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Sleep behavior and depression: Findings from the China Kadoorie Biobank of 0.5 million Chinese adults

Xiaoyan Sun[a], **Bang Zheng**[a], **Jun Lv**[a], **Yu Guo**[b], **Zheng Bian**[b], **Ling Yang**[c], **Yiping Chen**[c], **Zhenwang Fu**[d], **Hong Guo**[e], **Peng Liang**[f], **Zhengming Chen**[c], **Junshi Chen**[g], **Liming Li**[a,b,**], **Canqing YU**[a,*] **on behalf of the China Kadoorie Biobank (CKB) Collaborative Group**

[a]Department of Epidemiology & Biostatistics, School of Public Health, Peking University, Beijing 100191, China

[b]Chinese Academy of Medical Sciences, China

[c]Clinical Trial Service Unit and Epidemiological Studies Unit (CTSU), Nuffield Department of Population Health, University of Oxford, UK

[d]NCDs Prevention and Control Department, Hainan CDC, China

[e]Liuyang Traditional Chinese Medical Hospital, China

[f]Liuyang People's Hospital, China

[g]China National Center for Food Safety Risk Assessment, China

Abstract

Background—Mixed results have shown the association between sleep behavior and depression, but evidence relating the joint effect of sleep duration and sleep disturbances is limited, especially in Chinese population.

Methods—A total of 512,891 adults aged 30–79 years from China Kadoorie Biobank (CKB) were included. Depression was defined by Composite International Diagnostic Inventory-short form (CIDI-SF). Sleep duration and sleep disturbances, including difficulty initiating and maintaining sleep (DIMS), early morning awakening (EMA), daytime dysfunction (DDF) and any sleep disturbances (ASD), were obtained by a self-reported questionnaire. Logistic regression was applied to examine the association between sleep behavior and depression.

Results—About 23.1% of participants reported short sleep duration (≤ 6 h), and 5.1% reported long sleep duration (> 9 h). Compared with normal sleep duration (7–9 h), both groups were associated greater likelihood of having depression (short sleep: OR = 2.32, 95%CI: 2.14–2.51; long sleep: OR = 1.56, 96%CI: 1.34–1.81). Participants reported sleep disturbances were significantly associated with depression (odds ratios ranged from 3.31 to 4.17). Moreover, the associations tended to be stronger for those who reported both abnormal sleep duration and sleep disturbances (p for interactions < 0.05), especially for those who slept long.

*Correspondence to: Department of Epidemiology and Biostatistics, School of Public Health, Peking University Health Science Center, 38 Xueyuan Road, Beijing 100191, China. **Corresponding author at: Department of Epidemiology & Biostatistics, School of Public Health, Peking University, Beijing 100191, China. lmlee@vip.163.com (L. Li), yucanqing@pku.edu.cn (C. YU).

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Limitations—The cross-sectional nature of the study design limits the interpretation of the results.

Conclusions—Abnormal sleep duration and sleep disturbances were associated with depression. The associations were stronger for abnormal sleep duration accompanied with sleep disturbances, especially for a long duration. More attention should be paid on these persons in clinical practice.

Keywords

Sleep duration; Sleep disturbances; Depression; Joint association

1 Introduction

Depression is one of the most common mental diseases. A meta-analysis estimated that the global point prevalence of depression was 4.7% (4.4–5.0%) and annual incidence was 3.0% (2.4–3.8%) (Ferrari et al., 2013). Meanwhile, the rank of depression in causes of death has been ascending (Theo Vos et al., 2016a). According to the Global Burden of Disease 2016 study, depression was the third leading cause of disability in 2015 (Theo Vos et al., 2016b). Sleep, on the other hand, is one of the most important health issues and attracted people's increasing concern recently. Researchers have indicated that sleep duration and sleep disturbances have great effects on total mortality (Liu et al., 2016; Parthasarathy et al., 2015) and several common chronic diseases (Li et al., 2014; Meng et al., 2013; Shan et al., 2015).

