Research Square

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Sleep quality, chronotype, and psychological distress in adults with chronic conditions: independent associations and nonlinear sleep-quality gradients

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Abstract

Background

We examined associations of sleep quality, chronotype, and chronic-condition burden with psychological distress in adults with chronic conditions and explored nonlinearity.

Methods

We analysed cross-sectional data from the Sichuan component of the 2023 Psychology and Behavior Investigation of Chinese Residents (PBICR-2023), collected from June to September 2023. Of 1,932 Sichuan respondents, 611 adults with at least one chronic condition were included. Chronotype, sleep quality, depression-anxiety symptoms, and perceived stress were assessed using the reduced Morningness-Eveningness Questionnaire (rMEQ), Brief Pittsburgh Sleep Quality Index (B-PSQI), Patient Health Questionnaire Anxiety and Depression Scale (PHQ-ADS), and four-item Perceived Stress Scale (PSS-4), respectively. Hierarchical multivariable linear regression with HC3 robust standard errors estimated adjusted associations. Unadjusted four-knot restricted cubic splines characterised nonlinear association patterns.

Results

PHQ-ADS and PSS-4 differed by age, household registration, income, education, body-mass-index category, relationship status, debt, recent life events, and chronic-condition count. They were strongly correlated ($r = 0.795$; $P < 0.001$), positively correlated with B-PSQI, and negatively correlated with rMEQ. In multivariable models, greater chronic-condition burden and higher B-PSQI scores were associated with higher scores on both outcomes. Each 1-standard-deviation increase in B-PSQI was associated with 1.51 points higher PHQ-ADS (95% confidence interval [CI], 0.69 to 2.32; $P < 0.001$) and 0.62 points higher PSS-4 (95% CI, 0.31 to 0.92; $P < 0.001$). Each 1-standard-deviation increase in rMEQ was associated with 0.95 points lower PHQ-ADS (95% CI, -1.79 to -0.11; $P = 0.027$); its PSS-4 association did not reach conventional significance (B=-0.31; 95% CI, -0.64 to 0.03; $P = 0.075$) and attenuated after broader adjustment. Splines indicated nonlinear B-PSQI associations with both outcomes (P for nonlinearity < 0.001 and $P = 0.029$), with fitted minima near 2.96 and 2.65, respectively. rMEQ nonlinearity was not statistically significant.

Conclusions

In this cross-sectional sample, Poorer sleep quality and greater chronic-condition burden were consistently associated with greater psychological distress. Morningness showed a weaker inverse

association that attenuated after broader adjustment. Longitudinal studies with objective sleep and circadian measures are needed.

1. Introduction

Noncommunicable diseases account for most deaths worldwide and increasingly require long-term management rather than episodic care. In 2021, they caused at least 43 million deaths, representing approximately 75% of non-pandemic-related mortality [1]. For people living with chronic conditions, recurrent symptoms, functional limitations, treatment demands, financial strain, and sustained lifestyle changes can accumulate into substantial psychological burden. Recent systematic evidence also indicates that depressive and anxiety disorders cluster with physical multimorbidity, although the strength and composition of these patterns vary across populations and study methods [2,3]. Psychological distress should be considered part of chronic-condition management rather than merely a secondary emotional response.

Sleep quality is a potentially modifiable correlate of psychological distress in people living with chronic conditions. Pain, nocturnal symptoms, medication use, metabolic disturbance, and illness-related worry can impair sleep, while poor sleep can compromise emotion regulation, stress recovery, and daytime functioning. Sleep is also a population-health resource rather than only a symptom of disease, and poor sleep has been linked to inflammatory and cardiometabolic processes that are relevant to chronic illness [4, 5, 6, 7, 8]. Systematic reviews have found that poor sleep quality, insomnia, and sleep duration outside recommended ranges are associated with multimorbidity across community populations [9, 10]. Persistent insomnia also predicts later depressive symptoms in longitudinal studies [11]. Complementing these observational findings, a meta-analysis of 65 randomised trials showed that interventions that improved sleep also reduced composite mental-health symptoms, depression, anxiety, rumination, and stress [12]. These findings position sleep as both a marker of vulnerability and a practical target within integrated chronic-care pathways.

Chronotype adds a distinct circadian dimension. It describes individual preferences for the timing of sleep, wakefulness, and activity, with lower rMEQ scores indicating greater eveningness. The construct is grounded in circadian biology but is expressed through behaviour and the social timetable, so it should not be treated as a fixed diagnosis [13, 14, 15]. Genetic studies confirm that chronotype reflects biological variation in circadian regulation rather than lifestyle preference alone [16]. Meta-analyses consistently associate eveningness with more depressive symptoms, although effect sizes are heterogeneous and prospective evidence remains limited [17, 18]. Longitudinal synthesis further suggests that eveningness and other sleep or circadian disturbances can precede incident depression, while Mendelian-randomisation evidence links genetically proxied earlier sleep timing with lower risk of major depressive disorder [19, 20]. Thus, chronotype may be a circadian correlate related to mental health through pathways that remain to be clarified.

Sleep quality and chronotype are nevertheless difficult to interpret in isolation. Evening-oriented individuals may be more exposed to social jetlag, accumulated sleep debt, irregular schedules, and mismatch between biological timing and social obligations. Social jetlag is a measurable discrepancy between biological and socially required timing and has been associated with adverse health behaviours and metabolic risk [21, 22]. In young adults, poor sleep quality fully mediated the observed association between eveningness and depression, anxiety, and stress, although that cross-sectional mediation result may not generalise to adults with chronic conditions [23]. Most previous work has focused on general, student, youth, or psychiatric samples, and reviews of youth evidence further underscore the concentration of chronotype research outside chronic-disease populations [24]. Moreover, many studies assume linear exposure-outcome relationships, potentially obscuring changes in slope across the sleep-quality distribution. A large Chinese cohort using restricted cubic splines found a graded association between poorer sleep quality and anxiety symptoms [25]. It is unclear whether the same associations between sleep, comorbidity burden, and distress hold for other forms of psychological distress in adults already living with chronic conditions.

