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## The association between active smoking, smokeless tobacco, secondhand smoke exposure and insufficient sleep

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### Abstract

**Background**—Studies have shown that cigarette smoking is associated with sleep disorders in the general population. But studies examining the association between smokeless tobacco use, secondhand smoke exposure and insufficient rest/sleep are limited.

**Methods**—We examined the association between smoking, smokeless tobacco use (n=83,072), secondhand smoke exposure (n=28,557) and insufficient rest/sleep among adults aged ≥20 years in the state-based 2008 Behavioral Risk Factor Surveillance System. Exposure to secondhand smoke was defined as >1 day of exposure to cigarette smoking either at home or in the workplace in the preceding 7 days. Insufficient rest/sleep was defined as not getting enough rest/sleep everyday in the preceding 30 days.

**Results**—Compared to never smokeless tobacco users, the odds ratio (OR; 95% confidence interval [CI]) of insufficient rest/sleep was 1.16 (1.00–1.36) and 1.74 (1.37–2.22) among former and current users. Compared to non-smokers/non-smokeless tobacco users, the OR (95% CI) of insufficient rest/sleep for those who were both current smokers and current smokeless tobacco users was 2.21 (1.66–2.94). Regarding secondhand smoke exposure among non-smokers, those with second-hand smoke exposure had higher odds for insufficient rest/sleep than those without. In contrast, the odds of insufficient rest/sleep were similar among current smokers with or without secondhand smoke exposure.

**Conclusions**—In a multiethnic sample of US adults, compared to non-smokers/non-smokeless tobacco users, those who were both current smokers and current smokeless tobacco users had twice the odds of insufficient sleep. Secondhand smoke exposure was associated with insufficient rest/sleep among non-smokers.

### Keywords

Smokeless tobacco; secondhand smoke; insufficient sleep; BRFSS

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Smokeless tobacco (including snuff, snus and chewing tobacco) is claimed to be a less harmful alternative for cigarette smoking and used in harm reduction strategy (1). Smokeless tobacco contains the same amount of or more nicotine and is as addictive as cigarette smoking (2). Recent studies conducted in the US and Europe have shown that smokeless tobacco increases the risk of coronary heart disease and stroke (2–5). Insufficient rest/sleep is an emerging public health problem in the modern world (6) associated with diabetes (7), hypertension (8), obesity (9), depression (10) and cardiovascular disease (11). Data from the 2008 Behavioral Risk Factor Surveillance System (BRFSS) showed that 11% of Americans reported insufficient rest/sleep for the preceding 30 days (12). Cigarette smoking has been shown to be associated with a range of sleep disorders including shorter sleep duration (13), difficulty initiating and maintaining sleep (14;15), snoring (16) and daytime sleepiness (17). Previous cross-sectional studies have reported associations between active cigarette smoking and insufficient rest/sleep (18) (19). But the association between smokeless tobacco and insufficient rest/sleep has not been studied before.

In a similar vein, the association between secondhand smoke exposure and insufficient rest/sleep has not been consistent in previous studies. While studies among specific populations including pregnant women (20), working men (21), children with asthma (22) and pre-school children (23) reported a positive association between secondhand smoke and insufficient rest/sleep, Davila et al. reported that secondhand smoke exposure was not significantly associated with sleep disorders in the US general population, although active smoking was associated with sleep disorders (18). In this context, we examined the association among active smoking, smokeless tobacco, secondhand smoke and insufficient rest/sleep in a large representative sample of US adults using the latest 2008 BRFSS data.

## METHODS

The BRFSS is an ongoing, state-based telephone survey conducted by random-digit dialing of non-institutionalized US adults aged  $\geq 18$  years in all 50 states, District of Columbia, Guam, Puerto Rico and U.S. Virgin Islands. The details of the study design, questionnaire and methods are available online (24). For the current study, we used data from the 2008 BRFSS survey. The questions to assess use of smokeless tobacco/other tobacco products and secondhand smoke exposure were offered to states as optional modules. Of the 414,509 participants, information on smokeless tobacco/other tobacco products was available for 91,155 participants, and information on secondhand smoke was available for 31,094 participants. After excluding participants who were pregnant, age  $< 20$  years, and those with missing information on insufficient rest/sleep, smoking status and other important covariates, 83,072 provided data for the smokeless tobacco analysis and 28,557 provided data for the secondhand smoke analysis. Subjects were required to sign a consent form before their participation, and approval was obtained from the Human Subjects Committee in the US Department of Health and Human Service. Also this secondary data analysis was approved by the West Virginia University Institutional Review Board.