Previous researchers have also explored the association between sleep and depression, but the results were equivocal. Some researchers suggested a U-shaped relationship between sleep duration and depression (Kim et al., 2014; van den Berg et al., 2009; van Mill et al., 2010; Zhai et al., 2015), while others found only short sleep duration was related to depression (Lee et al., 2015; Sakamoto et al., 2013). Meanwhile, a strong relationship between insomnia and depression has been demonstrated in recent meta-analyses (Baglioni et al., 2011; Li et al., 2016), and several studies probed into the association between specific symptoms of sleep disturbances and depression (Almeida et al., 2011; Jaussent et al., 2011; Salo et al., 2012; Szklo-Coxe et al., 2010; Yokoyama et al., 2010). However, they mainly focused on the geriatric population with small sample size (Almeida et al., 2011; Szklo-Coxe et al., 2010), which was not appropriate be generalized to a general population. Recently, several studies have explored the joint effect of sleep duration and insomnia, and found short sleep duration combined with sleep disturbances had an elevated risk of having depression (Chang et al., 2012; Fernandez-Mendoza et al., 2015), but didn’t examine the effect of long sleep duration combined with sleep disturbances.

Therefore, the aim of the current study was to examine the relationships between sleep behavior and depression among Chinese adults using the baseline data of half a million adults from the China Kadoorie Biobank (CKB) Study, and to clarify the joint association of both short and long sleep duration and sleep disturbances with depression.

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2 Methods

2.1 Study population

The baseline survey of the China Kadoorie Biobank (CKB) Study enrolled over 0.5 million adults from 10 geographically defined regions of China interviewed between 2004 and 2008. Further details of the CKB study have been described elsewhere (Chen et al., 2011, 2005). Briefly, a total of 512,891 adults aged 30–79 years completed a standardized laptop-based questionnaire to collect detailed information by a face-to-face interview, including demographic and socioeconomic characteristics, behavior factors, sleep behavior, physical and mental health status. A range of physical measurements were also undertaken for each participant by trained staff, using standardized instruments and protocols at baseline. The Ethical Review Committee of the Chinese Center for Disease Control and Prevention (Beijing, China) and the Oxford Tropical Research Ethics Committee, University of Oxford (UK) approved the study. All the participants provided written informed consent.

2.2 Measurement

2.2.1 Sleep assessment—Sleep duration was self-reported at baseline by the question of "On average, how many hours of sleep do you get in a 24-h period (including naps)?" Respondents could report in only 1-h increments. We categorized it into 6 or fewer hours, 7–9 h, or more than 9 h, and defined 7–9 h of sleep as the reference group in present study according to the American National Sleep Foundation (Hirshkowitz et al., 2015).

Participants were requested to answer "yes" or "no" to whether they had experienced three forms of sleep disturbance in the past month. If they reported "having trouble falling asleep (sleep onset latency ≥ 30 min) after going to bed or waking up in the middle of the night at least 3 days a week", they were classified as having disorders of initiating and maintaining sleep (DIMS); those reporting "waking up too early and not be able to get back to sleep at least 3 days a week" were classified as having disorders of early morning awakening (EMA); those who reported "having trouble keeping sober-minded during daytime because of bad sleep at least 3 days a week" were classified as having daytime dysfunction (DDF); and those reporting one or more of the three aforementioned disorders were classified as any sleep disturbances (ASD).

2.2.2 Definition of depression—Past year major depression episode (MDE) at baseline was defined using the Chinese version of the computerized Composite International Diagnostic Inventory-short form (CIDI-SF) using face-to-face interviews by trained clinicians. The CIDI-SF is a fully-structured diagnostic instrument based on criteria from the Diagnostic and Statistical Manual of Mental Disorders-IV (DSM-IV) (Kessler and Mroczek, 1998). The Chinese version of the CIDI (calibrated as part of the World Mental Health Surveys) produces similar population estimates of MDE to the Structured Clinical Interview for SCID (Kessler et al., 2004). An MDE was defined by the presence of dysphoria and/or anhedonia for ≥ 2 weeks during the past 12 months, and accompanied by at least 3 of 7 following symptoms, including weight or appetite change, sleeping problems, psychomotor changes, fatigue, concentration problems, feelings of guilt or worthlessness and thoughts of suicide (Mezuk et al., 2013).

