European Child & Adolescent Psychiatry (2019) 28:635–643
https://doi.org/10.1007/s00787-018-1227-8

ORIGINAL CONTRIBUTION

# Sleep apnea may be associated with suicidal ideation in adolescents

Wen-Che Tseng[1,2] · Yun-Chieh Liang[3] · Mei-Hsin Su[4] · Yun-Ling Chen[4] · Hao-Jan Yang[5] · Po-Hsiu Kuo[4,6]

Received: 21 December 2017 / Accepted: 8 September 2018 / Published online: 15 September 2018


## Abstract

Suicide is a major threat to adolescent health. Sleep problems increase the risk of adolescent suicidal behavior, but the role of sleep-disordered breathing (e.g., sleep apnea) is unclear. We investigated whether sleep apnea had an effect on suicidal ideation that was independent of depression and perceived stress. We examined a series of sleep variables with suicidal ideation in 746 fifth and seventh graders using self-reported questionnaires to assess time in bed, sleep quality, insomnia, and sleep apnea while controlling depression and perceived stress. Overall, 8.8% of students aged 10–14 years reported having recent suicidal ideation, and 33% or 3.8%, depending on the screening criteria, reported having suspected sleep apnea. The sleep variables were all associated with an increased risk of suicidal ideation, but the magnitude of effects was largely attenuated when depression and perceived stress were included in the models. Suspected sleep apnea using daytime sleepiness as a screening criterion was independently associated with suicidal ideation (odds ratio = 2.25, $p < 0.05$). Suspected sleep apnea was associated with suicidal ideation that was partly independent of depression and stress, which reveals the pertinence of screening for sleep apnea among school students and designing proper prevention strategies for reducing youth suicidal behavior.

**Keywords** Sleep · Adolescents · Suicidal ideation · Sleep apnea

**Implications and contribution** We investigated the associations between suspected sleep apnea, several sleep variables, and suicidality among adolescents, and found that students with suspected sleep apnea were more likely to have suicidal ideation independent of depression or stress. The results revealed the need to screen for sleep apnea in addition to other sleep problems, in the hope of preventing youth suicide.

✉ Po-Hsiu Kuo
phkuo@ntu.edu.tw

1 Department of Epidemiology, Harvard T.H. Chan School of Public Health, 677 Huntington Ave, Boston, MA 02215, USA

2 National Taiwan University Hospital, 7, Zhongshan S. Rd., Taipei, Taiwan

3 Clinical Trial Center, National Taiwan University Hospital, 7, Zhongshan S. Rd., Taipei, Taiwan

4 Department of Public Health and Institute of Epidemiology and Preventive Medicine, College of Public Health, National Taiwan University, 17, Xuzhou Rd., Taipei, Taiwan

5 Department of Public Health, Chung Shan Medical University, 110, sec.1, Jianhuo N. Rd., Taichung, Taiwan

6 Research Center for Genes, Environment and Human Health, National Taiwan University, 2, Xuzhou Rd., Taipei, Taiwan

**Abbreviations**

| | |
|---|---|
| WHO | World Health Organization |
| OSA | Obstructive sleep apnea |
| CPAP | Continuous positive airway pressure |
| ESS | Epworth's Sleepiness Scale |
| CPSQI | Chinese version of the Pittsburg Sleep Quality Index |
| ESS-7 | 7-item modified Epworth's Sleepiness Scale |
| PSS | Perceived Stress Scale |
| CES-D | Center for Epidemiologic Studies Depression Scale |
| CBT-I | Cognitive behavioral therapy for insomnia |

## Introduction

Suicide is one of the leading causes of death worldwide. The World Health Organization estimated that 800,000 people died due to suicide in 2012 [1], and there were considerably more suicide attempts than suicides. Eastern Asia has one of the highest suicide mortality rates in the world. For example, approximately 4000 people die annually from suicide in Taiwan, representing a suicide morality rate of 16.2/100,000 person-years, which is two times higher than that in most

European and South American countries [1, 26]. Suicide is particularly a critical issue for adolescents and young adults, because it is the second leading cause of death worldwide after road traffic injuries in young people aged 15–29 years [1]. Therefore, numerous studies have examined the risk and protective factors for suicidal behaviors among youths.

Several sleep-related traits were associated with suicidal behavior in adolescents, including sleep duration, insomnia, and sleep disturbances. A relatively short or long time in bed has been associated with suicidality, although the results have been inconsistent. In Asian adolescents, a short time in bed was associated with suicidal ideation and plans [15, 21, 42]. Moreover, a 1-h reduction in weekday sleep increased the risk of hopelessness, suicide ideation, and suicide attempts [38]. Conversely, a relatively long-sleep duration has been associated with suicidal ideation and suicide attempts in adolescents in some studies [10, 15], but not others [17].

