.511, 2.658)	<0.0001	1.894 (1.408, 2.548)	<0.0001
7 h	*Reference*		*Reference*	
8 h	0.919 (0.619, 1.364)	0.6753	1.013 (0.669, 1.535)	0.9508
9 h	0.558 (0.227, 1.371)	0.2035	0.329 (0.149, 0.724)	0.0057
≥10 h	1.226 (0.528, 2.846)	0.6351	1.353 (0.580, 3.153)	0.4841
7 days/week insufficient sleep (always insufficient)				
≤5 h	4.839 (2.487, 9.415)	<0.0001	4.376 (1.967, 9.738)	0.0003
6 h	3.347 (1.608, 6.969)	0.0012	3.270 (1.375, 7.776)	0.0073
7 h	*Reference*		*Reference*	
8 h	1.018 (0.305, 3.395)	0.9765	0.955 (0.248, 3.675)	0.9467
9 h	4.693 (0.639, 34.447)	0.1285	5.279 (0.730, 38.193)	0.0994
≥10 h	5.670 (1.754, 18.330)	0.0037	5.514 (1.563, 19.450)	0.0079
0 days/week insufficient sleep (always sufficient)				
≤5 h	2.814 (1.313, 6.029)	0.0078	2.589 (1.121, 5.976)	0.0259
6 h	2.597 (1.246, 5.416)	0.0109	2.955 (1.344, 6.495)	0.0070
7 h	*Reference*		*Reference*	
8 h	1.119 (0.657, 1.906)	0.6782	1.139 (0.633, 2.048)	0.6643
9 h	0.396 (0.096, 1.643)	0.2022	0.467 (0.109, 2.000)	0.3048
≥10 h	0.393 (0.117, 1.326)	0.1324	0.469 (0.137, 1.609)	0.2286

4.1. Limitations

This study incorporated survey data from a large, population-based sample which represented a population of ~21 million. While the large sample size enhanced our ability to detect small effect sizes, and the use of a population-based cohort enhances generalizability of the results, several limitations in study design should be mentioned. The assessment of sleep duration, frequency of perceived insufficient sleep, and drowsy driving were made at a single time point, which limits causal inference. Moreover, our assessments were subjective, raising the possibility of misclassification and possible under-reporting of drowsy driving. Our findings would be strengthened by linking these self-reports with objective data, such as actigraphy, vigilance testing, assessments of driving performance on the road or via simulators, and crash records.

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