2.2.3 Other covariates—Demographic and socioeconomic characteristics including age (continuous, years), gender, survey sites, marital status (married, widowed, divorced or separated, or never married), level of education (no formal school, primary school, middle school, high school, college, or university or higher), occupation (manual workers, non-manual workers or others, such as retired, unemployed or housewife/husband), living alone (yes or no) and household income (< 10,000, 10,000–19,999 or ≥ 20,000 yuan (CNY)/year). Behavior factors including alcohol consumption (not weekly drinking,ex-regular drinkers, not daily, daily and < 15 g/day, daily and 15–29 g/day, daily and 30–59 g/day,or daily and ≥ 60 g/day), smoking status (never/occasional, former, current and 1–14 cigarettes/day, current and 15–24 cigarettes/day, or current and ≥ 25 cigarettes/day), tea consumption (never or seldom, always), physical activity estimated as metabolic equivalent task (continuous, MET-h/day) and intake frequencies of red meat, fresh fruits, vegetables and milk (daily, 4–6 days/wk, 1–3 days/wk, monthly, or rarely or never). Physical and mental health status included the history of common chronic diseases (yes or no), anxiety status, stressful life events and self-rated health (poor, fair or good). At baseline, body weight and height were measured using calibrated instruments by trained staff. Body mass index (BMI) was calculated as weight in kilograms divided by the height in meters squared.

2.3 Statistical analysis

Characteristics of participants were described according to different sleep durations and different status of sleep disturbances, using adjusted means and percentages for continuous and categorical variables respectively. General linear models or logistic models were used to test differences in these variables between subgroups, adjusting for age, gender and survey sites.

Logistic regression models were used to estimate the association between sleep behavior (include sleep duration, subtypes and number of sleep disturbances) and MDE. Each model included known and potential confounders. Model 1 adjusted for baseline social-demographic factors and behavioral factors. Model 2 further adjusted for physical health status. Model 3 further included mental health status. We also explored the linear trend between the numbers of sleep disturbance and MDE.

We further examined the joint association of sleep duration and sleep disturbances with MDE, we performed logistic regression models including five dummy variables to represent all six possible combinations of sleep duration and sleep disturbances, Take ASD as an example, normal sleep duration without ASD (reference group), normal sleep duration with ASD, short sleep duration with or without ASD and long sleep duration with or without ASD.

To examine the robustness of our findings, we conducted several sensitivity analyses by restricting analyses to participants without a history of psychological diseases (n = 505,468), those reported sleep duration between 4 h and 12 h (n = 509,150) and participants who had never used sleep medications (n = 506,461). Furthermore, we re-analyzed with the MDE definition without sleep disturbances criteria as Skapinakis (Skapinakis et al., 2013) suggested, to avoid the artificial overlapping of depression and sleep disturbances.

All statistical analyses were conducted using SAS 9.3 statistical software (SAS Institute Inc., Cary, NC, USA) and all p-values refer to two-tailed tests. Statistical significance was set at $P < 0.05$.

3 Results

3.1 Characteristics of study population

The participants included 44.1% urban residents, 59.0% females and with the mean age of 51.5 years. Baseline characteristics stratified by sleep behavior are shown in Table 1. Compared with participants who had normal sleep behavior, those who suffered from sleep disturbances or abnormal sleep duration were more likely to be elder, female, living alone, with a history of chronic diseases or with poor selfrated health. Similar results were observed when stratified by each sleep disturbance (i.e. DIMS, EMA, and DDF), see Supplementary Table 1.

3.2 Association between sleep behavior and depression

The overall prevalence of MDE was 6.40%. The associations of the sleep duration and sleep disturbances with depression are presented in Table 2. Participants slept ≤ 6 h and > 9 h were associated 2.32 and 1.56 times greater likelihood of having depression respectively. All types of sleep disturbances were significantly associated with depression in the fully adjusted model, the ORs varied between 3.31 (95% CI: 3.07, 3.58) for EMA and 4.17 (95% CI: 3.74, 4.64) for DDF. A significant positive linear trend ($P < 0.001$) was observed between the number of sleep disturbances and MDE. Compared with participants reported no symptoms, those with more symptoms had a stronger association with depression, especially for the group with all three symptoms (OR = 7.68, 95% CI: 6.71–8.77).