We examined 611 adults with chronic conditions to determine whether sleep quality and chronotype were independently associated with depression-anxiety symptoms and perceived stress after accounting for chronic-condition burden and sociodemographic and psychosocial covariates. We further used exploratory restricted cubic splines to characterise the shape of these associations. We expected poorer sleep quality, greater eveningness, and a higher chronic-condition count to be associated with greater psychological distress, with the most stable association anticipated for sleep quality. Because the available analyses did not include joint exposure groups or formal interaction terms, the study evaluates mutually adjusted independent associations rather than a statistical joint effect.

2. Methods

2.1 Study design and participants

We conducted a cross-sectional analysis of the Sichuan component of the 2023 Psychology and Behavior Investigation of Chinese Residents (PBICR), following the sampling and field procedures reported for the parent survey [26]. The parent survey was conducted from June to September 2023. In Sichuan Province, China, 12 cities were selected using a random-number-table method, and each city contributed six rural communities and four urban communities. Trained investigators administered electronic questionnaires face to face at community survey sites. Of 1,985 questionnaires distributed, 53 were excluded because of completion times shorter than 20 min, incomplete information, or major logical inconsistencies, leaving 1,932 valid respondents in the parent sample [26]. The present analysis then selected 611 respondents with at least one chronic condition. Eligible participants were aged 18 years or older, had at least one chronic condition documented by self-report or medical records (for example, hypertension or diabetes), and provided written informed consent. Individuals were excluded if severe cognitive impairment, schizophrenia, or another condition prevented questionnaire completion, or if questionnaires contained major logical inconsistencies or excessive missingness.

2.2 Measures

2.2.1 Sleep characteristics

Subjective sleep quality was assessed using the six-item Brief Pittsburgh Sleep Quality Index (B-PSQI). The original PSQI was developed by Buysse et al. [27], and its Chinese adaptation was reported by Liu et al. [28]. The B-PSQI used in this study followed the six-item structure and scoring algorithm described by Sancho-Domingo et al. [29], comprising five scored components and a global score from 0 to 15; higher scores indicate poorer sleep quality. The abbreviated B-PSQI is not interchangeable with the full PSQI. Internal consistency in this sample was Cronbach's alpha = 0.666.

Chronotype was assessed using the five-item reduced Morningness-Eveningness Questionnaire (rMEQ). The original rMEQ was developed by Adan and Almirall [30], and the Chinese-language version used in this study was translated and revised by Zhang et al. [31]. Items 1, 3, and 4 are scored from 5 to 1, item 2 from 1 to 4, and item 5 from 6 to 0. Total scores range from 4 to 25; higher scores indicate a stronger morning preference and lower scores indicate a stronger evening preference. Cronbach's alpha was 0.676 in the present sample.

2.2.2 Psychological distress

Depression and anxiety symptoms were assessed with the Patient Health Questionnaire Anxiety and Depression Scale (PHQ-ADS), which combines the nine-item Patient Health Questionnaire and seven-item Generalized Anxiety Disorder scale. Scores range from 0 to 42, with higher values indicating greater combined depression-anxiety symptom burden [32]. Cronbach's alpha was 0.960 in this sample.

Perceived stress was assessed using the four-item Perceived Stress Scale (PSS-4), originally developed by Cohen et al. [33]. The Chinese-language version used in this study was based on the Chinese health-education measurement materials described by Yang and Zheng [34]. The four items are rated on a five-point Likert scale from 0 (never) to 4 (very often), yielding a total score from 0 to 16; higher scores indicate greater perceived stress. Cronbach's alpha was 0.909 in the present sample.

2.2.3 Covariates

Covariates included sex, age (18–50 or > 50 years), ethnicity (Han or ethnic minority), household registration (agricultural or non-agricultural), education, personal monthly income, residence during the previous three months (urban or rural), body mass index (BMI), chronic-condition count (1, 2, or ≥ 3), relationship status (single, partnered, or divorced/widowed), debt, an injury event during the previous year, and a major life event during the previous year. Education was grouped as junior secondary or below, technical secondary/high school, or college or above. Personal monthly income was recorded in Chinese yuan (CNY) and grouped as < 3,000, 3,000–5,000, or > 5,000 CNY. BMI was classified according to Chinese adult criteria as underweight (< 18.5 kg/m^2), normal weight (18.5–23.9 kg/m^2), overweight (24.0-27.9 kg/m^2), or obesity (≥ 28.0 kg/m^2); underweight and normal weight were combined, as were

overweight and obesity, for analysis. Injury and major-life-event variables were binary self-reported indicators of whether any such event had occurred during the previous year.

2.3 Statistical analysis

Two researchers independently checked returned questionnaires for duplicate responses, excessive missingness, patterned responses, and logical inconsistencies. Potential outliers were compared with the source questionnaires and field records before analysis. The analytic dataset contained complete values for all variables used in the reported models, so no imputation was performed. Continuous variables are summarised as means and standard deviations, and categorical variables as counts and percentages. Between-group differences in PHQ-ADS and PSS-4 were assessed using independent-samples *t* tests or one-way analysis of variance, as appropriate. Because the core continuous variables did not satisfy normality assumptions, Spearman rank correlations were used for bivariate associations. Univariate comparisons were treated as descriptive; primary inference was based on the prespecified mutually adjusted regression models. Separate hierarchical multivariable linear regression models were fitted for PHQ-ADS and PSS-4 using HC3 heteroscedasticity-robust standard errors. B-PSQI and rMEQ were standardised before regression. Model M0 simultaneously included chronic-condition count, B-PSQI, and rMEQ. M1 additionally adjusted for age, sex, and ethnicity. M2, designated the primary adjusted model, further adjusted for body mass index, education, income, relationship status, household registration, and recent residence. M3 additionally adjusted for debt, injury during the previous year, and major life events during the previous year and was treated as an extended-adjustment sensitivity model. We report unstandardised coefficients (B), 95% confidence intervals (CIs), standardised coefficients (β), *P* values, and adjusted R-squared values. Analyses were conducted in R version 4.6.0; the rms package was used for restricted cubic spline modelling, and sandwich and lmtest were used for HC3-robust inference where applicable. Exploratory restricted cubic spline models with four knots were fitted separately for each exposure-outcome pair using unstandardised rMEQ and B-PSQI scores. These spline models did not include covariates and were treated as descriptive shape analyses rather than adjusted association estimates. Overall and nonlinear Wald tests were reported. The displayed turning point was the internal stationary point of the fitted curve searched within the 5th to 95th percentile of the exposure distribution; when none was detected, the point of greatest absolute curvature was shown descriptively. These points were not prespecified clinical cut-offs and were not externally validated. All tests were two-sided with $\alpha = 0.05$. The manuscript was prepared with reference to the STROBE recommendations [35].

