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Research paper

Healthy sleep patterns and common mental disorders among individuals with cardiovascular disease: A prospective cohort study

Zhi Cao [a,b,c], Yabing Hou [d], Hongxi Yang [e], Xianhong Huang [a,c], Xiaohe Wang [a,c], Chenjie Xu [a,c,*]

[a] School of Public Health, Hangzhou Normal University, Hangzhou, China
[b] School of Public Health, Zhejiang University School of Medicine, Hangzhou, China
[c] Hangzhou International Urbanology Research Center & Center for Urban Governance Studies, Hangzhou, China
[d] Yanjing Medical College, Capital Medical University, Beijing, China
[e] School of Basic Medical Sciences, Tianjin Medical University, Tianjin, China

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ABSTRACT

Background: Sleep behaviors are potentially modifiable risk factors for common mental disorders and cardiovascular disease (CVD). However, the associations between combined sleep behaviors and common mental disorders among individuals with CVD remain unclear.

Methods: A total of 18,776 participants with a history of CVD from UK Biobank, who were free of depression or anxiety from 2006 to 2010 were included. A composite healthy sleep score was constructed based on five sleep behaviors (chronotype, sleep duration, insomnia, snoring, and excessive daytime sleepiness). Cox proportional hazard regression models were performed to calculate hazard ratios (HRs) and 95 % confidence intervals (CIs) for incident depression and anxiety.

Results: During a median follow-up of 11.8 years, 965 depression and 812 anxiety cases were recorded. The adjusted HRs for participants with a healthy sleep pattern compared with a poor sleep pattern were 0.45 (95 % CI: 0.35–0.57) for depression and 0.77 (95 % CI: 0.58–1.03) for anxiety. There was a linear dose-response association of healthy sleep score with incident depression and anxiety (HR = 0.82, 95 % CI: 0.77–0.87; HR = 0.92, 95 % CI: 0.86–0.99 per 1-score increase, respectively). Likewise, these associations were observed among individuals with coronary heart disease, stroke, heart failure and atrial fibrillation.

Conclusions: A healthy sleep pattern is significantly associated with a lower risk of depression among individuals with CVD, highlighting the importance of monitoring and improving sleep health in the prevention of common mental disorders among individuals with CVD.

1. Introduction

It is now widely recognized that cardiovascular disease (CVD) is the primary cause of premature mortality and disability worldwide (Roth et al., 2020). The global burden of CVD has nearly doubled, increasing from 271 million cases in 1990 to 523 million cases in 2019 (GBD 2019 Diseases and Injuries Collaborators, 2020). Evidence indicates that CVD frequently coexists with the morbidity of physiological disorders, and the developing or worsening of CVD may have adverse effects on mental health (Lichtman et al., 2008; Rutledge et al., 2006).It has been demonstrated that the prevalence of depression among individuals with CVD is three times higher than that in the general population, as evidenced by a previous population-based study (Chaddha et al., 2016). Therefore, it is increasingly imperative to prioritize prognostic care for individuals diagnosed with CVD.

In recent years, numerous studies have established that unhealthy sleep behaviors constitute significant risk factors for mental health. For instance, both short and long sleep duration (Schäfer et al., 2022), late chronotype, insomnia disorder (Li et al., 2016), snoring (Jeong et al., 2021), and excessive daytime sleepiness (Zhang et al., 2021) have been associated with an elevated risk of mental disorders in the general population. However, it remains unclear whether this association holds true for individuals with CVD. There is compelling evidence to suggest that obstructive sleep apnea may significantly contribute to the development and progression of CVD (Shamsuzzaman et al., 2003). The disruption of sleep and circadian rhythms can impair both physiological

* Corresponding author at: School of Public Health, Hangzhou Normal University, No.2318, Yuhangtang Road, Yuhang District, 311121 Hangzhou, China.
E-mail address: xuchenjie@hznu.edu.cn (C. Xu).

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and psychological function, ultimately increasing the risk for CVD and psychiatric disorders (Medic et al., 2017). Therefore, investigating the combined effects of CVD and sleep disorders may be relevant to prevention strategies for mental health among individuals with CVD.

It is widely acknowledged that sleep behaviors are intricate, and the aforementioned sleep factors typically interact with one another (Antelmi et al., 2021). Alterations in one's sleep behavior may result in compensatory modifications in other aspects of their sleep (Fan et al., 2020). For example, the co-occurrence of insomnia disorder and short sleep duration are significantly associated with the risk of cardiovascular events (Chien et al., 2010). Evening-oriented individuals tend to experience shorter sleep duration and a higher incidence of sleep problems compared to those with an earlier chronotype (Lang et al., 2022). The question of whether the combined impact of sleep patterns on subsequent mental disorders following CVD diagnosis remains unanswered. Therefore, the objective of this study was to prospectively assess the association between a combined healthy sleep pattern and common mental disorders among individuals diagnosed with CVD.