The association between sleep behavior and depression did not change appreciably in a series of sensitivity analysis, see Supplementary Table 2.

3.3 The joint association of sleep duration and sleep disturbances with depression

Table 3 presents the joint association of sleep duration and sleep disturbances with depression. Compared with people slept 7–9 h and without sleep disturbances, the association between short sleepers and depression was stronger than long sleepers in people without sleep disturbances, except for ASD.

The association with depression was significantly increased among persons with sleep disturbances and abnormal sleep duration. Those who slept with long duration and sleep disturbances have the largest association with depression (e.g., DIMS: OR = 7.30, 95%CI: 5.44–9.64), followed by short sleep duration with sleep disturbances (OR = 4.52, 95% CI: 4.11–4.97) and normal sleep duration with sleep disturbances (OR = 3.35, 95% CI: 2.96–3.78). Among the four subtypes, the association between DDF and depression was the largest. What's more, there was statistical evidence of an interaction for all sleep disturbances and sleep duration.

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4 Discussion

To the best of our knowledge, the present study is the largest study of the relationship between sleep behavior and depression in a Chinese population. We observed that both short and long sleep duration, as well as all types of sleep disturbances, was significantly related to depression. Furthermore, sleep disturbances combined with abnormal duration had the most likelihood of depression, especially for those who had long sleep duration. We also observed a dose-response relationship between the number of sleep disturbances and depression.

A recent meta-analysis consists of prospective studies to assess the risk of depression of the sleep duration has also demonstrated the U-shaped relationship, which was consistent with our findings in the Chinese population (Zhai et al., 2015). However, some researchers only found the significant association between short duration and depression maybe because they defined long duration as ≥ 8 h, which is irrational since the American National Sleep Foundation has recommended 7–9 h sleep duration for adults. Meanwhile, our results of all subtypes of sleep disturbances were associated with depression in general Chinese population was consistent with previous literature (Almeida et al., 2011; Salo et al., 2012; Szklo-Coxe et al., 2010; Yokoyama et al., 2010). For instance, a population-based study conducted in 19–70 years old participants (Salo et al., 2012) showed that difficulty initiating sleep, difficulty maintaining sleep and early morning awakening appeared to significantly associate with depression. Furthermore, our results also demonstrated a linear trend between the number of sleep disturbances and depression, which was in accordance with longitudinal studies (Salo et al., 2012; Szklo-Coxe et al., 2010).

The present study was consistent with existing evidence. A cross-sectional study conducted by Kalmbach et al. indicated that short sleeping insomniacs were at greater depression risk than insomniacs with normal sleep duration (≥ 6 h) (Kalmbach et al, 2016). Fernandez-Mendoza et al. (2015) in a longitudinal study also suggested the odds of incident depression were highest (OR = 2.2) in insomnia with objective short sleep duration compared with normal sleep duration. However, both of them did not explore the joint association of insomnia and long sleep duration with depression, which was the strongest association in the present study. Besides, insomniacs usually underestimate their sleep duration (Fernandez-Mendoza et al., 2011), which means that sleep disturbances combined with long sleep duration would have a greater effect on depression.

Recent neurobiological findings indicated the crucial role for sleep in the affective modulation of human brain functioning (Riemann et al., 2001). Some studies stated that under conditions of sleep loss, a strengthening of negative memories may occur during subsequent REM sleep, which potentially predisposes people to an imbalance in memory encoding yet creating a long-term dominance of negative experiences. Under such situation, people are at higher risk of developing depression (Baglioni and Riemann, 2012). Some researchers stated that depressed people worry so much that emotionally charged thoughts cause an overload of dreaming or REM sleep-robbing the brain of SWS, the recuperative sleep of stage three and four causing depressed patients to feel exhausted the next day and suffer from sleep disturbances (Edge, 2010). Additionally, the interactions between circadian

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system and hypothalamic-pituitary-adrenal (HPA) axis may also explain the mechanism between them (Landgraf et al., 2014; Nader et al., 2010). However, the mechanisms in the relationship between sleep disturbances combined with abnormal sleep duration (especially long sleep) and depression are still unclear, but recent studies have shown that insomnia with short sleep duration is associated with physiologic hyperarousal and cardio-metabolic (Fernandez-Mendoza, 2017), which may identify potential explanatory.