2.4 Use of generative AI tools

During the preparation of this work, the authors used generative AI to assist with spell-checking, grammar checking, and to improve clarity of expression. All authors have reviewed the final text and take full responsibility for the accuracy and integrity of the manuscript.

3. Results

3.1 Participant characteristics

The analysis included 611 participants, of whom 320 (52.4%) were women and 417 (68.2%) were older than 50 years. Most participants had one chronic condition (60.1%), 26.8% had two, and 13.1% had three or more. PHQ-ADS scores differed by sex, household registration, age, income, education, body mass index, relationship status, debt, injury events, major life events, and chronic-condition count. PSS-4 scores differed across the same characteristics except sex, and additionally differed by recent residence. Ethnicity was not associated with either outcome in univariate analyses (Table 1).

Table 1
Participant characteristics and univariate comparisons of PHQ-ADS and PSS-4 scores

Characteristic	***n***	**%**	**PHQ-ADS, mean ± SD**	***t/F***	***P***	**PSS-4, mean ± SD**	***t/F***	***P***
Sex								
Male	291	47.6	10.81 ± 9.554	-2.103*	0.036	4.24 ± 3.431	-1.289	0.198
Female	320	52.4	12.42 ± 9.331	-2.103*	0.036	4.6 ± 3.456	-1.289	0.198
Ethnicity								
Ethnic minority	39	6.4	11.23 ± 8.308	-0.288	0.774	4.56 ± 3.432	0.259	0.795
Han	572	93.6	11.68 ± 9.544	-0.288	0.774	4.42 ± 3.450	0.259	0.795
Household registration								
Agricultural	404	66.1	12.50 ± 9.553	3.131**	0.002	4.68 ± 3.395	2.543*	0.011
Non-agricultural	207	33.9	9.99 ± 9.084	3.131**	0.002	3.93 ± 3.501	2.543*	0.011
Age, years								
18–50	194	31.8	14.45 ± 9.976	5.090***	< 0.001	5.28 ± 3.678	4.073***	< 0.001
> 50	417	68.2	10.35 ± 8.934	5.090***	< 0.001	4.03 ± 3.261	4.073***	< 0.001
Monthly income, CNY								
< 3000	321	52.5	11.85 ± 9.305	5.705**	0.004	4.55 ± 3.304	3.112*	0.045

Note. Values are mean ± SD unless otherwise indicated. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$. CNY, Chinese yuan; PHQ-ADS, Patient Health Questionnaire Anxiety and Depression Scale; PSS-4, four-item Perceived Stress Scale.

Characteristic	*n*	%	PHQ-ADS, mean ± SD	*t/F*	*P*	PSS-4, mean ± SD	*t/F*	*P*
3000–5000	157	25.7	9.75 ± 8.725	5.705**	0.004	3.86 ± 3.239	3.112*	0.045
> 5000	133	21.8	13.44 ± 10.317	5.705**	0.004	4.80 ± 3.933	3.112*	0.045
Education								
Junior secondary or below	370	60.6	10.08 ± 8.420	12.736***	< 0.001	4.14 ± 3.180	3.698*	0.026
Technical secondary/high school	114	18.7	13.53 ± 10.636	12.736***	< 0.001	4.51 ± 3.563	3.698*	0.026
College or above	127	20.8	14.56 ± 10.276	12.736***	< 0.001	5.18 ± 3.961	3.698*	0.026
Body mass index								
Underweight/normal weight	467	76.4	12.26 ± 9.507	2.857**	0.004	4.66 ± 3.454	3.014**	0.003
Overweight/obesity	144	23.6	9.69 ± 9.083	2.857**	0.004	3.67 ± 3.324	3.014**	0.003
Relationship status								
Single	44	7.2	16.23 ± 11.387	5.627**	0.004	6.00 ± 4.595	5.044**	0.007
Partnered	479	78.4	11.28 ± 9.222	5.627**	0.004	4.29 ± 3.266	5.044**	0.007
Divorced/widowed	88	14.4	11.39 ± 9.233	5.627**	0.004	4.39 ± 3.589	5.044**	0.007
Residence in previous 3 months								

Note. Values are mean ± SD unless otherwise indicated. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$. CNY, Chinese yuan; PHQ-ADS, Patient Health Questionnaire Anxiety and Depression Scale; PSS-4, four-item Perceived Stress Scale.

Characteristic	*n*	%	PHQ-ADS, mean ± SD	*t/F*	*P*	PSS-4, mean ± SD	*t/F*	*P*
Urban	329	53.8	11.30 ± 9.639	-0.985	0.325	4.16 ± 3.518	-2.054*	0.040
Rural	282	46.2	12.06 ± 9.256	-0.985	0.325	4.73 ± 3.340	-2.054*	0.040
Debt								
Yes	169	27.7	14.83 ± 10.289	5.238***	< 0.001	5.46 ± 3.803	4.313***	< 0.001
No	442	72.3	10.44 ± 8.844	5.238***	< 0.001	4.03 ± 3.218	4.313***	< 0.001
Injury event in previous year								
Yes	211	34.5	13.46 ± 9.302	3.458***	< 0.001	4.83 ± 3.389	2.110*	0.035
No	400	65.5	10.70 ± 9.421	3.458***	< 0.001	4.21 ± 3.462	2.110*	0.035
Major life event in previous year								
Yes	278	45.5	14.44 ± 9.694	6.897***	< 0.001	5.28 ± 3.454	5.774***	< 0.001
No	333	54.5	9.33 ± 8.617	6.897***	< 0.001	3.71 ± 3.277	5.774***	< 0.001
Number of chronic conditions								
1	367	60.1	10.50 ± 9.059	9.411***	< 0.001	4.08 ± 3.391	6.950***	< 0.001

Note. Values are mean ± SD unless otherwise indicated. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$. CNY, Chinese yuan; PHQ-ADS, Patient Health Questionnaire Anxiety and Depression Scale; PSS-4, four-item Perceived Stress Scale.