### Outcome of interest

Insufficient rest/sleep was assessed from the question, “During the past 30 days, for about how many days have you felt you did not get enough rest or sleep?” For the current analysis insufficient rest/sleep was defined as not getting enough rest or sleep everyday in the preceding 30 days.

### Measurement of exposure

Smoking status was categorized into never smokers (smoked  $< 100$  cigarettes during their lifetime), former smokers (smoked  $\geq 100$  cigarettes lifetime and currently not smoking),

current smokers (smoked  $\geq 100$  cigarettes lifetime and currently smoking). Use of smokeless tobacco was assessed from the questions, "Have you ever used smokeless tobacco products such as chewing tobacco, snuf or snus?" and "Do you currently use chewing tobacco, snuf or snus every day, some days or not at all?" Based on the responses, use of smokeless tobacco was categorized into never, former and current smokers. We assessed current use of tobacco products other than cigarette (cigars, pipes, bidis, kreteks) from the question, "Do you currently use any tobacco products other than cigarettes?" with the response coded as a dichotomous variable (no, yes). Secondhand smoke exposure was assessed from the questions, "On how many of the past 7 days, did someone smoke in your indoor workplace while you were there?" and "On how many of the past 7 days, did anyone smoke in your home while you were there?" Participants were considered to be exposed to secondhand smoke if they reported  $>1$  day of exposure to cigarette smoking either at home or in the workplace in the preceding 7 days (25).

### Assessment of covariates

Age, gender, race/ethnicity, alcohol intake, level of education, employment, physical activity and mental illness were assessed using a standardized questionnaire. Heavy alcohol drinking was defined as having more than 2 drinks per day for men and more than 1 drink per day for women in the past month. Education was categorized into below high school, high school, or above high school education. Employment status was categorized as employed, unemployed, retired, student/home maker or unable to work. Body mass index (BMI) was categorized into  $<25$ ,  $25-29$ ,  $\geq 30$   $\text{kg/m}^2$ . "No regular exercise" was defined as not participating in any physical activities such as running, calisthenics, golf, gardening, or walking for exercise in the past month. Individuals were classified as having mental illness if they reported ever having been told by a doctor or other healthcare provider they had a depressive disorder (depression, major depression, dysthymia, or minor depression) or anxiety disorder (acute stress disorder, anxiety, generalized anxiety disorder, obsessive-compulsive disorder, panic disorder, phobia, posttraumatic stress disorder, or social anxiety disorder).

### Statistical analysis

We examined the baseline characteristics of the study population by means or proportions as appropriate for the variable. We examined the association between categories of smoking, smokeless tobacco and insufficient rest/sleep in two logistic regression models: 1) unadjusted and 2) multivariate model adjusted for covariates previously shown to impact sleep including age, sex, race-ethnicity, education, employment status, heavy drinking, body mass index, no regular exercise and mental illness (10;26). We initially examined the association among cigarette smoking, smokeless tobacco use and other tobacco use on sleep in separate multivariable models. However, cigarette smokers may also use smokeless tobacco. Such combined exposure to different tobacco products may be more strongly associated with insufficient rest/sleep than their individual association. Therefore, to examine the association between combined exposure to cigarette smoking and smokeless/other tobacco use and insufficient rest/sleep we defined four mutually exclusive tobacco use categories: non-smoker/non-smokeless tobacco user (referent), smokeless/other tobacco only, cigarette smoking only, and smoking and smokeless/other tobacco use. Then we examined the association between secondhand smoke exposure and insufficient rest/sleep using the same logistic regression models. Since we observed a positive association between secondhand smoke exposure and insufficient rest/sleep in preliminary analysis we proceeded to examine the joint effect of smoking and secondhand smoke on insufficient rest/sleep in four exposure categories: never/former smokers with no secondhand smoke exposure (referent), never/former smokers with secondhand smoke exposure, current smokers with no secondhand smoke exposure and current smokers with secondhand smoke exposure using

the same regression models. To account for unequal probabilities of selection, oversampling, and non-response, BFRSS survey weights were applied for all analyses using SUDAAN (version 8.0; Research Triangle Institute, Research Triangle Park, NC) and SAS (version 9.2; SAS Institute, Cary, NC) software.