Although our data were based on a quite large sample size and plenty of established and potential confounding factors were controlled, these findings should also be interpreted in light of some limitations. First, as a cross-sectional study, we could not rule out reverse causality. Participants with depression may also fall asleep later and for shorter durations than others, leading to a spurious association. Second, the prevalence of depression is relatively lower compared with a recent meta-analysis in the Chinese population (Gu et al., 2013). The potential bias may arise that the participants in the present study covered a much older population (i.e., aged 30–79 years) than the typical onset age of MDE (i.e., aged 15–30 years). Another reason may be that the participants voluntarily enrolled in the present study usually have better mental conditions than the general population. Third, we must acknowledge the potential threats to validity due to the use of self-report sleep duration and sleep disturbances, distinctions between time awake in bed and physiologic sleep could not be reported as clear as measured by actigraphy or polysomnography. Fourth, the measurement of sleep disturbances was also not entirely in compliance with clinical diagnostic criteria (i.e., DSM-5), though the definitions of sleep disturbances in the present study were quite strict with the minimum frequency of three times a week during the past month. Finally, although we adjusted for a number of potential confounders, our results might still be affected by unmeasured and residual confounding.

In summary, the large population-based study shows a U-shaped relationship between sleep duration and depression, as well as the significant associations between all types of sleep disturbances (DIMS, EMA, DDF, ASD) and depression. More importantly, the associations were stronger for abnormal sleep duration accompanied by sleep disturbances, especially for long sleep duration. Further prospective studies are required to identify the pathways and causal relations between them.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Baseline characteristics by sleep duration and sleep disturbances [a].

	Total	Sleep Duration			ASD	
		≤ 6 h	7–9 h	> 9 h	Yes	No
Age, years	51.5	54.8	50.7	51.0	54.3	51.2
City	44.1	48.9	43.8	24.2	37.8	45.1
Female	59.0	62.1	58.4	58.5	67.5	57.5
Education						
primary school and below	50.8	48.7	44.5	51.1	48.7	45.4
middle school	43.4	48.8	51.9	47.3	48.8	51.3
college and above	5.9	2.5	3.6	1.6	2.5	3.3
Occupation						
manual workers	55.8	64.4	63.1	60.8	64.9	62.9
non-manual workers	12.9	12.8	13.6	9.3	11.4	13.6
others	31.3	22.8	23.3	29.9	23.7	23.5
Income						
<10,000	28.2	26.3	23.4	30.5	28.2	23.6
10,000–19,999	29.1	35.9	35.9	38.1	36.1	36.0
≥ 20,000	42.7	37.8	40.7	31.4	35.7	40.4
Married	90.6	91.7	93.8	93.1	91.7	93.6
Live alone	2.8	2.0	1.4	1.7	2.0	1.5
Tea consumption	33.3	29.3	32.5	32.4	28.3	32.4
Current smoker	29.4	19.4	18.2	18.9	19.6	18.3
Regular alcohol drinker	14.9	8.2	7.5	7.5	7.9	7.6
BMI						
normal	56.2	58.3	55.9	55.5	60.9	55.5
over weight	33.2	32.5	34.4	34.0	31.1	34.5
obesity	10.6	9.2	9.7	10.5	8.0	10.0
Good Self-rated health	45.8	39.7	48.1	47.2	34.3	48.4
History of Chronic disease	34.3	34.5	31.6	34.9	38.4	31.3
Stressful life events	8.5	10.0	7.2	8.3	13.1	6.9
PA, MET-hr/d	21.1	21.4	21.0	18.3	21.0	20.9
Menopause[b]	52.5	70.2	65.5	63.9	71.1	65.5

Values are percentages otherwise specified.
All p values refer to comparisons across subgroups < 0.001.
ASD = any sleep disturbances; BMI = body mass index; PA = physical activity; MET = metabolic equivalent.