Characteristic	*n*	%	PHQ-ADS, mean ± SD	*t/F*	*P*	PSS-4, mean ± SD	*t/F*	*P*
2	164	26.8	12.25 ± 9.412	9.411***	< 0.001	4.59 ± 3.350	6.950***	< 0.001
≥ 3	80	13.1	15.70 ± 10.258	9.411***	< 0.001	5.69 ± 3.613	6.950***	< 0.001

Note. Values are mean ± SD unless otherwise indicated. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$. CNY, Chinese yuan; PHQ-ADS, Patient Health Questionnaire Anxiety and Depression Scale; PSS-4, four-item Perceived Stress Scale.

3.2 Distribution and correlation of core variables

PHQ-ADS and PSS-4 were strongly correlated ($r = 0.795$, $P < 0.001$). Both psychological outcomes were inversely correlated with rMEQ and positively correlated with B-PSQI (all $P < 0.001$). rMEQ and B-PSQI were also inversely correlated (r=-0.164, $P < 0.001$), indicating that greater morningness was associated with better self-reported sleep quality (Fig. 1).

3.3 Multivariable associations with PHQ-ADS

All four PHQ-ADS models included 611 participants. In the primary M2 model, participants with two chronic conditions had PHQ-ADS scores 2.69 points higher than those with one condition (95% CI, 1.05 to 4.32; $\beta = 0.126$; $P = 0.001$), and those with three or more conditions scored 5.70 points higher (95% CI, 3.32 to 8.08; $\beta = 0.203$; $P < 0.001$). Each 1-standard-deviation increase in B-PSQI was associated with a 1.51-point higher PHQ-ADS score (95% CI, 0.69 to 2.32; $\beta = 0.159$; $P < 0.001$). Each 1-standard-deviation increase in rMEQ was associated with a 0.95-point lower score (95% CI, -1.79 to -0.11; β=-0.100; P = 0.027). In M3, associations for chronic-condition count and B-PSQI remained similar, whereas the rMEQ confidence interval included zero (B=-0.71; 95% CI, -1.55 to 0.14; $P = 0.100$). Adjusted R-squared increased from 0.090 in M0 to 0.196 in M3 (Fig. 2).

3.4 Multivariable associations with PSS-4

In the primary M2 model, participants with two chronic conditions had PSS-4 scores 0.79 points higher than those with one condition (95% CI, 0.18 to 1.41; $\beta = 0.102$; $P = 0.012$), and those with three or more conditions scored 1.81 points higher (95% CI, 0.95 to 2.66; $\beta = 0.177$; $P < 0.001$). Each 1-standard-deviation increase in B-PSQI was associated with a 0.62-point higher PSS-4 score (95% CI, 0.31 to 0.92; $\beta = 0.179$; $P < 0.001$). The inverse association for rMEQ did not meet the conventional significance threshold (B=-0.31; 95% CI, -0.64 to 0.03; β=-0.089; $P = 0.075$). In M3, the associations for chronic-condition count and B-PSQI remained, while rMEQ remained imprecise (B=-0.23; 95% CI, -0.57 to 0.11; P = 0.193). Adjusted R-squared increased from 0.077 in M0 to 0.138 in M3 (Fig. 3).

3.5 Exploratory nonlinear associations

In unadjusted restricted cubic spline models, both rMEQ and B-PSQI were associated overall with PHQ-ADS and PSS-4 (all *P*overall < 0.001). For rMEQ, the tests for nonlinearity were not statistically significant for PHQ-ADS or PSS-4 (*P*nonlinear = 0.087 and 0.481, respectively). The fitted PHQ-ADS curve reached a stationary point near an rMEQ score of 12.37 and decreased at higher rMEQ scores, whereas the fitted PSS-4 curve showed maximum curvature near an rMEQ score of 19.01, with no internal stationary point detected. For B-PSQI, the tests for nonlinearity were statistically significant for both PHQ-ADS (*P*nonlinear < 0.001) and PSS-4 (*P*nonlinear = 0.029). The lowest fitted PHQ-ADS and PSS-4 values occurred near B-PSQI scores of 2.96 and 2.65, respectively, followed by progressively higher fitted values as B-PSQI scores increased. Confidence intervals widened at the extremes of the B-PSQI distribution, particularly at very low scores (Fig. 4).

4. Discussion

The central finding of this cross-sectional study of 611 adults with chronic conditions was a consistent association between poorer sleep quality and two related but distinct psychological outcomes. Higher B-PSQI scores remained associated with greater depression-anxiety symptoms and perceived stress across all levels of adjustment, whereas greater morningness showed a weaker inverse association with PHQ-ADS that attenuated after broader adjustment and was not independently associated with PSS-4. Chronic-condition burden showed a graded association with both outcomes. Exploratory spline analyses indicated nonlinear B-PSQI gradients for both outcomes, whereas there was no statistically significant evidence of nonlinearity in the rMEQ associations. These findings identify sleep quality as a more consistent correlate of psychological distress than chronotype in this sample.

