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Transitioning from adequate to inadequate sleep duration associated with higher smoking rate and greater nicotine dependence in a population sample

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Abstract

Introduction—Inadequate sleep (6 and 9 h) is more prevalent in smokers than non-smokers but the extent to which sleep duration in smokers relates to smoking behaviors and cessation outcomes, is not yet clear. To begin to address this knowledge gap, we investigated the extent to which sleep duration predicted smoking behaviors and quitting intention in a population sample.

Methods—Data from current smokers who completed the baseline (N=635) and 5-year follow-up (N=477) assessment in the United Kingdom Biobank cohort study were analyzed. Multivariable regression models using smoking behavior outcomes (cigarettes per day, time to first cigarette, difficulty not smoking for a day, quitting intention) and sleep duration (adequate (7–8 h) versus inadequate (6 and 9 h) as the predictor were generated. All models adjusted for age, sex, race, and education.

Results—Worsening sleep duration (adequate to inadequate) predicted a more than three-fold higher odds in increased cigarettes per day (OR =3.18; 95% CI =1.25–8.06), a more than three-fold increased odds of not smoking for the day remaining difficult (OR =3.90; 95% CI =1.27–12.01), and a > 8-fold increased odds of higher nicotine dependence (OR= 8.98; 95% CI =2.81–28.66). Improving sleep duration (i.e., inadequate to adequate sleep) did not predict reduced cigarette consumption or nicotine dependence in this population sample.

Conclusion—Transitioning from adequate to inadequate sleep duration may be a risk factor for developing a more “hard-core” smoking profile. The extent to which achieving healthy sleep may promote, or optimize smoking cessation treatment response, warrants investigation.

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Keywords

Sleep duration; Smoking behaviors; Hardcore smoker

1. Introduction

Despite significant declines in smoking prevalence rates, tobacco use rates remain high (30–50%) in underserved groups (Perkett et al., 2016), while current front-line treatments for nicotine dependence (i.e., patch, spray, gum, lozenge, varenicline, bupropion) are effective for only one-quarter to one-third of treatment seekers (Cinciripini et al., 2013). Novel treatment targets, and strategies to enhance current nicotine dependence treatments, are needed.

As a common physiologic function, sleep is related to tobacco use with smokers having less healthy sleep than non-smokers (Patterson, Malone, Lozano, Grandner, & Hanlon, 2016). Smokers are more likely to report inadequate (< 6 and < 9 h) sleep duration (Mehari, Weir, & Gillum, 2014; Patterson et al., 2016) have longer sleep latency (take longer to fall asleep) (Zhang, Samet, Caffo, & Punjabi, 2006), have increased perceptions of insufficient sleep (Grandner et al., 2015), and increased risk for insomnia than non-smokers (Brook, Zhang, Brook, & Finch, 2012). Night-time smoking, a frequent cause of disrupted and shortened sleep, occurs in approximately 41% of smokers (Scharf, Dunbar, & Shiffman, 2008). Unhealthy sleep before and during cessation have been implicated as an independent cause of relapse (Peltier, Lee, Ma, Businelle, & Kendzor, 2017). While insomnia is a clinically verified withdrawal symptom. Moreover, several of the front-line treatments for smoking cessation (e.g., varenicline, transdermal nicotine) can cause sleep disturbances (McClure et al., 2009). Although it is well established that smokers are more vulnerable to unhealthy sleep, the prospective relationship between habitual sleep and smoking behaviors is less well understood.

To address this knowledge gap, we used a population sample to examine the extent to which sleep duration, and in particular, transitioning from the recommended adequate (7–8 h/night) to the unhealthy inadequate (< 6 and < 9 h) sleep duration, is associated with the smoking behavior characteristics of cigarettes per day, nicotine dependence, difficulty not smoking for one day, and, quitting intention across time. Data from this population study will go toward quantifying the extent to which inadequate sleep duration may be a viable risk factor for continued smoking.

2. Methods

To examine the prospective relationship between sleep duration and smoking behaviors, population data from the United Kingdom (UK) Biobank (application # 3474) were analyzed. The UK Biobank is a large prospective cohort study. Baseline assessments were conducted between 2006 and 2010 and a 5-year follow-up assessment was carried out between 2012 and 2013 in 20,000 participants. More expansive details about the UK Biobank methodology have been described elsewhere (UK Biobank, 2007). Study procedures were approved by the UK Biobank Institutional Review Board.

2.1. Measures

Sleep duration is the primary predictor of interest and was assessed with the survey item, “About how many hours sleep do you get in every 24 hours?” Responses were categorized as short (≤ 6 h), adequate (7–8 h), and long (≥ 9 h); (Grandner, Chakravorty, Perlis, Oliver, & Gurubhagavatula, 2014) short and long sleep were coded as “inadequate” for the current analysis. Change sleep duration variables were derived indicating whether participants had reported one of the following transitions between baseline and follow-up: adequate to inadequate, inadequate to adequate, adequate to adequate, or inadequate to inadequate sleep.