Insomnia and sleep disturbances among adolescents have also been examined, including specific insomnia symptoms (e.g., difficulty falling asleep, staying asleep, and waking early). In a prospective cohort study, having trouble falling asleep or staying asleep showed direct and indirect effects on suicidal behaviors [39]. In a study on those who died by suicide using a psychological autopsy approach, Goldstein and colleagues found that insomnia preceded suicide and was a strong predictor for such risky behaviors in adolescents, and the results held after accounting for severity of depressive symptoms [12]. Parent-reported sleep disturbance was associated with self-harming in adolescents [35], and nonrestorative sleep was significantly associated with suicidal ideation in adolescents [29]. Although different sleep dimensions exhibit various effects on suicidality, few studies have examined the extreme effects of sleep disorders on the risk of suicidal behavior. Because sleep disorders [e.g., obstructive sleep apnea (OSA)] have substantial effects on sleep quality and sleep disturbances, we investigated the influence of sleep disorders on the magnitude of suicidality risk in Taiwanese youths.

OSA is the most common sleep disorder in children, with a worldwide prevalence ranging from 1 to 4% [23]. In children, sleep apnea and oxygen desaturation during sleep was associated with the development of depressive symptoms, which are well-known predictors of suicidal behavior [3]. However, whether sleep apnea directly affects suicidal behavior in youths independent of depression or indirectly affects it via depression has been less studied. Clinical observations provide one line of evidence for the link between sleep disorders and suicidality, because treating sleep apnea often improves depressive symptoms, and potentially suicidality. In a meta-analysis incorporating 19 randomized controlled trials, continuous positive airway pressure (CPAP) therapy reduced depressive symptoms and severity, although the heterogeneity among the trials was high [Q statistic, $p < 0.001$; $I^2 = 71.3\%$, 95% confidence interval (CI): 54–82%] [33]. In one clinical study, depressive symptoms in 293 patients who were newly diagnosed as having OSA improved markedly after receiving CPAP therapy for 3 months. Conversely, a case report described the rapid resolution of suicidal ideation in a man without a history of psychiatric disorder after receiving OSA treatment, which suggests that the effect of improving sleep apnea on suicide is independent of depression [18]. Furthermore, findings from a prospective study showed that patients with OSA who complied with CPAP therapy had markedly reduced depressive symptoms. In particular, 18.3% of the patients had suicidal ideation before treatment, but none of them did at a 3-month follow-up [8]. Despite the mechanism between OSA treatment and reduced suicidality being unknown, it is possible that sleep apnea has an effect on suicidal risk either through or independent of depression.

Among nonreferred adolescents, screening for sleep apnea is available through self-reported questionnaires, which enables the collection of data from a relatively large sample compared with using medical examinations. In the current study, we used the modified Epworth's Sleepiness Scale (ESS). The ESS has been significantly correlated with the apnea–hypopnea Index (AHI) in children, with a cut-off point for screening OSA [4]. Few studies have examined the influence of sleep apnea on suicidality in adolescents and children. The present study utilized the ESS to screen for OSA among school students, and examined the associations between sleep duration, sleep quality, insomnia, suspected OSA, and suicidal ideation in youths in Taiwan. We also examined whether the effects of sleep variables on suicidal ideation were independent of perceived stress and depression.

## Hypotheses

We hypothesized that sleep variables are independently associated with suicidal ideation in children and adolescents, namely, shorter or longer sleep duration, poor sleep quality, insomnia, and sleep apnea.

## Methods

### Participants

This was a cross-sectional study, whereby the data were collected from the baseline survey of a large prospective project that investigated the influence of sleep problems on children's mental health in Taiwan. The baseline survey was conducted from 2011 to 2014; more details regarding

the study design and sampling can be found in Chiu et al. [7]. Briefly, participants from Northern and Central Taiwan were recruited in eight administrative areas using a stratified cluster-sampling method. We recruited 3521 students in elementary or junior high schools at baseline, and 2655 completed the questionnaires designated for each age-group stratum. Only students in the fifth and seventh grades were asked suicide-related questions, because students aged less than 10 years may not have understood the concept of suicidal ideation. Thus, we used a subset of the data in our analysis, which comprised 746 students.

## Measures

The present study used self-reported questionnaires and school records to collect demographic and behavioral data. We used suicidal ideation as the outcome variable. Students were asked whether they had suicidal ideation in the previous week, and the item was dichotomized with a "Yes/No" option.

For sleep-related measures, we used the Pittsburgh Sleep Quality Index (PSQI) to measure overall subjective sleep quality. The PSQI comprises seven subscales, which are commonly used to screen insomnia with a defined total score greater than 5. The Chinese version of the PSQI (CPSQI) has a reliability coefficient of 0.82–0.83. A CPSQI greater than 5 yields a sensitivity and specificity of 98% and 55%, respectively, for primary insomnia [37]. This scale showed acceptable reliability in our samples (Cronbach's $\alpha = 0.64$).