2. Methods

2.1. Study design and population

UK Biobank (UKB) is a prospective cohort study that systematically gathers comprehensive information on sociodemographic, lifestyle, and health-related factors of approximately 500,000 individuals aged 37–73 years across the United Kingdom from 2006 to 2010 (Sudlow et al., 2015). Participants were requested to provide details about their lifestyle, medical history, and other health-related factors through physical measurements and touch-screen questionnaires. The biological samples were also collected at the assessment centers for genomic, proteomic, and metabolomic testing. The UK Biobank has received full ethical approval from the NHS National Research Ethics Service (NW/0382). Each participant provided written informed consent and researchers were granted permission to use data from the UKB under application No.79095.

In the UK Biobank, 27,233 participants were identified as having a history of CVD at recruitment, including ischemic heart disease (IHD), stroke, heart failure (HF), and atrial fibrillation (AF). These diagnoses were obtained by linking to Health Episode Statistics in England and Wales, as well as the Scottish Morbidity Records in Scotland, based on medical records. Overall and individual CVD diagnoses identified through hospital inpatient records were classified based on the International Classification of Diseases edition 10 (ICD-10) codes (Appendix 1) (Arnett et al., 2019).

Participants with depression, anxiety, or use of antidepressants at baseline and with missing sleep behavior data were excluded from the analysis. Ultimately, 18,778 individuals with CVD at baseline were included in the final analyses (Appendix 2).

2.2. Assessment of sleep behaviors

The sleep behaviors analyzed were self-reported and included the duration of sleep, chronotype preference, insomnia disorder, snoring, and daytime sleepiness as in previous studies (Fan et al., 2020; Li et al., 2021b). Sleep duration was recorded as the total numbers of hours of slept within a 24-hour period, including any naps taken. Chronotype preference was ascertained by responding to the inquiry: "Do you consider yourself to be 1) definitely a 'morning' person; 2) more a 'morning' person than 'evening' person; 3) more an 'evening' person than a 'morning' person; or 4) definitely an 'evening' person." Insomnia disorder was assessed by asking if the individual had difficulty falling asleep or waking up during the night with response options of never/rarely, sometimes, or usually. Snoring was assessed by asking if the participant's partner, close relative or friend complains about their snoring (yes or no), and daytime sleepiness was evaluated by asking how likely they are you to doze off during the daytime when not intending to (never/rarely; sometimes; often; and all of the time).

2.3. Definition of a healthy sleep score and sleep patterns

Healthy sleep behaviors include getting 7–8 h of sleep per day, being a morning person, reporting never/rarely or sometimes insomnia, not snoring according to self-report, and experiencing never/rarely or sometimes excessive daytime sleepiness. Each participant received one point for each low-risk factor reported, resulting in a sleep score ranging from 0 to 5 based on their questionnaire responses (Li et al., 2021a; Li et al., 2021b). The higher sleep score indicated the healthier sleep pattern they adhered to. Participants were grouped into poor (0–1); intermediate (2–3); and healthy (4–5) sleep patterns based on their sleep scores.

Moreover, we created a weighted sleep score according to the composite score: weighted sleep score = ($\beta_1 \times$ sleep duration + $\beta_2 \times$ chronotype preference + $\beta_3 \times$ insomnia disorder + $\beta_4 \times$ snoring + $\beta_5 \times$ daytime sleepiness) $\times$ (5 / sum of the β coefficients). The weighted sleep score combines five sleep behaviors and ranges from 0 to 5 points, taking into account the adjusted relative risk magnitudes of each sleep behavior in the sleep pattern.

2.4. Assessment of outcomes

The main outcomes of this study were depression and anxiety incidence, determined from hospital inpatient records using the ICD-10 coding system (F32-F33 for depression; F40-F41 for anxiety). The termination of follow-up was ascertained based on the availability of medical record data in UKB, which was censored until September 30, 2021.

2.5. Assessment of covariates

A list of covariates was selected a priori from the existing literature and theory (Walsh, 2011). These factors included age, sex, ethnicity, socioeconomic status (Townsend Deprivation Index), educational achievement, body mass index (BMI, calculated as weight divided by the square of height, kg/m^2), self-reported smoking status, alcohol consumption (g/day), intake of vegetable and fruit (portions/day), physical activity [total metabolic equivalent task (MET) hours per week, MET-h/week], C-reactive protein (CRP, mg/L), hypertension, and type 2 diabetes. The Townsend Deprivation Index (TDI) measures deprivation based on post codes, using data on housing, unemployment, social class and car ownership. Higher scores indicate greater levels of deprivation (Townsend, 1988). The International Physical Activity Questionnaire (IPAQ) was utilized to collect physical activity data, recording the total amount of mild, moderate, and vigorous physical activities performed in the past seven days. The baseline assessment measured CRP levels using high-sensitivity assays. The prevalence of hypertension was defined as systolic blood pressure $\geq$ 140 mmHg, or diastolic blood pressure $\geq$ 90 mmHg, or reported use of antihypertensive medication. The prevalence of type 2 diabetes was ascertained through self-reported data or hospital diagnoses.

