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Associations of Insufficient Sleep with Substance Use among U.S. Youth: Mediational Processes of Depressive Symptoms

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Abstract

While sleep problems and substance use are prevalent among U.S. youth and appear interrelated, relatively little research has explored the possible mediational process to explain associations between insufficient sleep and substance use. This study explored associations of insufficient sleep with the use of nicotine products, alcohol, and marijuana and whether depressive symptoms would mediate the relations. A cross-sectional analysis of binary logistic regression models for each substance use outcome (yes/no) was conducted using the 2019 Youth Risk Behavior Survey, including a nationally representative sample of U.S. high school students. Among the analytic sample (N=13,677), 77.9% of youth reported insufficient sleep (7 or fewer hours), which was significantly associated with increased odds of past 30-day use of cigarettes (OR=1.33; 95% CI=1.05, 1.63; p=.007), e-cigarettes (OR=1.73; 95% CI=1.56, 1.92; p<.001), alcohol (OR=1.79; 95% CI=1.60, 1.99; p<.001), and marijuana (OR=1.50; 95% CI=1.33, 1.68; p<.001) by 33% to 79%. In subsequent mediation tests, we adjusted for insufficient sleep and depressive symptoms simultaneously, and depressive symptoms were significantly associated with the odds of each substance use outcome after controlling for the effects of insufficient sleep. The results indicated that the main effects of insufficient sleep on substance use were significantly explained (i.e., mediated) by depressive symptoms. This study highlights the potential for depressive symptoms to explain the connection between youth insufficient sleep and substance use. Findings from this study may provide insight into the risk of insufficient sleep for mental health and substance use problems, which can facilitate targeted interventions and psycho education for professionals who work with adolescents.

Keywords: Insufficient Sleep; Substance Use; Depressive Symptoms; Youth

Introduction

Many adolescents are vulnerable to either experimental or recreational substance use as their substance use rates remain high. Recent national data of U.S. high school students showed that 7.5% and 24.7% of 12th-grade students reported using combustible cigarettes and vaping electronic cigarettes (e-cigarettes) in the past month. The prevalence of alcohol and marijuana use was also high, 33.6% and 21.1%, respectively [1]. What is more alarming is that there is a more than threefold increase in the prevalence of substance use from 8th grade to 12th grade, especially with a steep increase in the use of alcohol (from 15.2% to 51.9%) and marijuana (from 8.3% to 30.7%) [2]. Previous studies have documented that substance use during adolescence is linked to various adverse long-term effects, including academic problems [3], delinquency and social problems [4], mental and physical health problems [5], and developing other substances [6]. Given these high prevalence rates of youth substance use and their adverse influences, it is important to investigate the factors related to the risk of using alcohol, nicotine products (i.e., combustible cigarettes, vaping e-cigarettes), and marijuana.

One factor that may be related to substance use is sleep. Sleep health is important for all ages, and sufficient amount of sleep is particularly vital for adolescents' mental and physical well-being [7, 8]. Sleep patterns and duration change throughout adolescence, and the quality of sleep may vary among adolescents. According to the National Survey of Children's Health [9], it is reported that more than 30% of adolescents do not have sufficient sleep (i.e., less than 8 hours), while other studies showed that almost 60-70% of adolescents sleep an average of < 8 hours on school nights in the United States [10, 11]. Previous studies suggest correlations between sleep and other problem behaviors in adolescence, including substance use [12-14]. For instance, in their review study, Kwon (2019) evaluated a total of

13 studies on adolescents and found positive associations between sleep problems (e.g., sleep disturbance, shorter sleep duration) and the frequency of combustible cigarettes, e-cigarettes, marijuana use, and increased alcohol consumption [12]. Wong and colleagues (2009) also showed that young children who experienced sleep problems, in comparison to those with no sleep problems, were more likely to have smoked and used alcohol and marijuana in adolescence [13]. Pieters and colleagues (2015) investigated bidirectional relationships between sleep problems, substance use, internalizing and externalizing problems in young adolescents [14]. Sleep problems had prospective associations with cigarette smoking, alcohol use, and marijuana use, while the reverse associations between sleep problems and substance use were not significant. These findings suggest that sleep problems should be considered as an important risk factor for substance use among adolescents.