Several smoking variables were assessed as the outcomes of interest. Current **smoking rate** was measured as a continuous variable where respondents recorded “how many cigarettes [he/she] smoked daily.” Change in number of cigarettes per day was calculated for each participant by subtracting the response at baseline from the response at follow-up, and were categorized as no change (change = 0), decreased (change < 0), or increased (change > 0). **Nicotine dependence** was assessed using a single item where participants indicated the time from waking to their first cigarette of the day on an ordinal scale (< 5 min, 5–15 min, between 30 min and 1 h, between 1 and 2 h and > 2 h). Note that the 15–30 min after waking option for this scale was mistakenly omitted. Smokers who reported having their first cigarette of the day within 15 min (higher nicotine dependence) were compared to all others (higher dependence versus not higher dependence).

In terms of smoking cessation readiness, smokers indicated if they would have **Difficulty not smoking for one day** by answering yes or no to the question: “I would have difficulty not smoking for a day.” **Quitting Intention** was measured using a single item where participants indicated if they wanted to stop smoking on a four-level scale: “yes, definitely,” “yes, probably,” “no, probably not,” and, “no, definitely not.” For analytic purposes a dichotomous variable was generated (Yes, definitely and probably versus No, definitely and probably). Change variables were derived for all smoking related variable transitions from baseline to follow-up.

Demographic and health behavior covariates included age, sex (male/female), race (coded as White/Non-White), education (attended college versus did not), measured body mass index (BMI, kg/m²), and self-reported alcohol consumption (daily or almost daily consumption, 3–4 times a week, 1–2 times a week, 1–3 times a month, special occasions only, never).

2.2. Statistical analysis

Repeated assessment data from 20,000 United Kingdom Biobank participants who completed a baseline and 5-year follow-up assessment was obtained. Participants not present at both time points with responses coded “don't know,” “prefer not to answer” or missing data for sleep duration, were excluded ($N = 3758$), leaving 16,242 participants. Of these, participants who did not report current cigarette smoking, or who reported cigar or pipe smoking were excluded ($n = 15,607$ at baseline, $n = 15,765$ at follow-up), leaving 635 baseline and 477 follow-up participants in the analytic sample. A total 411 participants were identified as continued smokers from baseline to follow-up.

Descriptive statistics were used to characterize the sample at both time points. Continuous variables were described with means and standard deviations, and categorical variables with frequencies and percentages. Separate logistic regression models were generated to examine the baseline associations between binary smoking variables and sleep duration. Poisson regression modeling was used to assess the baseline association between cigarettes per day and sleep duration. Adequate sleep duration was used as the reference group in the baseline models. Lastly, multinomial logistic regression models were generated to examine the associations between changes in smoking behaviors and changes in sleep duration from baseline to follow-up among continued smokers. Continued adequate sleep duration was used as the reference group for odds ratio calculations in these models. Participants included in the final sample were significantly more likely to be female, white, non-college attendees, and employed, thus all multivariable models were adjusted for these variables. Multivariable models also adjusted for body mass index and alcohol consumption. Statistical significance was taken at the 0.05 level. All statistical analyses were completed using SAS V9.4 (SAS Institute, Cary, NC).

3. Results

3.1. Baseline sample characteristics

The majority of the sample were White (97.2%) and did not attend college (61.4%). The mean age was 54.5 (SD = 7.6) years, while 51.6% were female (Table 1). Most of the sample reported getting adequate (63.6%) sleep. The mean cigarettes per day was 15.0 (SD = 8.4), 43.7% reported smoking their first cigarette within 15 min of waking; and, while the majority of the sample reported wanting to quit (75.9%), most reported having difficulty not smoking for one day (69.7%) (see Table 1).

3.2. Baseline association between sleep duration with smoking behaviors (N = 635)

At baseline, sleep duration was significantly associated with cigarettes per day such that compared to smokers with adequate sleep duration, the expected number of cigarettes per day was 5% higher among inadequate sleepers (RR= 1.05, 95% CI =1.00–1.10, $p = 0.0373$), adjusting for socio-demographic characteristics. Sleep duration was not associated with time to first cigarette, difficulty not smoking, or quitting intention at baseline (data not shown; see Supplemental Table 1).