2.6. Statistical analyses

Baseline characteristics were reported as means and standard deviation (SD) for continuous variables, or numbers (percentages) for categorical variables, stratified by three sleep patterns. Time on study was calculated from baseline assessment until the first diagnosis of outcomes, death, or end of follow-up.

Cox proportional hazards models were used to estimate the hazard ratios (HRs) and 95 % confidence intervals (CI), with age modeled as the time scale. The Schoenfeld residuals method confirmed that the Cox models satisfied the proportional hazards assumption (Grambsch and

Therneau, 1994). The reference group for subsequent analyses consisted of participants with a poor sleep pattern, and three models were constructed. Model 1 was adjusted for age (timescale) and sex, while Model 2 included additional adjustments for ethnicity, TDI, qualifications, employment status, physical activity, smoking status, alcohol drinking, intake of vegetable and fruit, and CRP. Finally, Model 3 was fully adjusted by incorporating BMI along with hypertension and type 2 diabetes. Moreover, we used restricted cubic splines models to investigate the dose-response association between healthy sleep patterns and common mental disorders. HRs per 1-score increase were estimated. Missing information on covariates were handled by coding categorical variables as a missing indicator category and continuous variables with mean values.

Subsequently, stratified analyses were conducted to assess the potential effect modifications by the potential covariates including age (<60 or ≥60 years), sex (female or male), ethnicity (white or non-white), education attainment (college or university degree, professional qualifications), Townsend Deprivation Index (<median or ≥median), BMI (<30 kg/m^2 or ≥30 kg/m^2), current smoking (no or yes), moderate alcohol intake (no or yes), CRP (>10 mg/L or ≤10 mg/L), hypertension (no or yes), type 2 diabetes (no or yes). We examined the potential impact of effect modifications by incorporating a cross-product term between stratified variables and healthy sleep score in a fully adjusted model.

We also conducted several sensitivity analyses to confirm the reliability of our findings. Firstly, a weighted sleep score was therefore adopted to examine its association with common mental disorders. Secondly, in consideration of disease duration among CVD patients, we further adjusted for time since CVD diagnosis in the Cox models (Teh and Prepageran, 2022). Thirdly, adjustments were made for other dietary components such as fish and meat in the Cox model. Fourthly, we excluded individuals who developed common mental disorders within 2 years of follow-up to avoid possible reverse causation. Fifthly, we conducted the complete-case analyses by excluding individuals with missing covariates. Finally, we excluded all participants who reported symptoms of depression or anxiety as assessed by the Patient Health Questionnaire-4 (PHQ-4) at baseline and repeated the main analyses. The use of PHQ-4 at baseline to assess depression and anxiety symptoms was described in previous work (Kroenke et al., 2009).

We used Stata version 15 (Stata Corp) for all statistical analyses, with a significance level set as $P < 0.05$ (two-tailed test).

3. Results

Of all the 18,778 individuals, 31.22 % adhered to a "healthy sleep pattern" (4–5 healthy sleep scores) (Table 1). Over a median follow-up of 11.8 years, there were 965 cases of depression and 812 cases of anxiety observed. Compared to those adhered to poor sleep patterns, individuals adhering to healthy sleep pattern were older, more likely to be male and of white ethnicity, less deprived with higher education levels, healthier lifestyle behaviors, lower BMI and CRP levels, and reported never or rarely experiencing insomnia at baseline.

In the fully-adjusted Cox regression models, a healthy sleep pattern was associated with a 55 % lower risk of depression (HR = 0.45, 95 % CI: 0.35–0.57) compared to poor sleep pattern; however, no significant association was observed between healthy sleep pattern and anxiety (HR = 0.77, 95 % CI: 0.58–1.03) (Table 2 and Appendix 3). In the dose-response analysis, restricted cubic spline regression demonstrated a linear correlation between sleep score and incident depression and anxiety (P for linearity <0.001) (Fig. 1). Specifically, each one-point increase in sleep score was associated with an 18 % reduction in the risk of developing depression (HR = 0.82, 95 % CI: 0.77–0.87), as well as an 8 % decrease in the risk of developing anxiety (HR = 0.92, 95 % CI: 0.86–0.99). Similar trends were observed among individual CVD population, with the exception of strokes, where a significant dose-response relationship between healthy sleep scores and depression but not anxiety (Table 3).

Table 1
Baseline characteristic of participants stratified by healthy sleep pattern.