The sleep-quality findings accord with evidence that sleep problems are embedded in the burden of multimorbidity. Across community studies, poorer sleep quality and sleep duration outside recommended ranges are consistently associated with multimorbidity, although definitions and effect estimates vary [9]. A separate meta-analysis found higher odds of multimorbidity among people reporting short sleep, long sleep, or insomnia [10]. The present study extends this literature by showing that sleep quality remained associated with two related but distinct dimensions of psychological distress after simultaneous adjustment for chronotype, chronic-condition count, and a broad set of covariates. Prior literature has proposed pathways involving emotional memory, stress regulation, and inflammatory signalling; these pathways were not measured in the present study [6, 7, 36]. Evidence from randomised trials and clinical guidance provides a rationale for evaluating sleep-focused interventions and their effects on depression, anxiety, and stress in chronic-care settings [12, 37, 38].

Chronic-condition burden showed a clear graded association with both outcomes. Multimorbidity is common in primary care and becomes more prevalent with age, yet its clinical and social consequences are not captured by disease counts alone [39–41]. Systematic review evidence identifies depression and anxiety as recurrent components of multimorbidity patterns, while also noting substantial heterogeneity

and limitations in the underlying literature [2]. Sleep and chronic-condition burden may be linked through reciprocal pathways involving symptoms, pain, medication effects, illness-related worry, emotional regulation, and coping capacity. A longitudinal study of 9,823 middle-aged and older Chinese adults found bidirectional associations between poor sleep and multimorbidity, consistent with reciprocal relationships rather than a single temporal direction [42]. The present findings are compatible with such relationships, although the simultaneous assessment of sleep, chronic conditions, and psychological outcomes does not establish their temporal sequence.

Chronotype requires more restrained interpretation. The inverse crude correlations and the primary-model association with PHQ-ADS are directionally consistent with meta-analyses linking eveningness to depression [17, 18]. Prospective synthesis suggests that eveningness and other circadian disturbances can precede depression, and genetic evidence links earlier sleep timing with lower depression risk [19, 20]. Nevertheless, the inverse association between rMEQ and PHQ-ADS attenuated in M3, whereas rMEQ was not independently associated with PSS-4 at the conventional significance threshold. One possible explanation is that the observed association between chronotype and psychological distress may partly reflect sleep quality, social timing, or psychosocial context. This interpretation is consistent with evidence that poor sleep quality mediated the association between chronotype and mental health in young adults [23]. A second possibility is limited precision or residual confounding. Because most chronotype evidence comes from younger or general populations, its applicability to heterogeneous adults with chronic conditions remains uncertain [24].

In the present unadjusted spline analyses, fitted PHQ-ADS and PSS-4 values were lowest near B-PSQI scores of 2.96 and 2.65, respectively, and increased at scores above these points. A large rural Chinese cohort likewise reported a dose-response association between PSQI scores and anxiety using restricted cubic splines [25]. However, the fitted minima were identified from the fitted curves rather than prespecified and may have been influenced by sample composition, sparse observations at the distributional extremes, or unmeasured confounding. These values are also specific to the B-PSQI scale and are not directly transferable to the full PSQI. Thus, the spline results indicate nonlinear associations and increasing fitted psychological-distress scores above the B-PSQI minima but do not establish diagnostic or intervention thresholds.

These findings suggest that sleep and circadian assessment may warrant consideration during chronic-condition follow-up. Brief sleep-quality assessment may provide additional information when evaluating depression, anxiety, perceived stress, pain, nocturnal symptoms, medication effects, and social constraints in adults with chronic conditions. Clinical insomnia guidelines support behavioural and cognitive interventions rather than reliance on generic sleep-hygiene advice alone [38]. The weaker chronotype findings do not support using chronotype alone to guide recommendations about sleep timing. Clinical assessment could also consider whether biological timing conflicts with treatment, work, caregiving, or family demands and whether such conflicts coincide with sleep restriction or irregularity. Interventional studies should test whether improving sleep quality reduces psychological distress in

populations with chronic conditions and whether the effects differ by chronotype or multimorbidity burden [37].

Several limitations constrain the interpretation of these findings. First, the cross-sectional design precludes determination of temporality, and reverse causation remains possible. Second, sleep quality, chronotype, chronic conditions, and psychological outcomes were largely assessed using self-reported measures, which may be affected by recall bias and common-method variance. Third, residual and unmeasured confounding cannot be excluded; therefore, the observed associations should not be interpreted as causal effects. Fourth, the sample was drawn from a single Chinese province, which may limit generalisability to populations with different demographic, clinical, or healthcare characteristics.

5. Conclusions

Among 611 adults with chronic conditions in the Sichuan PBICR survey, poorer sleep quality and greater chronic-condition burden were associated with higher levels of depression-anxiety symptoms and perceived stress. Greater morningness was associated with fewer depression-anxiety symptoms, although this association weakened after broader psychosocial adjustment and was not observed for perceived stress. Restricted cubic spline analyses showed nonlinear associations between sleep quality and both psychological outcomes. Longitudinal and intervention studies using objective sleep and circadian measures are needed to clarify temporal relationships and assess the reproducibility of these findings.

Abbreviations

B-PSQI
Brief Pittsburgh Sleep Quality Index
CI
confidence interval
CNY
Chinese yuan
GAD-7
seven-item Generalized Anxiety Disorder scale
HC3
heteroscedasticity-consistent covariance estimator type 3
PBICR-2023
Psychology and Behavior Investigation of Chinese Residents 2023
PHQ-9
nine-item Patient Health Questionnaire
PHQ-ADS
Patient Health Questionnaire Anxiety and Depression Scale
PSS-4

four-item Perceived Stress Scale
rMEQ
reduced Morningness-Eveningness Questionnaire
SD
standard deviation.

Declarations

Ethics approval and consent to participate

The parent PBICR-2023 protocol was approved by the Biomedical Research Ethics Committee of Shandong Provincial Hospital involving People (SWYX: No. 2023-198; 5 May 2023). The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and its subsequent amendments. It was filed in the National Health Security Information Platform (Record No. MR-37-23-017876) and prospectively registered in the Chinese Clinical Trial Registry (ChiCTR2300072573; 16 June 2023) as a cross-sectional observational study with no intervention. The present analysis used data from the Sichuan component of PBICR-2023. All participants provided written informed consent before participation.

Consent for publication

Not applicable. No individual-level identifiable information or identifiable images are reported.