We used the 7-item modified Epworth Sleepiness Scale (ESS-7) to assess daytime sleepiness and screen for pediatric OSA, because the last item (about driving) in the Chinese version of the ESS was deleted. A study that used the same ESS-7 for a Mexican sample reported that this scale enables an accurate assessment of daytime sleepiness in individuals who do not regularly travel in automobiles [14]. Moreover, the ESS score was significantly correlated with the AHI in children [4]. In the current study, the Cronbach's alpha of the ESS was 0.79, revealing good internal consistency. The cut-off value for screening OSA in the children using the ESS-7 was obtained using Cohen's kappa statistic, with a score greater than 6 indicating a positive response for suspected pediatric OSA. In addition to excessive daytime sleepiness, one of the core symptoms in the diagnosis of OSA is breathing cessation during sleep. Therefore, to evaluate the robustness of our findings, we combined data from one item in the PSQI "During the past month, how often have you had trouble sleeping because you cannot breathe comfortably?" with the ESS for a narrower definition of suspected OSA and reconducted the analysis. To determine the risk of suicidal ideation, participants who had an ESS score greater than 6 and a positive response to this disordered breathing (once a week or more) were compared with participants who had a score less than 6 and a negative response to this question.

For depression- and stress-related measures, students were asked to complete two questionnaires, the Perceived Stress Scale (PSS) and the Center for Epidemiologic Studies Depression Scale (CES-D). The PSS is a 10-item questionnaire with a 5-point rating scale designed to measure individuals' perceived stress. Relatively high total scores represent high levels of perceived stress. The Chinese version of the PSS showed good reliability (Cronbach's $\alpha = 0.76$) in our samples. The CES-D is a 20-item questionnaire with a 4-point rating scale that measures students' depression. It is a useful screening tool for major depressive disorder in nonreferred adolescents [41], and a study reported that the Chinese version of the CES-D has favorable psychometric properties in Taiwanese adolescents [5]. The Chinese version also showed good reliability (Cronbach's $\alpha = 0.87$) in our samples. Respondents with a score of $> 21$ were considered to have depression, and this scale was utilized to identify students with a depressive status.

## Statistical analyses

Descriptive statistics were used to report demographic variables such as grade, age, sex, and school location among the participants. Chi-square and Fisher's exact tests were used to determine whether demographic variables, time in bed, insomnia (defined as a PSQI score $> 5$), and suspected pediatric OSA (defined as an ESS score $> 6$) differed between the students with and without suicidal ideation. Student's *t* test was used to determine whether the PSS and CES-D scores differed in students with and without suicidal ideation. Logistic regression models were used to evaluate the effects of the sleep variables on suicidal ideation, namely, a relatively short or long time in bed, insomnia, sleep quality, and suspected OSA while controlling demographic variables, depression, and perceived stress.

# Results

Table 1 shows the characteristics among our participants. Two-thirds of the sample group were elementary students, and the students' age ranged from 10 to 14 years. There were slightly more female than male students. The proportions of participants who had suicidal ideation did not differ by sex and school location (Taipei vs. Taichung areas).

## The relationships between depression, perceived stress, and suicidal ideation

Overall, 8.8% of the students reported having recent suicidal ideation. Table 1 shows that the average CES-D score in

**Table 1** Sample descriptions for students with or without a history of suicidal ideation

| Variables | Total *N* (%) | No suicidal ideation *N* (%) | Suicidal ideation *N* (%) | *p* value |
|---|---|---|---|---|
| Grade | | | | 0.2837 |
| 5 | 496 (66.49) | 443 (65.73) | 47 (72.31) | |
| 7 | 250 (33.51) | 231 (34.27) | 18 (27.69) | |
| Age | | | | 0.4025 |
| 10 | 5 (0.68) | 5 (0.76) | 0 (0.00) | |
| 11 | 321 (43.91) | 293 (44.26) | 25 (40.32) | |
| 12 | 167 (22.85) | 144 (21.75) | 20 (32.26) | |
| 13 | 171 (23.39) | 158 (23.87) | 12 (19.35) | |
| 14 | 67 (9.17) | 62 (9.37) | 5 (8.06) | |
| Gender | | | | 0.8997 |
| Female | 396 (53.23) | 357 (53.13) | 34 (52.31) | |
| Male | 348 (46.77) | 315 (46.88) | 31 (47.69) | |
| Location | | | | 0.1739 |
| Taipei | 192 (25.74) | 166 (24.63) | 21 (32.31) | |
| Taichung | 554 (74.26) | 508 (75.37) | 44 (67.69) | |
| Time in bed | | | | 0.0007[a] |
| ≤ 6 h | 18 (2.49) | 11 (1.67) | 7 (11.11) | |
| 7 ~ 9 h | 664 (91.71) | 608 (92.26) | 54 (85.71) | |
| ≥ 10 h | 42 (5.80) | 40 (6.07) | 2 (3.17) | |
| PSQI score | | | | < 0.0001 |
| ≤ 5 | 545 (77.86) | 513 (80.53) | 30 (49.18) | |
| > 5 | 155 (22.14) | 124 (19.47) | 31 (50.82) | |
| ESS score | | | | < 0.0001 |
| ≤ 6 | 482 (66.94) | 456 (69.30) | 25 (40.98) | |
| > 6 | 238 (33.06) | 202 (30.70) | 36 (59.02) | |
| ESS + symptom[b] | | | | |
| ESS > 6 plus symptom | 26 (3.81) | 18 (2.88) | 8 (13.79) | 0.0008 |
| Others | 657 (96.19) | 606 (97.12) | 50 (86.21) | |
| CES-D score[c] | 712 | 644 (10.93 ± 7.43) | 61 (23.89 ± 10.13) | < 0.0001 |
| < 21 | 609 | 580 (90.06) | 22 (36.07) | < 0.0001 |
| ≥ 21 | 103 | 64 (9.94) | 39 (63.93) | |
| PSS score[c] | 722 | 655 (14.89 ± 6.09) | 65 (22.35 ± 5.92) | < 0.0001 |