Baseline characteristics	Healthy sleep pattern		
	Poor	Intermediate	Healthy
	(0–1)	(2–3)	(4–5)
Number of participants	1182 (6.29)	11,734 (62.49)	5862 (31.22)
Age (years), mean (SD)	60.69 (6.42)	61.82 (6.02)	62.32 (6.01)
Female	320 (27.07)	3472 (29.59)	1708 (29.14)
Ethnicity, White	1078 (91.20)	11,103 (94.62)	5572 (95.05)
Townsend Deprivation Index, mean (SD)	−0.43 (3.33)	−0.95 (3.23)	−1.24 (3.13)
Education level			
College or university degree	208 (17.60)	2521 (21.48)	1484 (25.32)
Professional qualifications	549 (46.45)	5488 (46.77)	2631 (44.88)
Other	406 (34.35)	3565 (30.38)	1664 (28.39)
Lifestyle factors			
Current smoker	554 (46.87)	5831 (49.69)	2740 (46.74)
Alcohol drinking (g/day)	16.13 (21.72)	16.13 (20.00)	14.66 (17.80)
Vegetable and fruit intake (portions/day)	4.40 (3.04)	4.65 (3.16)	4.94 (3.09)
Physical activity (MET-h/week)	36.64 (38.53)	41.27 (39.86)	45.50 (40.96)
BMI (kg/m^2), mean (SD)	30.93 (5.76)	29.24 (4.93)	28.30 (4.62)
CRP (mg/L), mean (SD)	3.69 (5.23)	3.10 (4.99)	2.91 (5.23)
Low-risk sleep factors (%)			
Early chronotype	140 (11.84)	6580 (56.08)	5346 (91.20)
Sleep 7–8 h/day	68 (5.75)	6006 (51.18)	5462 (93.18)
Never/rarely insomnia	13 (1.10)	1256 (10.70)	2691 (45.91)
No self-reported snoring	100 (8.46)	5807 (49.49)	5065 (86.40)
No frequent daytime sleepiness	780 (65.99)	11,215 (95.58)	5.862 (99.69)

Values are numbers (percentages) unless stated otherwise.
BMI: body mass index; CRP: C-reactive protein.

The association between each predefined low-risk sleep factor and the common mental disorders were examined separately (Table 4). For the overall CVD participants, adequate sleep duration (between 7 and 8 h/day), free of insomnia, no frequent daytime sleepiness was associated with incident depression, with HR of 0.83 (95 % CI: 0.64–0.83), 0.77 (95 % CI: 0.64–0.92), and 0.71 (95 % CI: 0.56–0.89) in multivariable-adjusted models, respectively. Similar prospective associations were also observed among individuals with IHD. For those with other types of CVD (stroke, HF, and AF), sleeping between 7 and 8 h per day was significantly associated with a lower risk of depression. The early chronotype preference was found to be inversely associated with the risk of depression among individuals with HF and AF. For individuals with overall CVD, IHD, and HF, the risk of anxiety was significantly reduced by 33 %, 33 %, and 38 % respectively when free from insomnia. A reduced risk of anxiety was observed among individuals with stroke who did not report snoring, while a lower risk of anxiety was only associated with non-frequent daytime sleepiness in individuals with stroke.

We conducted subgroup analyses based on potential covariates (Appendix 4). After adjusting for various factors, we found a stronger association between healthy sleep score and lower risk of anxiety in White participants compared to non-White participants (P for interaction <0.001). In addition, we observed a lower HR between healthy

Table 2
Multivariable-adjusted HRs (95 % CIs) for mental disorders by healthy sleep patterns among participants with cardiovascular disease.

Healthy sleep pattern	Cases	Model 1		Model 2		Model 3	
		HR (95 % CI)	*P*	HR (95 % CI)	*P*	HR (95 % CI)	*P*
Depression							
Poor	105	1 (Reference)		1 (Reference)		1 (Reference)	
Intermediate	653	0.59 (0.48–0.73)	<0.001	0.39 (0.25–0.61)	<0.001	0.68 (0.55–0.84)	<0.001
Healthy	207	0.37 (0.29–0.46)	<0.001	0.20 (0.12–0.34)	<0.001	0.45 (0.35–0.57)	<0.001
Per 1 increase of healthy sleep score		0.75 (0.71–0.80)	<0.001	0.80 (0.75–0.85)	<0.001	0.82 (0.77–0.87)	<0.001
Anxiety							
Poor	64	1 (Reference)		1 (Reference)		1 (Reference)	
Intermediate	524	0.76 (0.59–0.98)	0.037	0.84 (0.65–1.09)	0.186	0.87 (0.67–1.13)	0.308
Healthy	224	0.63 (0.48–0.83)	0.001	0.73 (0.55–0.97)	0.028	0.77 (0.58–1.03)	0.075
Per 1 increase of healthy sleep score		0.87 (0.81–0.93)	<0.001	0.91 (0.84–0.97)	0.006	0.92 (0.86–0.99)	0.020

HR: hazard ratio; CI: confidence interval.
Model 1: adjusted for age (timescale) and sex.
Model 2: further adjusted for ethnic, Townsend Deprivation Index, qualifications, employment status, physical activity, smoking status, alcohol drinking, intake of vegetable and fruit, and C-reactive protein.
Model 3: fully adjusted for body mass index, hypertension, and type 2 diabetes.

sleep score and the risk of anxiety in participants with professional qualifications (*P* for interaction <0.001).