Availability of data and materials

The participant-level PBICR-2023 data are third-party data and are not publicly available. The authors are not authorised to deposit or independently distribute the raw or processed participant-level data. Requests for access should be directed to the PBICR project team and are subject to its data-governance review and prevailing access procedures. Project information is available at https://www.x-mol.com/groups/pbicr/research; this webpage is not a data repository or download link. Because access decisions rest with the PBICR project team, the authors cannot guarantee third-party access but will cooperate with any verification process approved and arranged by PBICR.

Competing interests

The authors declare no competing interests.

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Authors' contributions

YL: Conceptualization, Methodology, Data curation, Formal analysis, Visualization, and Writing - original draft. YWL: Investigation, primary responsibility for the participant-level dataset and data collection, Validation, Writing - original draft, and Writing - review and editing. XSY:Investigation, Data curation, Formal analysis. XK: Supervision, Project administration, Methodology, Quality control, and Writing - review and editing. YL and YWL contributed equally and share first authorship. XK is the corresponding author. All authors approved the final manuscript.

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Figures

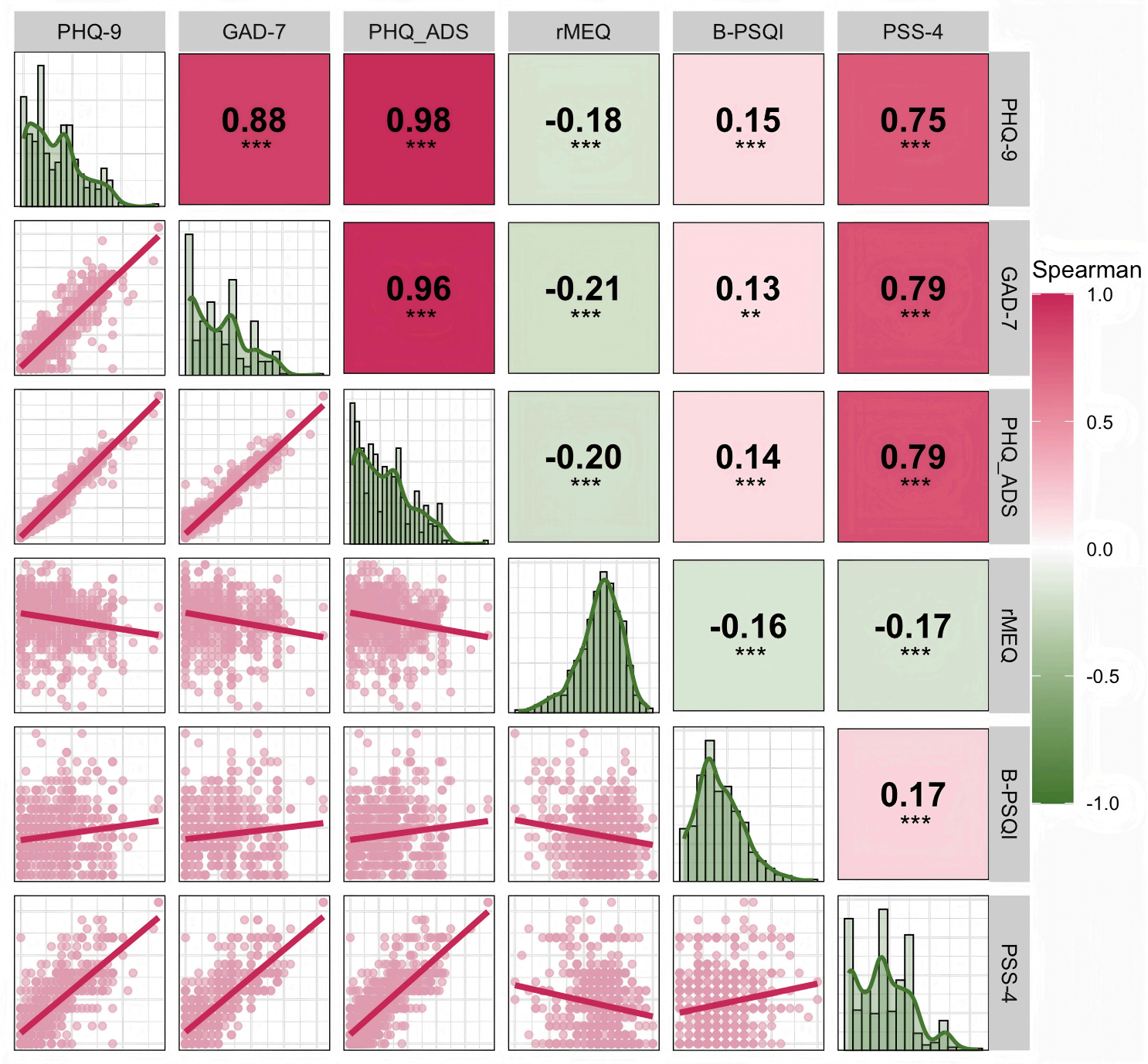


Figure 1

Spearman correlation matrix for sleep, chronotype, and psychological-distress measures.

***P* < 0.01; ****P*< 0.001. B-PSQI, Brief Pittsburgh Sleep Quality Index; GAD-7, seven-item Generalized Anxiety Disorder scale; PHQ-9, nine-item Patient Health Questionnaire; PHQ-ADS, Patient Health Questionnaire Anxiety and Depression Scale; PSS-4, four-item Perceived Stress Scale; rMEQ, reduced Morningness-Eveningness Questionnaire.