[a]Using Fisher Exact Test

[b]"Symptom" is defined as a positive response (once a week or more) to the question of disordered breathing "During the past month, how often have you had trouble sleeping because you cannot breathe comfortably?" in PSQI

[c]Mean and standard deviation

the suicidal ideation group was two to three times that in the nonsuicidal ideation group (23.89 vs. 10.93). Moreover, the students in the suicidal ideation group had higher perceived stress ($p < 0.0001$). The results of a univariate logistic regression are displayed in Table 2. Students with a depressive status and with relatively high PSS scores had a significantly higher risk of perceiving suicidal ideation ($p < 0.001$).

## Sleep problems and suicidal ideation

Overall, 33.1% of the students had suspected pediatric OSA (Table 1) and were significantly more likely to report recent suicidal ideation than those who did not have suspected pediatric OSA ($p < 0.0001$). The results in Table 2 reveal that the students with suspected pediatric OSA had an odds ratio (OR) of 3.25 (95% CI = 1.90–5.56, $p < 0.001$) for suicidal ideation, and this association remained significant (OR = 2.25, 95% CI = 1.23–4.25, $p = 0.015$) after controlling for depression and perceived stress (Table 3). When adding the criterion of a positive response to the question related to disordered breathing together with excessive daytime sleepiness, the prevalence of suspected pediatric OSA decreased to 3.8% (Table 1). When students with suspected OSA were analyzed according to this additional criterion,

**Table 2** Univariate logistic regression for suicidal ideation

| Variables | Odds ratio | 95% CI |
|---|---|---|
| Grade (7 vs. 5) | 0.74 | 0.42–1.29 |
| Age | 0.99 | 0.77–1.27 |
| Gender | 1.03 | 0.62–1.72 |
| Location | 1.46 | 0.84–2.53 |
| PSQI score (> 5 vs. ≤ 5) | 4.28 | 2.49–7.33* |
| Time in bed | | |
| ≤ 6 h vs. 7 ~ 9 h | 7.17 | 2.67–19.24* |
| ≥ 10 h vs. 7 ~ 9 h | 0.56 | 0.13–2.39 |
| ESS score (> 6 vs. ≤ 6) | 3.25 | 1.90–5.56* |
| ESS score > 6 plus symptom[a] | 7.38 | 2.92–18.62* |
| CES-D score (≥ 21 vs. < 21) | 16.07 | 8.97–28.78* |
| PSS score | 1.22 | 1.17–1.29* |

*$p < 0.001$

[a]"Symptom" is defined as a positive response (once a week or more) to the question of disordered breathing "During the past month, how often have you had trouble sleeping because you cannot breathe comfortably?" in PSQI. Comparison was made between students who had ESS score > 6 plus symptom vs. ESS score ≤ 6 without symptom

the risk of suicidal ideation increased (OR = 7.38, 95% CI = 2.92–18.62, $p < 0.001$), but this association became nonsignificant (OR = 2.87, 95% CI = 0.87–9.46, $p = 0.084$) after controlling for depression and perceived stress (Tables 2, 3), possibly due to the insufficient sample size of students with suspected OSA ($n = 26$).

Suspected insomnia demonstrated a 4.28-fold risk for suicidal ideation (95% CI = 2.49–7.33, $p < 0.001$), as shown in Table 2. However, after adjusting for depression and perceived stress, the association became nonsignificant (95% CI = 0.87–3.54, $p = 0.114$ in Table 3). Similarly, the association between poorer sleep quality (measured using the PSQI score) and suicidal ideation became nonsignificant after controlling for depression and perceived stress (95% CI = 0.93–1.18, $p = 0.484$ in Table 3). Table 2 shows that the students who slept fewer than 6 h per night had significantly more suicidal ideation than students who slept 7–9 h at night (OR = 7.17, 95% CI = 2.67–19.24, $p < 0.001$). However, the association became nonsignificant (OR = 3.48, 95% CI = 0.90–13.50, $p = 0.071$) after adjusting for depression and perceived stress (Table 3).

## Discussion

This study examined the associations between sleep problems and suicidality in a nonreferred sample of fifth and seventh graders in Taiwan. In particular, we contributed to the current knowledge on the influence of sleep disorders on the risk of suicidality in early adolescents. We found that suspected OSA increased the risk of suicidal ideation, partly independent of depression and perceived stress. Among the students (aged 10–14 years), 8.8% reported recent suicidal ideation, which is similar to that reported in related studies (range 5.1–7.1% in adolescents) [11, 40]. A high prevalence of suicidal behaviors and common problems associated with sleep disturbances in youths pose serious problems to mental health [28], which reveals the need for effective intervention and prevention strategies. According to Klonsky's three-step theory of suicide, suicidal ideation serves as the main factor for subsequent suicide attempts. Suicidal ideation can lead to an individual attempting or completing suicide once the suicidal ideation is sufficiently severe. [16]. A large cross-national study of approximately 85,000 participants in 17 countries found that 30% of those with suicidal ideation attempted suicide [27]. Our study highlights the importance of identifying modifiable risk factors for suicidal ideation, especially in the general population.