Similar results were found when excluding participants with depression or anxiety symptoms at baseline (determined by the PHQ-4, Appendix 5). In Model 3, a healthy sleep pattern was associated with a 41 % lower risk of depression compared to poor sleep pattern (HR = 0.59, 95 % CI: 0.41–0.85). The results remained consistent with the main analyses even after adjusting for duration since CVD diagnosis and consumption of fish and meat (Appendices 6 and 7); excluding participants who experienced two CMD events during the first two years of follow-up (Appendix 8); and conducting complete-case analyses by deleting missing covariates (Appendix 9).

4. Discussion

In this prospective cohort study, adherence to a healthy sleep pattern among individuals with CVD is significantly associated with a 55 % lower risk of depression compared to those who adhere to poor sleep patterns. Furthermore, we have also observed a linear dose-response relationship between the healthy sleep score and incident depression and anxiety, with HRs of 0.82 (95 % CI: 0.77–0.87) and 0.92 (95 % CI: 0.86–0.99) per one-point increase in score, respectively. Similar findings were predominantly observed in individuals with IHD, stroke, HF, and AF. More specifically, a sleep duration of 7 to 8 h per day was associated with a decreased risk of depression across all sub-types of CVD.

Individuals typically spend around one-third of their lifetime sleeping, and sleep behaviors are crucial for maintaining physical health (Roenneberg et al., 2007). Our findings suggest that modifiable sleep behaviors are associated with a reduced risk of common mental disorders in individuals with CVD. A previous study demonstrated that individuals with poor sleep quality had twice the likelihood of screening positive for depression (OR = 2.33, 95 % CI = 1.52–3.57) (Kalmbach et al., 2017). Previous studies both in experiments and epidemiology have shown that sleep disruption is associated with adverse outcomes of anxiety and depression (Freeman et al., 2020). Our findings provide further evidence for the multidimensional nature of sleep health as proposed by Buysse (2014), which highlights the collective impact of sleep factors on both health and functioning. However, there is a lack of research exploring the influence of health sleep patterns on the mental health of patients with CVD. To our knowledge, this study extends upon previous work in this area and contributes to existing knowledge.

It has been noted that individuals diagnosed with severe mental illness often exhibit comorbidities of myocardial infarction and stroke (Jayatilleke et al., 2017). Additionally, a cross-sectional survey revealed that individuals with CVD had an increase likelihood of experiencing sleep disturbance and burnout within Kyrgyz and East European ethnic groups (Azfar et al., 2021). Psychological factors may be prevalent in certain CVD and predict worse outcomes, or pre-existing psychological conditions may proceed the onset of CVD (Piña et al., 2018). Depressed patients have been found to exhibit abnormal heart rate variability which could lead to arrhythmias (Carney et al., 1995). Several risk factors for cardiovascular disease such as smoking, unhealthy diet, physical inactivity and drug abuse are commonly observed among individuals with severe mental illness (Nielsen et al., 2021). Furthermore, the treatment for mental health disorders may increase the risk of CVD due to potential side effects or drug interactions.

The relationship between CVD and mental health is linked by multiple pathways. Acute stress exerts an impact on the sympathetic nervous system, leading to arrhythmias, endothelial function, platelet activation, and other effects (Rozanski et al., 1999). The Kuopio Ischemic Heart Study has confirmed the hypothesis that mental stress-induced increases in activate heart rate and acute blood pressure can trigger atherosclerosis (Kamarck et al., 1997). Other potential mechanisms underlying the associations may involve the neuronal nitric oxide synthase pathways in coronary blood flow (Kamarck et al., 1997), as well as inflammatory processes implicated in both coronary plaque lesions and depression (Preisig et al., 2011).

Depression and cardiovascular risk have been commonly linked to unhealthy lifestyles, including poor sleep behavior (Riera-Sampol et al., 2021). The mechanism between diverse sleep behaviors, depression, and CVD is complex and not yet fully understood. Several observational studies have established a correlation between sleep behavior and incidence of CVD morbidity and mortality (Laugsand et al., 2014). A review of multiple studies found that individuals without pre-existing CVDs who suffer from insomnia are at a 45 % higher risk of the developing or dying from CVD within a follow-up from three to twenty years. Similarly, sleep disorders can exacerbate the severity of depressive symptoms and lead to poorer mental health outcomes. It may contribute to the onset of depression by disrupting mood and emotion regulation, as well as impairing cognitive function and reducing coping abilities (Crouse et al., 2021; Lo et al., 2016; Orzech et al., 2011). Additionally, sleep disorders may worsen pre-existing symptoms of depression and CVD. The proposed mechanisms are likely attributed to imbalances in the hypothalamic-pituitary axis, increased activity of the sympathetic nervous system, and heightened inflammation (Javaheri and Redline, 2017).