Although previous studies suggest that sleep problems are predictive of substance use among adolescents, studies on underlying mechanisms of sleep health and substance use are less abundant to date. One potential mechanism could be adolescents' internalizing problems. Sleep problems can contribute to impairments in cognitive

and emotional processing [14, 15] and have been linked to various mental health outcomes in adolescence, including impulsivity [16], anxiety [17], and suicidal thoughts [18]. Particularly, a large body of literature has reported substantial associations between insufficient sleep and depressive symptoms [19-21]. Adolescents' depression, in turn, has been shown to have strong associations with substance use [22, 23]. Adolescents with depressive symptoms are at higher risk of substance use and misuse because adolescents tend to use substances as a maladaptive coping strategy for their emotional distress [24, 25]. Previous studies supported this hypothesis showing that depression is a consistent risk factor of earlier onset and more frequent consumption of cigarettes [26, 27], alcohol [28], and marijuana [29].

In addition, several studies have shown that sleep problems could be common risk factors for depression and substance use and misuse problems [14, 15]. Specifically, Haynes and colleagues (2006) observed that adolescents with sleep problems experienced affective instability and substance abuse [30]. Gau and colleagues (2007) also identified that disrupted sleep cycles are linked to depression and more frequent use of tobacco and alcohol [31]. However, the research on sleep problems, depression, and substance use in adolescence has been limited primarily to studies of the impact of sleep problems on depression and substance use, which overlooks the potential mediating role of depression as a pathway leading to substance use. Adolescents who experience co-occurring problems in sleep, mental health, and substance use are at greater risks of more impairment and distress, and thus, further exploration of the relationship is warranted.

The current study explores the relationships among sleep problems, depressive symptoms, and substance use behaviors using data from the 2019 Youth Risk Behavior Surveillance System. We address the following research questions: (1) whether adolescents who report insufficient hours of sleep are more likely to use substances (i.e., nicotine products, alcohol, and marijuana) compared to adolescents who do not experience lack of sleep and (2) whether experiencing depressive symptoms mediates the association between sleep problems and substance use. We specifically hypothesize that (1) adolescents who report insufficient hours of sleep will be more likely to report having used substances and (2) the association between insufficient sleep and substance use will be at least partially explained by depressive symptoms, showing a mediational association.

Methods

Participants and procedures

We used the Youth Risk Behavior Surveillance System (YRBSS) data conducted by the Centers for Disease Control and Prevention (CDC) [32]. YRBSS is a nationally representative survey of high school students in grades 9 to 12 in the United States who attend public and private schools. The surveys contain a broad range of questions on adolescents' health-associated behaviors and are held every two years. Our analytic sample included 13,677 respondents from the 2019 YRBSS survey.

Measures

Insufficient sleep

Hours of sleep on an average school night were assessed by the question, "On an average school night, how many hours of sleep do you get?" Response options included "4 or fewer hours," "5 hours," "6 hours," "7 hours," "8 hours," "9 hours," and "10 or more hours." Informed by the prior studies and recent national guidelines [33, 34], responses were

dichotomized into insufficient sleep (7 or fewer hours of sleep [Yes=1]) and sufficient sleep (8 or more hours of sleep [No=0]).

Depressive symptoms

Depressive symptoms were measured with a single question: "During the past 12 months, did you ever feel so sad or hopeless almost every day for two weeks or more in a row that you stopped doing some usual activities?" The responses were coded dichotomously (0=No, 1=Yes).