[a] All variables were adjusted for age, gender and survey sites where appropriate.

[b] Menopause status: only for female.

Table 2

The association between sleep behavior and depression[a].

	No of participants	Model1	Model2	Model3
Sleep Duration/day				
≤ 6	118,450 (23.09%)	3.03 (2.81, 3.26)	2.97 (2.76, 3.20)	2.32 (2.14, 2.51)
7–9 h	368,172 (71.78%)	1.00	1.00	1.00
> 9 h	26,269 (5.12%)	1.66 (1.43, 1.92)	1.64 (1.42, 1.90)	1.56 (1.34, 1.81)
Sleep Disturbances				
DISM				
No	453,177 (88.36%)	1.00	1.00	1.00
Yes	59,714 (11.64%)	5.51 (5.13, 5.92)	5.33 (4.96, 5.73)	3.49 (3.23, 3.76)
EMA				
No	458,041 (89.31%)	1.00	1.00	1.00
Yes	54,850 (10.69%)	5.28 (4.91, 5.68)	5.12 (4.76, 5.51)	3.31 (3.07, 3.58)
DDF				
No	501,081 (97.7%)	1.00	1.00	1.00
Yes	11,810 (2.30%)	8.35 (7.57, 9.20)	7.96 (7.21, 8.77)	4.17 (3.74, 4.64)
ASD				
No	427,007 (83.25%)	1.00	1.00	1.00
Yes	85,884 (16.75%)	5.67 (5.28, 6.09)	5.50 (5.12, 5.91)	3.58 (3.32, 3.87)
Numbers of Sleep Disturbances[†]				
0	427,007 (83.25%)	1.00	1.00	1.00
1	51,780 (10.10%)	3.36 (3.05, 3.70)	3.29 (2.98, 3.61)	2.43 (2.20, 2.68)
2	27,718 (5.40%)	7.49 (6.84, 8.19)	7.25 (6.62, 7.94)	4.41 (4.00, 4.86)
3	6386 (1.25%)	16.2 (14.3, 18.2)	15.5 (13.7, 17.5)	7.68 (6.71, 8.77)

Model 2 further adjusted for numbers of chronic disease and body mass index.
Model 3 further included anxiety, stressful life events and self-rated health.
DIMS = difficulty in initiating and maintaining sleep; EMA = early morning awakening; DDF = daytime dysfunction; ASD = any sleep disturbances.

[a]Model 1adjusted for age, gender, survey sites, marital status, level of education, occupation, living alone and household income per year; alcohol consumption, smoking status, tea consumption and physical activity; intake frequencies of red meat, fresh fruits, and vegetables.

[†]All p values for linear trend < 0.001.

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Table 3

The joint association of sleep duration and sleep disturbances on depression[a].

Sleep disturbances	Sleep duration/day			p for interaction
	≤ 6 h	7–9 h	>9 h	
DIMS				< 0.001
No	1.76 (1.58, 1.96)	1.00	1.53 (1.28, 1.82)	
Yes	4.52 (4.11, 4.97)	3.35 (2.96, 3.78)	7.30 (5.44, 9.64)	
EMA				< 0.001
No	1.73 (1.56, 1.93)	1.00	1.53 (1.29, 1.80)	
Yes	4.30 (3.90, 4.73)	3.08 (2.69, 3.51)	7.11 (5.06, 9.78)	
DDF				< 0.001
No	2.09 (1.92, 2.27)	1.00	1.63 (1.39, 1.90)	
Yes	6.14 (5.38, 6.99)	4.49 (3.67, 5.45)	7.97 (4.42, 13.5)	
ASD				0.048
No	1.38 (1.20, 1.57)	1.00	1.53 (1.27, 1.82)	
Yes	4.36 (3.98, 4.78)	3.10 (2.77, 3.48)	6.84 (5.22, 8.85)	

DIMS = difficulty in initiating and maintaining sleep; EMA = early morning awakening; DDF = daytime dysfunction; ASD = any sleep disturbances.

[a]All analyses were conducted in the full model.