3.3. Longitudinal association between sleep duration with smoking behaviors (N = 411)

Multinomial logistic regression models of change in sleep duration showed that transitioning from adequate to inadequate sleep between baseline and follow-up was significantly associated with changes in cigarettes per day, time to first cigarette, and difficulty not smoking for one day in continued smokers. Compared to continued adequate sleepers, the odds of increased (relative to decreased) cigarettes per day was over 3-fold among continued smokers who went from adequate to inadequate sleep duration (OR = 3.18, 95% CI 1.25–8.06, $p = 0.0149$). Transitioning from inadequate to adequate sleep duration was not significantly associated with changes in cigarette consumption in this population sample (Tables 2a and 2b).

With regard to the association between sleep duration and time to first cigarette, continued smokers who reported going from adequate to inadequate sleep duration had an almost 9-fold increased odds in also reporting going from having their first cigarette of the day 30 min to 15 min (i.e., more nicotine dependent) (OR= 8.98, 95% CI 2.81–28.66, $p=0.0002$) and a > 4-fold increased odds in continuing to have their first cigarette of the day within 15 min (15 min at baseline and 15 min at follow-up) (OR =4.54, 95% CI 1.96–10.53, $p=0.0004$). Transitioning from inadequate to adequate sleep duration was not associated with time to first cigarette (Tables 2a and 2b).

The association between sleep duration and ease in not smoking for one day showed that continued smokers who reporting difficulty in not smoking for one day at both time points had an almost 4-fold increased odds in reporting adequate to inadequate sleep compared to continued adequate sleep (OR = 3.90, 95% CI 1.27–12.01, $p=0.0177$).

4. Discussion

We examined the extent to which transitioning from adequate (7–8 h) to inadequate (6 and 9 h) sleep across a 5-year period was associated with changes in smoking behaviors. Our results showed that transitioning from adequate to inadequate sleep duration was associated with a “hardening” (Warner & Burns, 2003) smoker profile in terms of a > 3-fold greater odds of increased daily smoking rate, an 8-fold greater odds of increased nicotine dependence, and a > 3-fold greater odds of not smoking for one day remaining “difficult.” These are some of the first prospective data to characterize the association between sleep duration and smoking behaviors across time in a non-treatment seeking population sample.

That transitioning to inadequate (either short or long) sleep was predictive of worsening smoking habits (independent of demographic factors), supports and extends earlier cross-sectional work. For example, short sleep (6 h) is known to be more prevalent in smokers than non-smokers (McNamara et al., 2014; Palmer, Harrison, & Hiorns, 1980). Short and long sleep (versus adequate sleep) is also associated with higher cigarette consumption and nicotine dependence (Krueger & Friedman, 2009). Our data extend this work by suggesting that transitioning to inadequate sleep duration may be a risk factor for increased tobacco use and nicotine dependence across time. Importantly, our data also showed that improving sleep (i.e., transitioning from inadequate to adequate sleep duration) did not result in significant changes in smoking outcomes. Thus, while worsening sleep duration resulted in “hardening” (Warner & Burns, 2003) smoking habits, improved sleep duration had limited impact on tobacco use. One reason why improving sleep habits did not significantly improve (i.e., reduce) smoking habits may be because the study sample were not treatment-seeking smokers. It may also be that improved sleep habits impact smoking behaviors indirectly. For instance, improved sleep may serve to optimize response to current first line treatments for nicotine dependence versus serve as a stand-alone treatment.

There are several potential mechanisms that may go toward explaining how inadequate sleep duration may impact tobacco use, with cognition and mood being leading candidates. Inadequate sleep duration has been shown to predict poorer cognitive function and mood (Xu et al., 2011), while nicotine use can ameliorate cognitive deficits (Myers, Taylor,

Moolchan, & Heishman, 2008) and improve mood. Thus, it could be that as sleep duration transitions from adequate to inadequate, cognitive and mood deficits are heightened, necessitating higher levels of nicotine administration to ameliorate these deficits. Prospective testing with multiple time-points of these hypothesized temporal, and mediating, relationships are needed.

Limitations of this study include the use of self-reported data and single-item survey items used to measure study constructs. The large number of participants excluded from the final analytic sample may limit the generalizability of study findings. E-cigarette use was not considered in this analysis and the item to assess time to first cigarette omitted the option of between 15 and 30 min after waking. Nevertheless, these data add to our temporal understanding of sleep duration and smoking behaviors in middle-older life smokers. Further work to verify this association using objective sleep and smoking assessments is needed. Other directions for future research include the prospective evaluation of potential moderating (i.e., gender, nicotine dependence) and mediating (i.e., mood, cognition) factors on the relationship between sleep and tobacco use. Clinical trials are needed to ascertain if improved sleep habits in treatment seeking smokers can optimize smoking cessation treatments. Ultimately this work could inform the extent to which sleep may be leveraged to improve response to nicotine dependence treatments.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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HIGHLIGHTS

- Transitioning from adequate to inadequate sleep duration increases smoking behaviors, and difficulty not smoking for one day.
- Transitioning to inadequate sleep duration may be an independent risk factor for a "hardening" smoking habit.
- Middle-to-older age smokers who have inadequate sleep duration may need adjunctive treatment to improve sleep.