**Table 3** Effects of sleep apnea, insomnia, time in bed, and sleep quality on suicidal ideation

| | Suicidal ideation | | | |
|---|---|---|---|---|
| | Unadjusted OR (95% CI) | *p* value | Adjusted OR[a] (95% CI) | *p* value |
| Sleep apnea (ESS only)[b] | 3.25 (1.90–5.56) | < 0.0001 | 2.25 (1.17–4.32) | 0.015 |
| Sleep apnea[c] (ESS + symptom) | 7.38 (2.92–18.62) | < 0.0001 | 2.87 (0.87–9.46) | 0.084 |
| Insomnia[d] | 4.28 (2.49–7.33) | < 0.0001 | 1.76 (0.87–3.54) | 0.114 |
| Time in bed | | | | |
| ≤ 6 h[e] | 7.17 (2.67–19.24) | < 0.0001 | 3.48 (0.90–13.5) | 0.071 |
| ≥ 10 h | 0.56 (0.13–2.39) | 0.437 | 0.46 (0.09–2.35) | 0.351 |
| Sleep quality[f] | 1.26 (1.16–1.37) | < 0.0001 | 1.04 (0.93–1.18) | 0.484 |

[a]Adjusted for age, gender, location, depression, and perceived pressure

[b]Measured by ESS score (> 6 vs. ≤ 6)

[c]Measured by ESS score (> 6) plus symptom vs. ESS score (≤ 6) without symptom

[d]Measured by PSQI score (> 5 vs. ≤ 5)

[e]Compared with students who slept 7 ~ 9 h at night

[f]Measured by PSQI score (as a continuous variable)

## OSA and suicide risk

Depression is among the most studied risk factors for suicide. Some sleep-related factors may have an effect on depression and increase the risk of suicidal behaviors, whereas other sleep factors may have an effect on suicidal risk independent of depression. One of the main objectives of the current study was to examine the contribution of suspected OSA to suicide while considering depression. The results showed that suspected sleep apnea increased the risk of suicidal ideation among the participants (OR = 2.25) independent of depression and perceived stress. A recent study that utilized national survey data in the United States found that OSA was associated with an increased risk of suicidal ideation in adults (OR = 1.50, 95% CI = 1.18–1.92) after controlling for depressive episodes, substance use disorder, and other key factors [2]. The adjusted effects of suspected OSA on suicidality were evident (OR = 2.25) in the present study, even in the relatively young participants.

In terms of screening strategies, although high ESS scores have been associated with high AHI among children [4], the prevalence of suspected OSA using self-reported screening scales is often considerably higher than that from being clinically diagnosed. The prevalence of suspected OSA was also high in the present study (33.1%) with only daytime excessive sleepiness criterion. However, using narrowly defined criteria after adding a positive response to the question related to disordered breathing in the PSQI, the prevalence decreased to 3.8% for suspected OSA, which was similar to the estimated prevalence for pediatric OSA. The association between suspected OSA and suicidal ideation after adding this item was significant (OR = 7.38), although it became nonsignificant after adjusting for depression and perceived stress (OR = 2.87, $p = 0.08$). This might have been caused by the considerably smaller sample size of suspected OSA after using these criteria ($n = 26$), because the magnitude of the increased risk remained similar when compared with the results obtained from not adding this item.

The mechanisms for the association between OSA and suicidal ideation might have different pathways: one might be linked with depression and one might be independent of depression. OSA has been associated with an increased risk of depression. A retrospective study that utilized the data of 4 million veterans in the Veterans Health Administration databases reported that the prevalence of depression was higher in patients with OSA than in patients without OSA (21.8% vs. 9.4%, $p < 0.0001$) [34]. A review article that incorporated eight studies from 2000 to 2011 examined the association between OSA and depression and found a higher risk of depression in patients with OSA compared with the general population [9]. Moreover, a study on children found that sleep-related breathing disorders (including OSA) were associated with depressive symptoms [3]. Our results revealed that the association between suspected OSA and suicidality was substantially attenuated when depression and perceived stress were included in the models, revealing that at least part of the influence relates to depression and stress responses.

Conversely, suspected OSA screened using the ESS independently increased the risk of suicidal ideation, which suggests a pathway that is not related to depression. We propose several mechanisms to explain this. First, repeated arousal during sleep, which is a typical symptom of OSA, may exacerbate suicidality through the effects of chronic sleep fragmentation [19]. Second, sleep-disordered breathing may cause attention problems and poorer communication and adaptive skills in children [30], which might reduce their resilience and increase the risk of suicide when challenges or difficulties are encountered. Third, OSA is linked to several physical comorbidities, such as cardiovascular diseases, metabolic syndrome, and structural brain changes. For example, a study found that white matter was extensively affected in patients with OSA, including axons linking structures within the limbic system [24]. Moreover, it is plausible that frequent suicidal ideation may hinder sleep quality or cause more severe sleep problems. Future neuroimaging studies adopting a prospective design are warranted to collect information on emotional regulation and suicidal phenotypes in patients with OSA, which would enable a better understanding of the mechanistic link between sleep problems and suicide.