The present study yielded inconclusive findings regarding the associations between sleep patterns and anxiety in CVD patients, with the exception of individuals who have suffered a stroke. This may be attributed in part of the limited number of anxiety events observed. Never or rarely experiencing insomnia was found to be significantly associated with a 33 % lower risk of anxiety among participants with

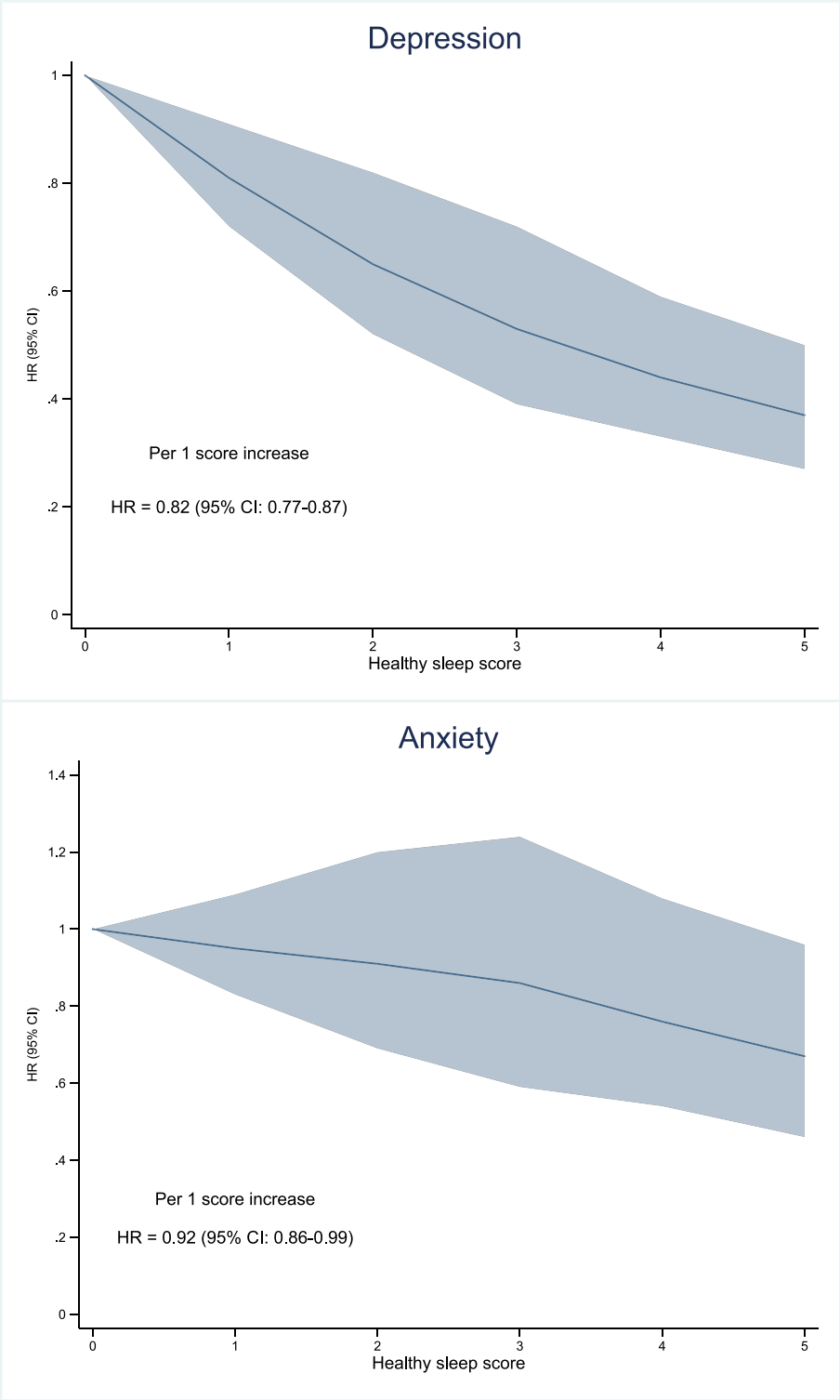

Fig. 1. Multivariable-adjusted hazard ratios (HRs) of CMD events risk according to healthy sleep score. Solid blue lines are multivariable adjusted HRs, with blue areas showing 95 % confidence intervals derived from restricted cubic spline regressions with three knots. The figure shows HRs for depression or anxiety adjusted for age (timescale), sex, ethnic, Townsend Deprivation Index, qualifications, employment status, physical activity, smoking status, alcohol drinking, intake of vegetable and fruit, C-reactive protein, body mass index, hypertension, and type 2 diabetes. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

total CVD (95 % CI: 0.54–0.82, $P < 0.001$) and IHD (95 % CI: 0.54–0.84, $P < 0.001$). These results suggest that insomnia may serve as an independent risk factor for the incidence of common mental disorders in individuals with CVD. The above findings require further investigation and attention in clinical practice, as previous studies have suggested that insomnia may increase the risk of CVD through various mechanisms such as sympathetic nervous system activation, inflammation, endothelial dysfunction, and metabolic dysregulation. These physiological changes can lead to hypertension, atherosclerosis, and other cardiovascular conditions (Baglioni et al., 2011; Kahal et al., 2018; Meier-Ewert et al., 2004; Tobaldini et al., 2017). It's crucial to evaluated the combination of these sleep factors as they are complex and often interconnected. For instance, frequent insomnia is often associated with reduced sleep duration (Bertisch et al., 2018), while chronotype significantly influences sleep duration on workdays and free days (Roenneberg et al., 2007). So far, the precise mechanisms underlying the impact of combined sleep behaviors on common mental disorders in individuals with CVD remain incompletely understood. However, these sleep