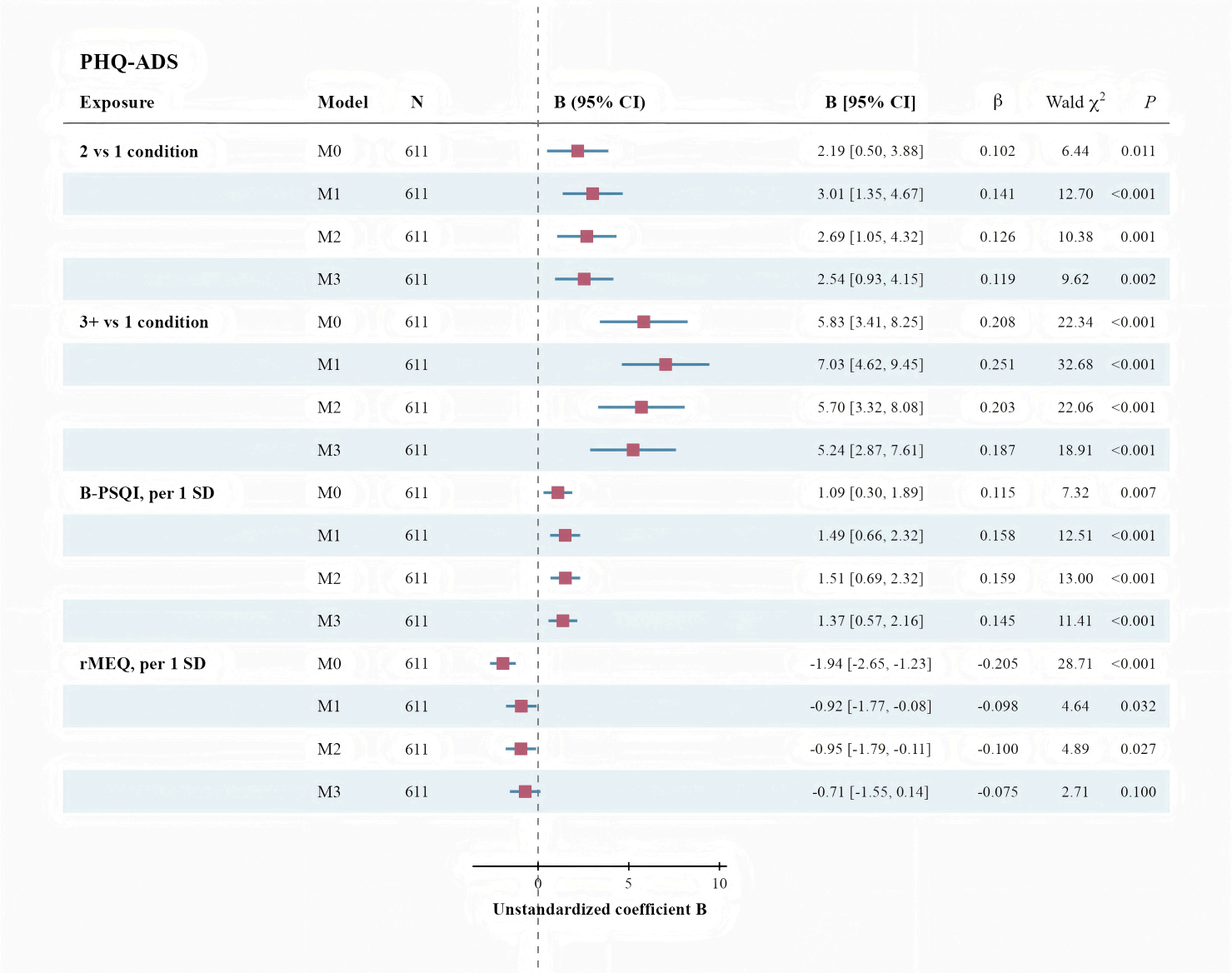


Figure 2

Hierarchical multivariable linear regression estimates for PHQ-ADS.

Squares and horizontal lines show unstandardised coefficients and HC3-robust 95% confidence intervals. B-PSQI and rMEQ are scaled per 1 standard deviation. M0 includes chronic-condition count, B-PSQI, and rMEQ; M1 additionally adjusts for age, sex, and ethnicity; M2 further adjusts for body mass index, education, income, relationship status, household registration, and recent residence; M3 additionally adjusts for debt, injury events, and major life events.