Substance use

As the dependent variables, various substance use behaviors within the past 30 days were assessed using the following items: (1) On how many days did you smoke cigarettes? (2) On how many days did you use electronic vapor? (3) On how many days did you have at least one drink of alcohol? and (4) On how many days did you use marijuana? For combustible cigarettes, electronic vapor (i.e., e-cigarettes), alcohol, and marijuana use, binary variables (yes/no) were used to identify students who reported using each substance on one or more days within the last 30 days.

Demographics

We used age, gender, grade, and race/ethnicity to characterize participants' demographics. In YRBSS, age was categorized as 12 years or younger, 13 years old, 14 years old, 15 years old, 16 years old, 17 years old, and 18 years or older. Due to the small sample size of participants ages 12 years or younger (n=60, 0.3%) and 13 years old (n=27, 0.1%), we combined participants in these two categories with those who were 14 years old (n=1,699, 11.9%). Gender was categorized as female and male. School grade level was categorized as 9th, 10th, 11th, and 12th grade. Race/ethnicity was coded into 5 categories, including White, Hispanic/Latino, Black/African American, Asian, and other races/ethnicities.

Statistical analyses

First, we tested descriptive statistics for study variables. Sampling weights in the YRBSS were incorporated into the analysis to reflect the complex survey design, and we presented unweighted frequency and weighted percentages of all sample characteristics in Table 1. Next, a series of binary logistic regression models were tested to examine direct and indirect effects among study variables. Following the analytic steps of mediational models stated by Baron and Kenny (1986) [35], we tested the following regression models: (1) insufficient sleep (independent variable) → depressive symptoms (mediator); (2) insufficient sleep (independent variable) → substance use (dependent variable); and (3) insufficient sleep and depressive symptoms (independent variable + mediator) → substance use (dependent variable). We calculated the Odds Ratio (OR) and 95% Confidence Interval (CI), adjusting for respondents' demographic characteristics. The p-values of less than .05 (two-tailed) were considered statistically significant. Data were analyzed with IBM SPSS software version 27 [36].

Results

Characteristics of the study population

As presented in Table 1, 49.4% of the total participants were female students, and race/ethnicity consisted of 51.2% White, 26.1% Hispanic/Latino, 12.2% Black/African American, 5.1% Asian, and 5.4% other race/ethnicity group. For key study variables, 77.9% of the analytic sample reported insufficient sleep (7 or fewer hours), and 36.7% of students reported depressive symptoms (i.e., feeling sad and hopeless)

Table 1: Descriptive results of study variables.

Variables	Unweighted N	Weighted %
Gender		
Female	6,885	49.4
Male	6,641	50.6
Age		
14 years or younger	1,786	12.3
15 years	3,473	24.8
16 years	3,628	25.6
17 years	3,102	23.7
18 years or older	1,616	13.7
Grade		
9th grade	3,637	26.6
10th grade	3,717	25.5
11th grade	3,322	24.3
12th grade	2,850	23.6
Race/ethnicity		
White	6,668	51.2
Hispanic/Latino	3,038	26.1
Black/African American	2,040	12.2
Asian	618	5.1
Other[a]	875	5.4
Insufficient sleep (7 or less hours vs. 8 or more hours)	10,175	77.9
Depressive symptoms (Yes vs. No)	4,926	36.7
Cigarette use (Any use vs. Non-use)[b]	726	6.0
E-cigarette use (Any use vs. Non-use)[b]	4,109	32.7
Alcohol use (Any use vs. Non-use)[b]	3,669	29.2
Marijuana use (Any use vs. Non-use)[b]	2,946	21.7

N=13,677. [a]Other category included American Indian/Alaska Native, Native Hawaiian/other Pacific Islander, and multi-ethnic/multi-racial options. [b]Any use=1 or more days in the past month; Non-use = 0 days.

Table 2: Associations of insufficient sleep with each substance use outcome via depressive symptoms.