Because sleep apnea may increase the risk of suicide even in young children, more attention should be given to the early diagnosis and treatment of sleep disorders as a suicide prevention strategy. Identifying individuals with potential pediatric OSA and providing timely and proper treatment (such as surgery or CPAP therapy) might be a promising strategy for suicide prevention. Some studies have shown that treating OSA reduced suicidal ideation in adults [8, 18]. Thus, screening for OSA and arranging referrals for further assessment and treatment might be beneficial as part of a suicide prevention campaign, especially given that pediatric OSA is not uncommon worldwide [23]. Without proper treatment, the problem can persist until adulthood. A recent review reported that the prevalence of OSA in adults was 28% [20].

## Insomnia, sleep quality, and suicide

The results of the present study revealed that the adolescents with insomnia were more likely to have suicidal ideation than those without insomnia ($p < 0.001$). Moreover, poor sleep quality was associated with suicidal ideation ($p < 0.0001$). Studies have identified insomnia as a modifiable risk factor for suicide [31, 40]. A meta-analysis reported that the association between insomnia and suicide was

significant and independent of psychiatric disorders in both adults and children [32]. Poor sleep quality was also found to have an independent effect on nonsuicidal self-injury [22]. The possible physiological mechanisms underlying such a link include serotonergic dysfunction and hyperarousal [25]. However, neither the effects of insomnia nor poor sleep quality remained significant after adjusting for depression and perceived stress in our student samples. It is likely that insomnia and poor sleep quality are highly correlated with depression and perceived stress among children and adolescents and that the effect of insomnia or poor sleep quality on suicide could be masked or mediated through these factors. Another possible reason is that our sample size was not sufficient to detect the independent but moderate effect size of insomnia or sleep quality on suicide.

### Time in bed and suicide

Short sleep duration has been considered an independent risk factor of suicide in adolescents [21, 42]. A recent meta-analysis reported strong curvilinear dose–response associations between sleep duration and suicidal ideation, with the lowest suicidal ideation at a daily sleep duration of 8 h. Moreover, in another study, depression did not moderate the association between sleep duration and suicidality in youths [6]. In the present study, we found that a short time in bed (< 6 h) increased the risk of suicidal ideation (OR = 7.17, $p < 0.001$), but this association weakened after we made adjustments for depression and perceived stress (adjusted OR = 3.48, $p = 0.07$). An explanation for our results with borderline significance is that a low number of the student slept fewer than 6 h daily ($n = 18$, 2.49% of all participants), which might have considerably reduced the power to detect an independent association.

### Sleep and suicide prevention

Suicide prevention is critical and actionable by identifying modifiable risk factors, especially in children and adolescents. Sleep-related behaviors and parameters are recognized as modifiable factors for suicide, including insomnia, sleep duration, and potential sleep disorders, which were investigated in the present study. Treatment of sleep disturbances has recently emerged as a practical tool for promoting mental health. A recent interventional study showed that cognitive behavioral therapy for insomnia effectively reduced suicidal ideation in veterans, even after accounting for the concurrent improvement of depressive symptoms [36]. Several ongoing clinical trials are examining the efficacy of behavioral treatment or medication in reducing suicidal ideation in adults [13]. Although such systematic research is lacking in children and adolescents, evidence provided in adult populations might make sleep disturbances a pertinent target for suicide prevention in younger age groups. In particular, evidence supports the effectiveness of sleep-oriented interventions and treatment for reducing suicidal risk. Thus, we suggest that sleep apnea is screened in addition to other sleep problems, in the hope of providing timely treatment for pediatric OSA to prevent youth suicide.

### Strengths and limitations

The present study revealed the effects of potential sleep apnea on the risk of suicidal ideation in children and adolescents, which were partly independent of depression and perceived stress. In addition to common sleep problems, screening for sleep apnea among school students is applicable and should be considered in future prevention strategies for suicidal behavior among youths.

This study has several limitations. First, our participants are not a nationally representative sample, because we only included students in Northern and Central Taiwan. Therefore, the results cannot be generalized for other geographic areas. Second, the sample size was only moderate, which makes it difficult to perform further subgroup analyses. For example, only 18 students spent fewer than 6 h in bed daily, which limits the statistical power to evaluate the effects of sleep hours on suicidal ideation in subgroups. Third, all measures were based on self-reported data rather than objective data, such as polysomnography, which hinders clinical diagnoses for sleep apnea. Recall bias has been a long-standing issue in studies based on subjective measures, which is also a potential limitation of the present study. Fourth, suicidal behavior was measured only once using a single item rather than a comprehensive longitudinal assessment. Finally, our study had a cross-sectional study design. The causal relationship between sleep problems and suicide cannot be established without a follow-up study.