Table 3
Multivariable-adjusted HRs (95 % CIs) for mental disorders by healthy sleep patterns among participants with individual CVD.

	Depression		Anxiety	
	HR (95 % CI)	*P*	HR (95 % CI)	*P*
Ischemic heart disease				
Poor	1 (Reference)		1 (Reference)	
Intermediate	0.76 (0.61–0.96)	0.018	0.94 (0.70–1.25)	0.672
Healthy	0.53 (0.40–0.68)	<0.001	0.86 (0.63–1.17)	0.335
Per 1 increase of healthy sleep score	0.83 (0.78–0.89)	<0.001	0.93 (0.87–1.01)	0.082
Stroke				
Poor	1 (Reference)		1 (Reference)	
Intermediate	0.66 (0.39–1.10)	0.109	0.39 (0.23–0.66)	<0.001
Healthy	0.53 (0.30–0.94)	0.029	0.31 (0.17–0.57)	<0.001
Per 1 increase of healthy sleep score	0.88 (0.75–1.02)	0.097	0.76 (0.63–0.91)	0.004
Heart failure				
Poor	1 (Reference)		1 (Reference)	
Intermediate	0.74 (0.51–1.07)	0.106	1.19 (0.72–1.98)	0.491
Healthy	0.41 (0.26–0.64)	<0.001	0.94 (0.54–1.62)	0.822
Per 1 increase of healthy sleep score	0.77 (0.68–0.86)	<0.001	0.92 (0.81–1.05)	0.226
Atrial fibrillation				
Poor	1 (Reference)		1 (Reference)	
Intermediate	0.72 (0.51–1.01)	0.060	1.20 (0.74–1.96)	0.455
Healthy	0.45 (0.31–0.68)	<0.001	1.11 (0.66–1.84)	0.698
Per 1 increase of healthy sleep score	0.80 (0.72–0.89)	<0.001	0.98 (0.87–1.09)	0.661

HR: hazard ratio; CI: confidence interval.
Cox models were fully adjusted for age (timescale), sex, ethnic, Townsend Deprivation Index, qualifications, employment status, physical activity, smoking status, alcohol drinking, intake of vegetable and fruit, C-reactive protein, body mass index, hypertension, and type 2 diabetes.

behaviors may independently increase the risk of depression or anxiety among those with CVD or at CVD risk, possibly through several synergistic mechanisms.

5. Strengths and limitations

To our knowledge, this is the first study to prospectively evaluate how various sleep behaviors collectively impact the risk of common mental disorders in individuals with CVD. This study highlights the crucial role of a healthy sleep pattern in secondary prevention of common mental disorders among individuals with pre-existing CVD. The utilization of UK Biobank data enabled us to account for a substantial number of covariates that are known to impact both sleep patterns and mental health.

There are still some limitations to mention. First, the identification of depression or anxiety in this study primarily relied on linked inpatient medical records, which may have missed some participants with clinically significant psychopathology. For participants from Scotland, it should be noted that the hospital inpatient data only capture psychiatric diagnoses recorded during non-psychiatric admissions, which may result in an underestimation of mental disorders among this subgroup when utilizing hospital data linkage based on ICD-10 diagnoses. However, caution should be exercised when interpreting mental disorders identified through symptom-based methods such as the Patient Health Questionnaire, as they may represent different constructs (Boschesi Barros et al., 2022). Second, sleep information used in this study was obtained from a self-reported questionnaire, which may be susceptible

Table 4
Multivariable-adjusted HRs (95 % CIs) for mental disorders by low-risk sleep factors among participant with overall and individual CVD.