## RESULTS

Majority of the study participants were non-Hispanic Whites, above high school educated, employed and were less likely to engage in physical exercises; 20.4% reported current cigarette smoking, 3.5% reported current smokeless tobacco use, 4.5% reported current other tobacco use, and 12.5% of the participants reported having insufficient rest/sleep for 30 days. Selected baseline characteristics of the study population by categories of insufficient rest/sleep included for the analysis of smokeless tobacco are shown in Table 1. Those who reported having insufficient rest/sleep for 30 days were younger, more likely to be female, non-Hispanic blacks, high school or below educated, obese, had higher prevalence of mental illness and were less likely to engage in physical exercises.

The association between cigarette smoking, other types of smoking (cigar, beedi, etc), ST use and insufficient rest/sleep is shown in Table 2. The prevalence of insufficient rest/sleep was lowest among never smokers, never ST users and highest among current smokers and current smokeless tobacco users. Compared with never smoking, both former and current smoking were positively associated with insufficient sleep in the multivariate-adjusted models ( $p$ -trend  $<0.0001$ ). Similarly, compared with those who have never used smokeless tobacco, former and current smokeless tobacco users had increased odds of insufficient rest/sleep ( $p$ -trend  $<0.0001$ ). The multivariate odds ratio (OR; 95% confidence interval [CI]) of insufficient rest/sleep was 1.16 (1.00–1.36) for former smokeless tobacco users and 1.74 (1.37–2.22) for current smokeless tobacco users. In Table 2 we also examined the combined effect of smoking and smokeless tobacco use on insufficient rest/sleep. Compared to non-smokers/non-smokeless tobacco users, those who were both current cigarette smokers and current smokeless tobacco users had more than twice the odds of insufficient sleep (OR [95% CI]=2.21 [1.66–2.94]).

In Table 3, we also examined the combined effect of smoking and secondhand smoke exposure on insufficient rest/sleep. Overall, 11.6% of the participants reported exposure to secondhand smoke including 19.5% of former smokers and 38.0% of current smokers. Compared to never smokers with no secondhand smoke exposure (referent), never/former smokers exposed to secondhand smoke had an increased odds of insufficient rest/sleep (OR [95% CI] =1.29 [1.02–1.63]). In contrast, among current smokers, exposure to secondhand smoke had little effect on insufficient rest/sleep (OR=1.77 vs. 1.83 among those with vs. without second hand smoke exposure).

## DISCUSSION

In a contemporary multiethnic sample of US adults, we found that compared to non-smokers/non-smokeless tobacco users, those who were both current smokers and current smokeless tobacco users had more than twice the odds of insufficient sleep. This association was independent of age, sex, race-ethnicity, education, employment status, heavy drinking, body mass index, and lack of regular exercise. In addition, we found that secondhand smoke exposure at home or work was associated with higher odds of insufficient rest/sleep among never and former smokers. In contrast, among current smokers, the odds of insufficient rest/sleep was not materially modified by secondhand smoke.

Consistent with previous studies, active smoking was associated with insufficient rest/sleep in the current study (14;17;21;27). Effect of smokeless tobacco on sleep has not been studied before. To our knowledge this is the first study showing an association between smokeless tobacco and insufficient rest/sleep. Animal studies have reported sleep disturbances following parenteral administration of nicotine (28;29). Several prospective studies have demonstrated an association between smokeless tobacco and cardiovascular disease (2–4). Lee et al. conducted a review of published literature from Sweden and the US and reported increased risk of heart disease among non-smoking smokeless tobacco users in two US studies (2). Boffetta et al., in a meta-analysis of observational studies from US and Sweden, found an association between smokeless tobacco and fatal myocardial infarction and stroke (3). Critchley et al., in a systematic review of epidemiological studies on smokeless tobacco use, reported a modest association between smokeless tobacco and cardiovascular disease (4). Hergens et al. studied 120,930 never smoking men working in Swedish construction industries. Thirty percent of men who reported using smokeless tobacco were at increased risk of developing hypertension compared to never smokeless tobacco users (30). Secondhand smoke exposure was shown to be associated with sleep disorders among the working population (21), pregnant women (20) and children (22;23). But in the 2005–2006 National Health and Nutrition Examination Survey, secondhand smoke was not significantly associated with sleep disorders among 4000+ adult participants (18). The authors concluded that the inconclusive evidence between secondhand smoke and sleep disorders could be due to lack of awareness and under-reporting of sleep disorders (6.8%).