**Acknowledgements** This study was supported by the Ministry of Science and Technology in Taiwan (MST101-2314-B-002-128-MY3 grant to Dr. P–H Kuo and NSC99-2511-S-040-004-MY3 grant to Dr. H-J Yang). We would like to especially thank all subjects who agree to participate in this study. We also thank JH Shen, PC Chu, SS Huang, and WH Chiu who assisted for data collection and data management.

**Author contributions** WCT hypothesized to test the associations between sleep-disordered breathing and suicidal ideation, and wrote the first draft of the manuscript. YCL and YLC assisted in data cleaning and analyses. MHS assisted in data collection and designing the coding book. HJY and PHK were in charge of the study design and the acquisition of the financial support from the government. PHK also coordinated this study, assisted to explain statistical analysis results, and made critical revision of the manuscript.

### Compliance with ethical standards

**Conflict of interest** There is no conflict of interest in the present study.

**Ethical standards** This study was approved by the Institutional Review Board of National Taiwan University Hospital. All procedures performed in the present study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards, and all participants and one of their parents provided informed consent.

## References


1. World Health Organization (2017) World Health Statistics 2016. World Health Organization, Geneva.http://www.who.int/gho/publications/world_health_statistics/2016/en/
2. Bishop TM, Ashrafioun L, Pigeon WR (2018) The association between sleep apnea and suicidal thought and behavior: an analysis of national survey data. J Clin Psychiatry 79:17m11480
3. Carotenuto M, Esposito M, Parisi L, Gallai B, Marotta R, Pascotto A, Roccella M (2012) Depressive symptoms and childhood sleep apnea syndrome. Neuropsychiatr Dis Treat 8:369–373
4. Chan EY, Ng DK, Chan CH, Kwok KL, Chow PY, Cheung JM, Leung SY (2009) Modified Epworth Sleepiness Scale in Chinese children with obstructive sleep apnea: a retrospective study. Sleep Breath 13:59–63
5. Cheng CP, Yen CF, Ko CH, Yen JY (2012) Factor structure of the Center for Epidemiologic Studies Depression Scale in Taiwanese adolescents. Compr Psychiatry 53:299–307
6. Chiu H-Y, Lee H-C, Chen P-Y, Lai Y-F, Tu Y-K (2018) Associations between sleep duration and suicidality in adolescents: a systematic review and dose–response meta-analysis. Sleep Med Rev. https://doi.org/10.1016/j.smrv.2018.07.003
7. Chiu WH, Yang HJ, Kuo PH (2017) Chronotype preference matters for depression in youth. Chronobiol Int 34:933–941
8. Edwards C, Mukherjee S, Simpson L, Palmer LJ, Almeida OP, Hillman DR (2015) Depressive symptoms before and after treatment of obstructive sleep apnea in men and women. J Clin Sleep Med 11:1029–1038
9. Ejaz SM, Khawaja IS, Bhatia S, Hurwitz TD (2011) Obstructive sleep apnea and depression: a review. Innov Clin Neurosci 8:17–25
10. Fitzgerald CT, Messias E, Buysse DJ (2011) Teen sleep and suicidality: results from the youth risk behavior surveys of 2007 and 2009. J Clin Sleep Med 7:351–356
11. Franic T, Kralj Z, Marcinko D, Knez R, Kardum G (2014) Suicidal ideations and sleep-related problems in early adolescence. Early Interv Psychiatry 8:155–162
12. Goldstein TR, Bridge JA, Brent DA (2008) Sleep disturbance preceding completed suicide in adolescents. J Consult Clin Psychol 76:84–91
13. Health USNIo (2017) ClinicalTrials.gov Identifier numbers: NCT03595254, NCT02038075, NCT03603717. https://clinicaltrials.gov
14. Jimenez-Correa U, Haro R, Poblano A, Arana-Lechuga Y, Teran-Perez G, Gonzalez-Robles RO, Velazquez-Moctezuma J (2009) Mexican version of the Epworth Sleepiness Scale. Open Sleep J 2:6–10
15. Kim JH, Park EC, Lee SG, Yoo KB (2015) Associations between time in bed and suicidal thoughts, plans and attempts in Korean adolescents. BMJ Open 5:e008766
16. Klonsky ED, May AM, Saffer BY (2016) Suicide, suicide attempts, and suicidal ideation. Annu Rev Clin Psychol 12:307–330
17. Koyawala N, Stevens J, McBee-Strayer SM, Cannon EA, Bridge JA (2015) Sleep problems and suicide attempts among adolescents: a case-control study. Behav Sleep Med 13:285–295
18. Krahn LE, Miller BW, Bergstrom LR (2008) Rapid resolution of intense suicidal ideation after treatment of severe obstructive sleep apnea. J Clin Sleep Med 4:64–65
19. Krakow B, Artar A, Warner TD, Melendrez D, Johnston L, Hollifield M, Germain A, Koss M (2000) Sleep disorder, depression, and suicidality in female sexual assault survivors. Crisis 21:163–170
20. Lee W, Nagubadi S, Kryger MH, Mokhlesi B (2008) Epidemiology of obstructive sleep apnea: a population-based perspective. Expert Rev Respir Med 2:349–364
21. Lee YJ, Cho SJ, Cho IH, Kim SJ (2012) Insufficient sleep and suicidality in adolescents. Sleep 35:455–460
22. Liu X, Chen H, Bo QG, Fan F, Jia CX (2017) Poor sleep quality and nightmares are associated with non-suicidal self-injury in adolescents. Eur Child Adolesc Psychiatry 26:271–279
23. Lumeng JC, Chervin RD (2008) Epidemiology of pediatric obstructive sleep apnea. Proc Am Thorac Soc 5:242–252
24. Macey PM, Kumar R, Woo MA, Valladares EM, Yan-Go FL, Harper RM (2008) Brain structural changes in obstructive sleep apnea. Sleep 31:967–977
25. McCall WV, Black CG (2013) The link between suicide and insomnia: theoretical mechanisms. Curr Psychiatry Rep 15:389
26. Ministry of Health and Welfare Taiwan (2017). https://www.mohw.gov.tw/dl-18472-6bf0ba7a-a435-47ff-ae4c-03b73ca1ae76.html
27. Nock MK, Borges G, Bromet EJ, Alonso J, Angermeyer M, Beautrais A, Bruffaerts R, Chiu WT, de Girolamo G, Gluzman S, de Graaf R, Gureje O, Haro JM, Huang Y, Karam E, Kessler RC, Lepine JP, Levinson D, Medina-Mora ME, Ono Y, Posada-Villa J, Williams D (2008) Cross-national prevalence and risk factors for suicidal ideation, plans and attempts. Br J Psychiatry 192:98–105
28. Ohida T, Osaki Y, Doi Y, Tanihata T, Minowa M, Suzuki K, Wada K, Suzuki K, Kaneita Y (2004) An epidemiologic study of self-reported sleep problems among Japanese adolescents. Sleep 27:978–985
29. Park JH, Yoo JH, Kim SH (2013) Associations between non-restorative sleep, short sleep duration and suicidality: findings from a representative sample of Korean adolescents. Psychiatry Clin Neurosci 67:28–34
30. Perfect MM, Archbold K, Goodwin JL, Levine-Donnerstein D, Quan SF (2013) Risk of behavioral and adaptive functioning difficulties in youth with previous and current sleep disordered breathing. Sleep 36:517–525
31. Pigeon WR, Caine ED (2010) Insomnia and the risk for suicide: does sleep medicine have interventions that can make a difference? Sleep Med 11:816–817
32. Pigeon WR, Pinquart M, Conner K (2012) Meta-analysis of sleep disturbance and suicidal thoughts and behaviors. J Clin Psychiatry 73:e1160–e1167
33. Povitz M, Bolo CE, Heitman SJ, Tsai WH, Wang J, James MT (2014) Effect of treatment of obstructive sleep apnea on depressive symptoms: systematic review and meta-analysis. PLoS Med 11:e1001762
34. Sharafkhaneh A, Giray N, Richardson P, Young T, Hirshkowitz M (2005) Association of psychiatric disorders and sleep apnea in a large cohort. Sleep 28:1405–1411
35. Singareddy R, Krishnamurthy VB, Vgontzas AN, Fernandez-Mendoza J, Calhoun SL, Shaffer ML, Bixler EO (2013) Subjective and objective sleep and self-harm behaviors in young children: a general population study. Psychiatry Res 209:549–553
36. Trockel M, Karlin BE, Taylor CB, Brown GK, Manber R (2015) Effects of cognitive behavioral therapy for insomnia on suicidal ideation in veterans. Sleep 38:259–265