Table 1

Sample characteristics among current cigarette smokers at baseline and 5-year follow-up.

	Baseline (t0)	Follow-up (t1)
	(N= 635)	(N= 477)
Age [Mean (SD)]	54.5 (7.6)	59.1 (7.5)
Sex [N (%)]		
Female	328 (51.6%)	245 (51.4%)
Male	307 (48.4%)	232 (48.6%)
Race [N (%)]		
White	613 (97.2%)	457 (96.6%)
Non-white	18 (2.8%)	16 (3.4%)
Education [N (%)]		
College	204 (38.6%)	145 (36.7%)
No College	325 (61.4%)	250 (63.3%)
Body mass index (BMI) [Mean (SD)]	26.4 (4.7)	26.5 (4.8)
Alcohol intake frequency [N (%)]		
Daily or almost daily	178 (28.1%)	143 (30.0%)
3–4 times a week	114 (18.0%)	79 (16.6%)
1–2 times a week	153 (24.1%)	115 (24.1%)
1–3 times a month	73 (11.5%)	63 (13.2%)
Special occasions only	83 (13.1%)	54 (11.3%)
Never	33 (5.2%)	23 (4.8%)
Sleep duration [N (%)]		
Adequate (7–8 h)	404 (63.6%)	303 (63.5%)
Inadequate (< 6 or ≥ 9 h)	231 (36.4%)	174 (36.5%)
Cigarettes per day [Mean (SD)]	15.0 (8.4)	13.9 (8.1)
Time from waking to first cigarette [N (%)]		
15 min	277 (43.7%)	216 (45.3%)
30 min	357 (56.3%)	261 (54.7%)
Difficulty in not smoking for 1 day [N (%)]		
Easy	192 (30.3%)	149 (31.2%)
Difficult	441 (69.7%)	328 (68.8%)
Wants to stop smoking [N (%)]		
Yes	479 (75.9%)	319 (67.0%)
No	152 (24.1%)	157 (33.0%)

Table 2

^a Prospective, multivariable associations^d between change in sleep measures with change in smoking behaviors among continued smokers.

Measure	Change in cigarettes/day, t0 to t1 ^a			Change in time to first cigarette, t0 to t1					
	No change			Increased		15 min to 30 min		30 min to 15 min	
	OR (95% CI)	P-value		OR (95% CI)	P-value	OR (95% CI)	P-value	OR (95% CI)	P-value
Change in sleep duration, t0 to t1									
Adequate to inadequate	2.59 (1.12–6.02)	0.0264	3.18 (1.25–8.06)	0.0149	1.90 (0.36–10.08)	0.4523	8.98 (2.81–28.66)	0.0002	4.54 (1.96–10.53)
Inadequate to adequate	0.96 (0.47–1.96)	0.9070	0.96 (0.40–2.29)	0.9250	1.06 (0.26–4.24)	0.9382	3.26 (1.11–9.57)	0.0314	1.03 (0.48–2.22)
Adequate to adequate	REF		REF		REF		REF		REF
Inadequate to inadequate	1.71 (0.90–3.25)	0.1042	1.55 (0.70–3.45)	0.2855	0.92 (0.23–3.63)	0.9049	2.13 (0.75–6.07)	0.1588	1.36 (0.71–2.59)

^b Associations^d between change in sleep duration with change in smoking behaviors among continued smokers.

Measure	Change in difficulty not smoking for 1 day, t0 to t1				Change in quitting intention, t0 to t1			
	Difficult to Easy		Easy to Difficult		Difficult to Difficult		No to Yes	
	OR (95% CI)	P-value	OR (95% CI)	P-value	OR (95% CI)	P-value	OR (95% CI)	P-value
Change in sleep duration, t0 to t1								
Adequate to inadequate	1.54 (0.25–9.54)	0.6399	3.92 (0.89–17.30)	0.0713	3.90 (1.27–12.01)	0.0177	0.84 (0.17–4.16)	0.8262
Inadequate to adequate	0.92 (0.25–3.35)	0.8962	1.39 (0.43–4.52)	0.5831	0.99 (0.46–2.16)	0.9832	0.29 (0.04–2.40)	0.2528
Adequate to adequate	REF		REF		REF		REF	
Inadequate to inadequate	0.95 (0.28–3.21)	0.9360	0.96 (0.28–3.29)	0.9493	1.51 (0.74–3.10)	0.2602	1.26 (0.39–4.04)	0.7031

^dModels adjusted for age, sex, race, education, BMI, and alcohol intake; REF =Reference category, SE= Standard Error, OR=Odds Ratio, 95% CI = 95% Confidence Interval.