The mechanism through which active smoking affects sleep has been established (27;28;31–34). Nicotine, the active component of cigarette smoke, stimulates the release of sleep regulating neurotransmitters including dopamine and serotonin, resulting in sleep disturbance (27;28). Cigarette smoking is associated with disturbances in sleep architecture including lighter sleep, long latency in sleep initiation, decreased sleep efficiency and increased daytime sleepiness (27;34). Nicotine dependence and nightly withdrawal are associated with anxiety and stress disorders (32). Further, cigarette smoking impacts sleep by exacerbating respiratory symptoms (31) or contributing to sleep disordered breathing (33). Nicotine withdrawal symptoms including anxiety, stress and restlessness affect sleep in former smokers (35). Smokeless tobacco use is shown to produce hemodynamic changes including increase in heart rate, blood pressure (36) and increased oxidative stress in vitro (37). The blood nicotine levels were shown to be similar after a single exposure to cigarette smoking or smokeless tobacco (38). Secondhand smoke exposure is speculated to affect sleep through nicotine stimulating effect (28), nicotine withdrawal during sleep (39), snore-related arousals (40), and impact on pulmonary function (41).

Strengths of our study include the large sample size, population-based study and information on potential confounders. Our study has several limitations. First, our assessment of exposure and outcome measurements based on self-reported questionnaire data may have resulted in misclassification bias. Second, the question to assess insufficient rest/sleep is subjective and does not distinguish between sleep restriction, poor sleep quality and insomnia. It is possible that blurring the lines between these distinct entities may lead to confusion and probably unnecessary angst about insomnia. As a measure of sleep restriction and poor sleep quality, our question on insufficient rest/sleep may be prone to measurement error. This measurement error is likely to introduce non-differential misclassification. Third, there may be residual confounding from unmeasured variables (e.g., shift work, job stress) in the observed association between smokeless tobacco, secondhand smoke exposure and insufficient sleep. Finally, the cross-sectional nature of the study limits making causal inferences.

In summary, in a multiethnic sample of US adults we found that compared to non-smokers/non-smokeless tobacco users, those who were both current smokers and current smokeless tobacco users had more than twice the odds of insufficient sleep. Also, secondhand smoke exposure at home or work was associated with higher odds of insufficient rest/sleep among never and former smokers. Our findings may have important public health implications in quitting smoking and smoke control programs as we provide new insights into the role of smokeless tobacco use and insufficient sleep.

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Table 1

Baseline characteristics of the study population by categories of insufficient sleep

| Characteristics                         | Insufficient rest/sleep <30 days (n=73,835) | Insufficient rest/sleep for 30 days (n=9,237) | p-value |
|---|---|---|---------|
| Age, years                              | 48.1±0.1                                    | 44.3±0.3                                      | <0.0001 |
| Women, %                                | 49.4±0.41                                   | 55.2±1.1                                      | <0.0001 |
| Race-ethnicity, %                       |   |   | <0.0001 |
| Non-Hispanic whites                     | 68.7±0.4                                    | 66.2±1.1                                      |         |
| Non-Hispanic blacks                     | 10.7±0.3                                    | 13.1±0.7                                      |         |
| Mexican Americans                       | 15.1±0.4                                    | 15.3±1.0                                      |         |
| Others                                  | 5.4±0.2                                     | 5.3±0.6                                       |         |
| Education categories, %                 |   |   | <0.0001 |
| Below high school                       | 10.6±0.3                                    | 15.5±0.8                                      |         |
| High school                             | 27.8±0.4                                    | 33.6±1.0                                      |         |
| Above high school                       | 61.5±0.4                                    | 50.9±1.1                                      |         |
| Employment status, %                    |   |   | <0.0001 |
| Employed                                | 55.1±1.1                                    | 61.6±0.4                                      |         |
| Unemployed                              | 5.2±0.2                                     | 7.2±0.7                                       |         |
| Student/home makers                     | 10.3±0.3                                    | 12.5±0.8                                      |         |
| Retired                                 | 18.3±0.2                                    | 11.1±0.5                                      |         |
| Unable to work                          | 4.6±0.1                                     | 14.0±0.7                                      |         |
| Heavy alcohol drinker, %                | 5.0±0.19                                    | 5.6±0.5                                       | 0.27    |
| No regular exercise, %                  | 24.7±0.4                                    | 38.6±1.1                                      | <0.0001 |
| Mental illness, %                       | 0.9±0.04                                    | 1.7±0.1                                       | <0.0001 |
| Body mass index, %                      |   |   | <0.0001 |
| Normal (<25 kg/m <sup>2</sup> )         | 35.1±0.4                                    | 29.6±1.0                                      |         |
| Overweight (25-29.9 kg/m <sup>2</sup> ) | 37.3±0.4                                    | 33.1±1.0                                      |         |
| Obese (≥30 kg/m <sup>2</sup> )          | 27.6±0.4                                    | 37.4±1.1                                      |         |

\* Data presented are row percentages or mean values and corresponding standard error

† P-value based on analysis of variance or chi-square test, as appropriate.