	Depression		Anxiety	
	HR (95 % CI)	*P*	HR (95 % CI)	*P*
Overall CVD				
Sleep 7–8 h/day	0.73 (0.64–0.83)	<0.001	0.98 (0.86–1.14)	0.864
Early chronotype	0.88 (0.77–1.01)	0.061	0.89 (0.77–1.03)	0.121
Never/rarely insomnia	0.77 (0.64–0.92)	0.004	0.67 (0.54–0.82)	<0.001
No self-reported snoring	0.95 (0.83–1.08)	0.425	1.14 (0.98–1.32)	0.084
No frequent daytime sleepiness	0.71 (0.56–0.89)	0.003	0.77 (0.59–1.01)	0.064
Ischemic heart disease				
Sleep 7–8 h/day	0.74 (0.64–0.85)	<0.001	0.98 (0.84–1.15)	0.838
Early chronotype	0.90 (0.78–1.03)	0.127	0.90 (0.77–1.05)	0.161
Never/rarely insomnia	0.79 (0.65–0.96)	0.017	0.67 (0.54–0.84)	<0.001
No self-reported snoring	0.96 (0.84–1.11)	0.618	1.14 (0.97–1.33)	0.103
No frequent daytime sleepiness	0.73 (0.57–0.93)	0.011	0.93 (0.68–1.26)	0.629
Stroke				
Sleep 7–8 h/day	0.72 (0.53–0.99)	0.043	0.93 (0.64–1.35)	0.711
Early chronotype	0.95 (0.69–1.30)	0.737	0.88 (0.61–1.26)	0.477
Never/rarely insomnia	0.98 (0.67–1.43)	0.908	0.78 (0.48–1.27)	0.321
No self-reported snoring	1.04 (0.75–1.43)	0.811	0.68 (0.47–0.99)	0.044
No frequent daytime sleepiness	0.67 (0.40–1.15)	0.149	0.40 (0.23–0.68)	0.001
Heart failure				
Sleep 7–8 h/day	0.67 (0.52–0.85)	0.001	1.08 (0.83–1.40)	0.572
Early chronotype	0.73 (0.57–0.93)	0.010	0.85 (0.66–1.10)	0.222
Never/rarely insomnia	0.78 (0.55–1.09)	0.148	0.62 (0.42–0.90)	0.013
No self-reported snoring	0.85 (0.66–1.09)	0.197	1.18 (0.90–1.56)	0.232
No frequent daytime sleepiness	0.94 (0.61–1.43)	0.766	0.79 (0.50–1.25)	0.316
Atrial Fibrillation				
Sleep 7–8 h/day	0.78 (0.63–0.97)	0.022	1.01 (0.81–1.28)	0.880
Early chronotype	0.73 (0.60–0.91)	0.004	0.82 (0.65–1.03)	0.082
Never/rarely insomnia	0.77 (0.57–1.03)	0.078	0.82 (0.61–1.11)	0.202
No self-reported snoring	0.90 (0.73–1.12)	0.347	1.29 (1.01–1.63)	0.038
No frequent daytime sleepiness	0.80 (0.54–1.19)	0.270	0.91 (0.57–1.46)	0.686

HR: hazard ratio; CI: confidence interval.
Cox models were fully adjusted for age (timescale), sex, ethnic, Townsend Deprivation Index, qualifications, employment status, physical activity, smoking status, alcohol drinking, intake of vegetable and fruit, C-reactive protein, body mass index, hypertension, and type 2 diabetes.

to greater measurement inaccuracies compared to objective measures (Willetts et al., 2018). However, gold-standard sleep measures such as direct observation and polysomnography are impractical for large-scale studies, and self-reported sleep variables are prevalent in other epidemiological investigations (Baglioni et al., 2016). Additionally, the healthy pattern defined in this study did not cover all aspects of sleep behaviors, such as different types of insomnia (i.e., difficulty initiating/maintaining sleep, early morning awakening), obstructive sleep apnea, and restless legs syndrome. These factors may increase the risk of

common mental disorders (Morin et al., 2015; Zhang et al., 2022). Third, it's difficult to make causality conclusions in an observational cohort study. Despite adjusting for many relevant confounders, there still may be unmeasured variables that could bias our results.

6. Conclusion

The American Heart Association has recently released a scientific statement recommending that clinicians routinely assess the mental health of individuals with CVD and those at risk for CVD (Levine et al., 2021). Our study provides new evidence in this field, demonstrating that a healthy sleep pattern is associated with a reduced risk of common mental disorders among individuals diagnosed with CVD. These findings highlight the importance of modifiable sleep patterns in secondary prevention strategies for co-occurring common mental disorders among individuals with CVD. Future research should concentrate on identifying specific mechanisms that link certain clusters of sleep behaviors to depression and anxiety.

List of abbreviations

CVD	cardiovascular diseases
HRs	Hazard Ratios
CIs	Confidence Intervals
IHD	ischemic heart disease
HF	heart failure
AF	atrial fibrillation
PHQ-4	Patient Health Questionnaire-4
TDI	Townsend Deprivation Index
BMI	body mass index
CRP	C-reactive protein

CRediT authorship contribution statement

CX and ZC contributed to the conception, study design and ideas. CX had full access to all of the data in the study. ZC performed the statistical analysis and results interpretation, assisted by CX, YH, HY and XH. ZC wrote the first and successive drafts of the manuscript. All authors reviewed the manuscript and approved the final version to be published.

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Declaration of competing interest

The authors declare that they have no conflicts of interests.

Data availability

The datasets used and/or analyzed during the current study are available from UK Biobank project site, subject to successful registration and application process. Further details can be found at https://www.ukbiobank.ac.uk/.

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Appendix A. Supplementary data

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