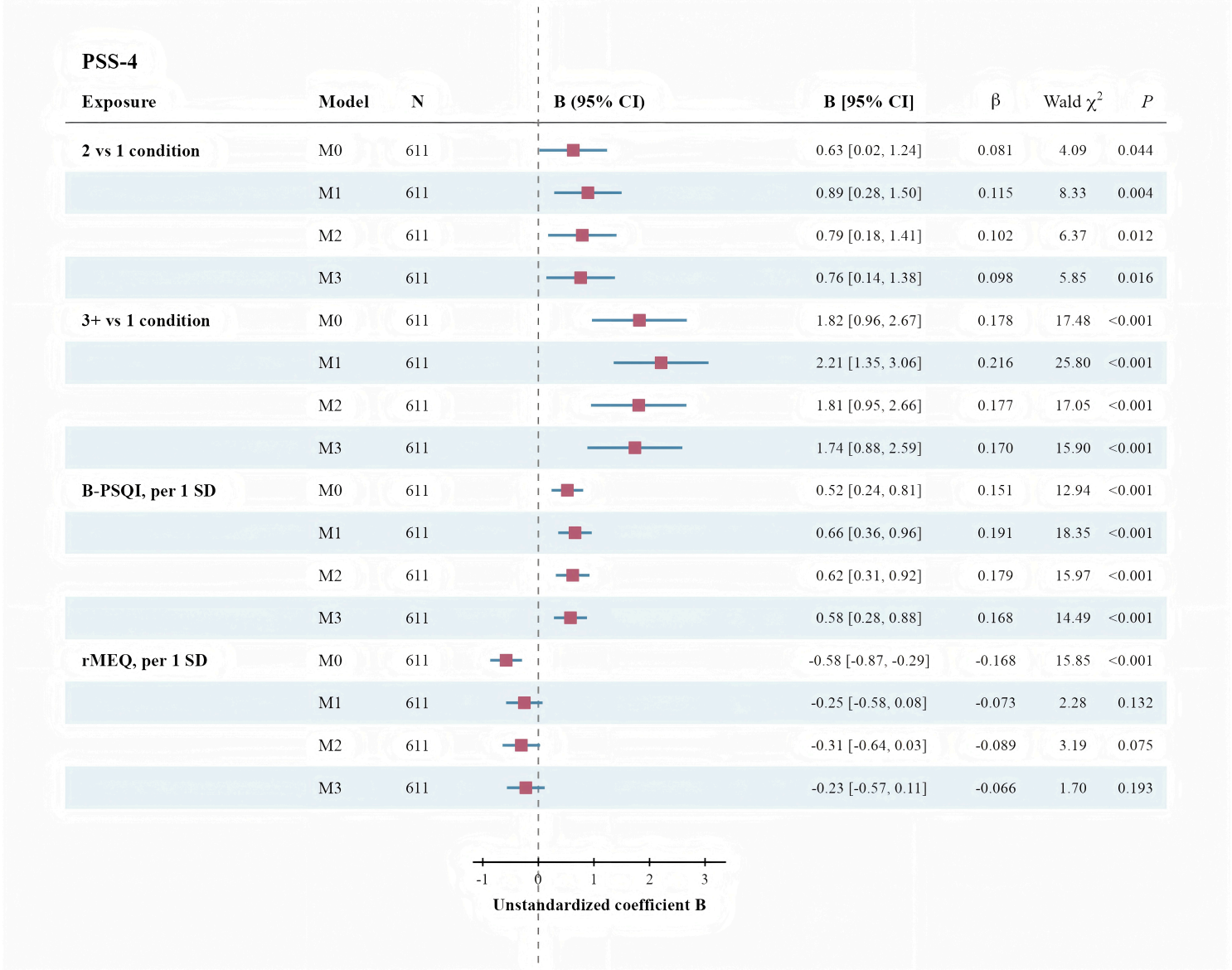


Figure 3

Hierarchical multivariable linear regression estimates for PSS-4.

Model definitions and statistical displays are the same as in Figure 2.

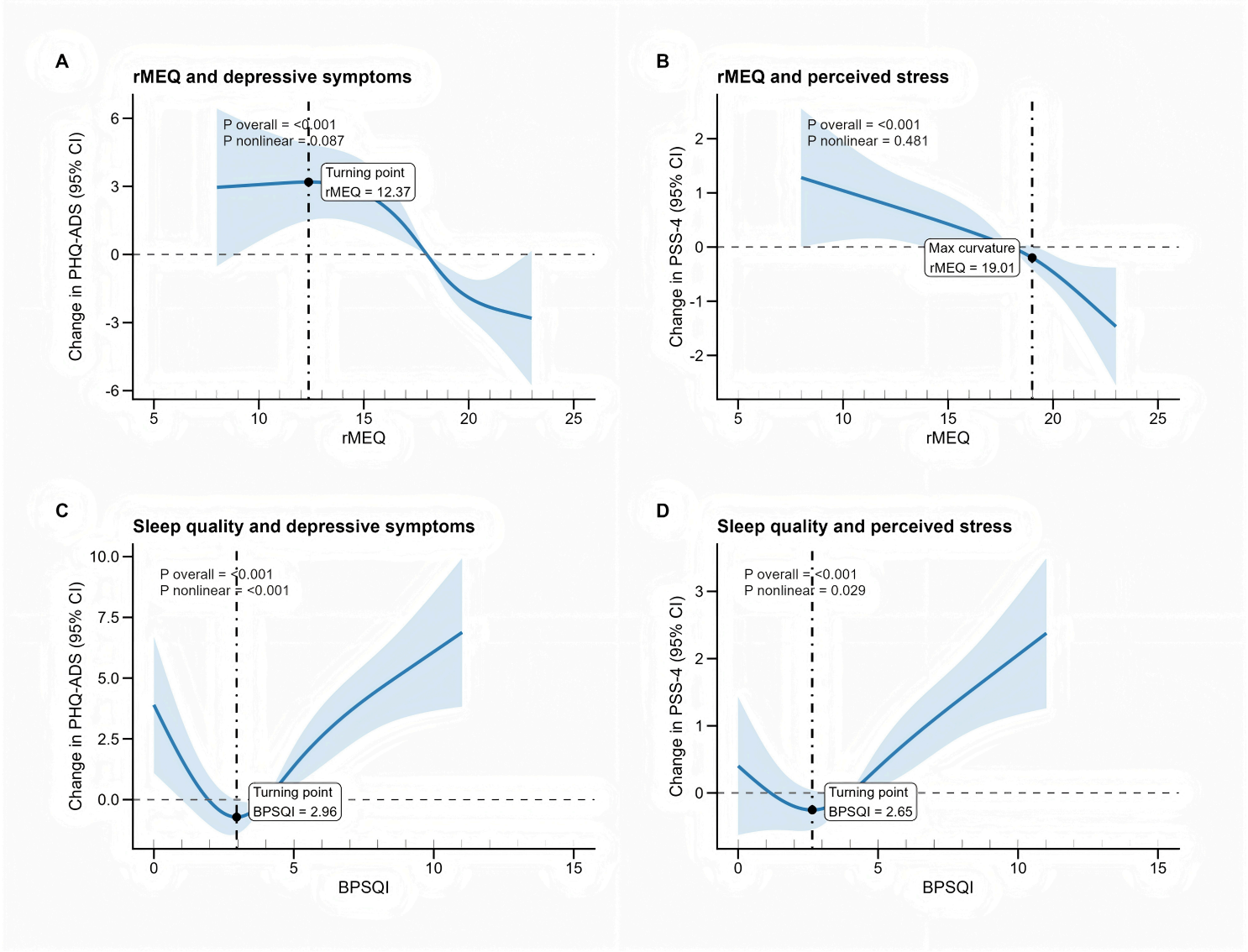


Figure 4

Restricted cubic spline associations of rMEQ and B-PSQI with PHQ-ADS and PSS-4.

Models were exploratory and unadjusted. Curves show fitted changes with 95% confidence intervals. Dotted vertical lines identify a stationary point or, if none was present, the point of greatest absolute curvature within the 5th to 95th percentile of the exposure distribution. These points are descriptive and should not be interpreted as validated diagnostic or intervention thresholds.