Model 1: Main Effect Model[a]								
	Substance Use Outcome							
Predictors	Cigarette		E-cigarette		Alcohol		Marijuana	
	OR (95%CI)	p	OR (95%CI)	p	OR (95%CI)	p	OR (95%CI)	p
Insufficient sleep	1.33 (1.08, 1.63)	.007	1.73 (1.56, 1.92)	<.001	1.79 (1.60, 1.99)	<.001	1.50 (1.33, 1.68)	<.001
Model 2: Mediation Effect Model[a]								
	Substance Use Outcome							
Predictors	Cigarette		E-cigarette		Alcohol		Marijuana	
	OR (95%CI)	p	OR (95%CI)	p	OR (95%CI)	p	OR (95%CI)	p
Insufficient sleep	1.15 (0.93, 1.42)	.21	1.55 (1.39, 1.72)	<.001	1.61 (1.45, 1.81)	<.001	1.32 (1.17, 1.49)	<.001
Depressive symptoms	2.83 (2.40, 3.33)	<.001	2.15 (1.98, 2.35)	<.001	1.90 (1.74, 2.07)	<.001	2.12 (1.93, 2.33)	<.001

N=13,677. [a]Binary logistic regression model for each substance use outcome adjusting for respondents' age, gender, grade, and race/ethnicity.

in the past 12 months. Among the total participants, 6.0% and 32.7% reported combustible cigarette use and e-cigarette use in the past 30 days, respectively. The prevalence of past 30-day alcohol use was 29.2%, and 21.7% reported marijuana use during the past 30 days.

Associations of insufficient sleep with substance use via depressive symptoms

Binary logistic regression models were tested to examine mediational associations linking insufficient sleep to current substance use outcomes via depressive symptoms. First, a binary logistic regression model tested the association between insufficient sleep (i.e., independent variable) and depressive symptoms (i.e., a possible mediator). After adjusting for demographic characteristics (i.e., age, gender, race/ethnicity, grade), insufficient sleep was significantly associated with increased odds of experiencing depressive symptoms (OR=2.15; 95%CI=1.94, 2.38; p<.001). This result showed that insufficient sleep (7 or fewer hours)

was positively associated with depressive symptoms among high school students.

As presented in Table 2, we then tested the main effects of insufficient sleep on each substance use outcome (Model 1). After controlling for sociodemographic factors, insufficient sleep was significantly associated with increased odds of past 30-day cigarette use (OR=1.33; 95%CI=1.05, 1.63; p=.007), e-cigarette use (OR=1.73; 95% CI=1.56, 1.92; p<.001), alcohol use (OR=1.79; 95% CI=1.60, 1.99; p<.001), and marijuana use (OR=1.50; 95% CI=1.33, 1.68; p<.001) by 33% to 79%. The findings showed that insufficient sleep had main effects on each substance use by having direct relations with all substance use outcomes.

Finally, we examined adjusted binary logistic regression models to identify if depressive symptoms were additionally associated with each substance use outcome after adjusting for insufficient sleep and sociodemographic covariates (Model 2). When we adjusted for

insufficient sleep and depressive symptoms simultaneously, depressive symptoms were significantly associated with the odds of each substance use outcome after controlling for the effects of insufficient sleep. In the models, depressive symptoms significantly and additionally increased the odds of cigarette use (OR=2.83; 95% CI=2.40, 3.33; $p<.001$), e-cigarette use (OR=2.15; 95% CI=1.98, 2.35; $p<.001$), alcohol use (OR=1.90; 95% CI=1.74, 2.07, $p<.001$), and marijuana use (OR=2.12; 95% CI=1.93, 2.33; $p<.001$). The results indicated that the main effects of insufficient sleep on substance use were significantly explained (i.e., mediated) by depressive symptoms.

Discussion

The associations between insufficient sleep and substance use among adolescents have been well-examined in the literature. The underlying mechanisms to explain the relationships, however, are less clear. The current study expands on the prior studies by examining the mediational association between insufficient sleep and the use of various substances via depressive symptoms among U.S. high school students.