37. Tsai PS, Wang SY, Wang MY, Su CT, Yang TT, Huang CJ, Fang SC (2005) Psychometric evaluation of the Chinese version of the Pittsburgh Sleep Quality Index (CPSQI) in primary insomnia and control subjects. Qual Life Res 14:1943–1952
38. Winsler A, Deutsch A, Vorona RD, Payne PA, Szklo-Coxe M (2015) Sleepless in Fairfax: the difference one more hour of sleep can make for teen hopelessness, suicidal ideation, and substance use. J Youth Adolesc 44:362–378
39. Wong MM, Brower KJ (2012) The prospective relationship between sleep problems and suicidal behavior in the National Longitudinal Study of Adolescent Health. J Psychiatr Res 46:953–959
40. Wong MM, Brower KJ, Craun EA (2016) Insomnia symptoms and suicidality in the National Comorbidity Survey—adolescent supplement. J Psychiatr Res 81:1–8
41. Yang HJ, Soong WT, Kuo PH, Chang HL, Chen WJ (2004) Using the CES-D in a two-phase survey for depressive disorders among nonreferred adolescents in Taipei: a stratum-specific likelihood ratio analysis. J Affect Disord 82:419–430
42. Yen CF, King BH, Tang TC (2010) The association between short and long nocturnal sleep durations and risky behaviours and the moderating factors in Taiwanese adolescents. Psychiatry Res 179:69–74