**Table 2**  
Association between smoking, smokeless tobacco products and insufficient rest/sleep

|  | No. at risk (n=83,072) | Prevalence of (%) insufficient rest/sleep | Unadjusted odds ratio (95% confidence interval) | Multivariate adjusted odds ratio (95% confidence interval) |
|--|------------------------|---|---|--|
| Cigarette smoking                            |                        |   |   |  |
| Never smoker                                 | 43478                  | 9.4                                       | 1.00 (Reference)                                | 1.00 (Reference)   |
| Former smoker                                | 24222                  | 10.0                                      | 1.09 (0.97–1.22)                                | 1.25 (1.11–1.41)   |
| Current smoker                               | 15372                  | 17.8                                      | 2.04 (1.82–2.27)                                | 1.83 (1.63–2.06)   |
| Smokeless tobacco (snuff, snus, chewing)     |                        |   |   |  |
| Never user                                   | 69493                  | 10.9                                      | 1.00 (Reference)                                | 1.00 (Reference)   |
| Former user                                  | 10755                  | 11.5                                      | 1.08 (0.94–1.24)                                | 1.16 (1.00–1.36)   |
| Current user                                 | 2824                   | 14.8                                      | 1.67 (1.33–2.10)                                | 1.74 (1.37–2.22)   |
| Current other tobacco smoking (cigar, beedi) |                        |   |   |  |
| No   | 80503                  | 11.0                                      | 1.00 (Reference)                                | 1.00 (Reference)   |
| Yes  | 2569                   | 13.5                                      | 1.22 (0.98–1.53)                                | 1.32 (1.04–1.66)   |
| Current cigarette smoking/smokeless tobacco  |                        |   |   |  |
| Non smoker/non smokeless tobacco user        | 64038                  | 9.4                                       | 1.00 (Reference)                                | 1.00 (Reference)   |
| Smokeless/other tobacco only                 | 3662                   | 12.6                                      | 1.32 (1.08–1.62)                                | 1.49 (1.20–1.84)   |
| Cigarette smoking only                       | 13876                  | 17.8                                      | 1.98 (1.78–2.21)                                | 1.71 (1.53–1.91)   |
| Both   | 1496                   | 17.9                                      | 2.28 (1.73–3.01)                                | 2.21 (1.66–2.94)   |

\* Adjusted for age (years), sex (men, women), race-ethnicity (non-Hispanic whites, non-Hispanic blacks, Mexican Americans, others), education categories (<high school, high school, >high school), employment status (employed, unemployed, student/home makers, retired, unable to work), body mass index categories (<25, 25–29, ≥30 kg/m<sup>2</sup>), no regular exercise (yes, no), heavy drinking (no, yes), mental illness (no, yes). These models were not adjusted for fellow smoking variables to avoid multicollinearity (cigarette smoking in models involving smokeless tobacco and vice versa)

**Table 3**  
Association between smoking, second hand smoke exposure and insufficient rest/sleep

| Smoking categories      | Second hand smoke exposure | No. at risk (28,557) | Weighted prevalence of (%) insufficient rest/sleep | Unadjusted odds ratio (95% confidence interval) | Multivariate adjusted odds ratio (95% confidence interval)* |
|-------------------------|----------------------------|----------------------|--|---|---|
| Non-smoker <sup>†</sup> | Absent                     | 21126                | 9.1%   | 1 (referent)                                    | 1 (referent)  |
|                         | Present                    | 2068                 | 14.1%  | 1.41 (1.13–1.77)                                | 1.29 (1.02–1.63)  |
| Current smoker          | Absent                     | 4288                 | 16.5%  | 1.99 (1.70–2.32)                                | 1.83 (1.56–2.15)  |
|                         | Present                    | 1075                 | 15.8%  | 1.88 (1.44–2.44)                                | 1.77 (1.35–2.32)  |

\* Adjusted for age (years), sex (men, women), race-ethnicity (non-Hispanic whites, non-Hispanic blacks, Mexican Americans, others), education categories (<high school, high school, >high school), employment status (employed, unemployed, student/home makers, retired, unable to work), body mass index categories (<25, 25–29, ≥30 kg/m<sup>2</sup>), no regular exercise (yes, no), heavy drinking (no, yes), mental illness (no, yes)

<sup>†</sup> Includes never and former smokers