Our findings indicate that insufficient sleep was positively associated with using nicotine products, alcohol, and marijuana. The findings are consistent with the literature as a large body of research has shown lower amounts of sleep were related to increased risk for nicotine product use [37], alcohol use [38], and marijuana use [39]. To explain the association between insufficient sleep among youth and their substance use, previous studies have suggested various behavioral and psychological characteristics of adolescents, such as lack of physical activity, healthy diets [40], internalizing and externalizing problems that can lead to the deficit of self-regulating behaviors like substance use [41]. The potential linking mechanisms between sleep and substance use, however, have not been extensively explored yet.

To provide a better understanding of the possible psycho-behavioral mechanisms linking insufficient sleep to various substance use behaviors among adolescents, the present study focuses on mediational pathways of insufficient sleep → depressive symptoms → substance use. Consistent with the prior studies [14, 15], we found that insufficient sleep was significantly associated with depressive symptoms. Researchers have found that insufficient sleep plays a pivotal role in normal biological functions [42]. Insufficient sleep can impair endocrine, physiological, and neuronal functions [43], leading to stress vulnerability, cognitive impairment, and difficulties in regulating emotions. This might be an even more salient problem among adolescents that are experiencing rapid brain development [44]. As such, adolescents with sleep loss may experience more difficulties in regulating their varied emotions, which can contribute to the development of depressive symptoms. Therefore, obtaining sufficient sleep is important in terms of reducing the risk of depressive symptoms and related substance use among adolescents.

We also found that depressive symptoms, in turn, were significantly associated with all substance use outcomes after accounting for insufficient sleep effects on substance use. Adolescents with higher levels of depressive symptoms are more likely to experience fatigue and irritability, which are known to be proximal risk factors of substance use [45]. Previous studies have suggested that adolescents may use substances in a self-medicating way [46]. That is, emotional struggles may lead adolescents to self-medicate with substances to alleviate their painful or problematic affective states. In accordance with the hypothesis, several studies have documented that adolescents' depressive symptoms were associated with use of alcohol, tobacco, and marijuana [25, 27-29].

The present study emphasizes the importance of sufficient sleep among adolescents by showing that an appropriate amount of sleep may help youth to be less engaged in substance use. Therefore, the substantial role that sleep plays in adolescents' behavioral health risks should be acknowledged, and insufficient sleep could be targeted in school-based prevention programs for students with substance use problems [47]. For instance, school nurses, counselors, and other health care professionals working for youth could assess adolescents experiencing mental health and substance use problems by developing prevention programs that emphasize sleep health and substance use prevention. At the same time, students could be educated about the importance of sufficient sleep and learn how to develop healthy sleep practices by avoiding excessive media use and irregular bedtime schedules [47]. Helping students to assess their sleep issues through sleep diaries or sleep problem screening assessments could also be beneficial.

There are some limitations to this study that are worth mentioning. A key study limitation is the cross-sectional study design. Causal inferences should not be determined because potential reciprocal influences among insufficient sleep, depressive symptoms, and substance use could be considered. Also, the current study only measured sleep duration (i.e., hours of sleep on school nights), which may not fully account for various characteristics of sleep among adolescents, such as patterns, quality, or efficiency of sleep. In addition, a single item of self-report measures was also used to assess depressive symptoms and each substance use in the YRBSS survey, and therefore more detailed information on these variables (e.g., levels of depressive symptoms and each product use) was not examined.

Conclusion

The current study expands on previous research, however, by evaluating the possible mediational process of depressive symptoms between insufficient sleep and substance use among U.S. high school students. This study highlights the potential for depressive symptoms to explain the connection between youth insufficient sleep and substance use. Findings from this study also provide insight into the risk of insufficient sleep for mental health and substance use problems, which can facilitate targeted school prevention and education for both health professionals and students.

Author's Contribution

AK conceptualized and designed the conceptual model and manuscript. AK conducted data analyses, interpreted the results, and drafted the manuscript. MM reviewed the manuscript for intellectual content and revised the manuscript. All authors approved of the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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