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Psychosocial, Sleep-Related, and Behavioral Correlates of Adult Psychological Burden: Evidence from a Cross-Sectional Survey and the China Health and Nutrition Survey

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Abstract

Background

Adult psychological burden is often linked to social support, sleep problems, and addictive behaviors, but these factors are usually examined separately. It remains unclear whether sleep problems account for symptom burden beyond addictive behaviors, and whether repeated sleep-related hours are associated with later perceived stress.

Methods

Study 1 included 1,223 adults from a cross-sectional online survey. Parallel bootstrap mediation models with 5,000 resamples examined whether subjective sleep problems, alcohol-related problems, nicotine dependence, and internet gaming symptoms accounted for the association between perceived social support and somatic-psychological symptom burden after removing the sleep item. Study 2 used longitudinal China Health and Nutrition Survey data from up to 8,557 adults. HC3-robust regression models tested whether latest, mean, and slope-based sleep-related hours from 2004 to 2011 were associated with perceived stress in 2015. Additional analyses examined nonlinearity, sleep-hour categories, measurement heterogeneity, and age-stratified patterns.

Results

In Study 1, greater perceived social support was associated with lower symptom burden (total effect = -0.1504, 95% CI: -0.1972 to -0.1061). The largest indirect association was through subjective sleep problems (indirect effect = -0.0761, 95% CI: -0.1021 to -0.0532), while internet gaming symptoms and alcohol-related problems showed smaller indirect associations. Nicotine dependence did not show a stable pathway. In Study 2, longer latest pre-2015 sleep-related hours were associated with higher perceived stress in the fully adjusted model (*B* = 0.193, 95% CI: 0.080 to 0.306). A more positive sleep-related hours slope showed a similar association (*B* = 0.853, 95% CI: 0.045 to 1.662). Quadratic models did not indicate a U-shaped pattern; higher stress was mainly observed among participants reporting ≥ 9 h.

Conclusions

Sleep-related indicators were associated with adult psychological burden across both data sources. Subjective sleep problems were the main pathway linking lower perceived social support to greater symptom burden, while longer and increasing sleep-related hours were associated with later perceived stress. These findings support sleep-related profiling, but require cautious interpretation because sleep

was self-reported, wording varied across CHNS waves, and the observational design does not support causal inference.

Trial registration

Not applicable.

Introduction

Adult psychological burden—encompassing perceived stress, chronic somatic complaints, anxiety, and depressive symptoms—presents an escalating and pervasive challenge to global public mental health systems [1, 2]. These clinical manifestations rarely manifest in isolation; rather, they frequently exhibit high rates of syndemic co-occurrence, suggesting the existence of shared behavioral, psychosocial, and physiological vulnerabilities within the general population [3]. To mitigate the societal and economic erosion catalyzed by widespread emotional distress, contemporary epidemiological research must transition from cataloging localized risk elements toward systemic frameworks that map how macro-level social contexts intersect with daily behavioral regulation strategies to govern subsequent somatic and affective resilience [4].

Perceived social support stands as a primary protective psychosocial resource, long conceptualized under the "stress-buffering hypothesis" as a vital socio-emotional reserve that de-escalates cognitive hyperarousal and facilitates adaptive coping repertoires [5]. A rich body of literature has established an inverse relationship between robust social integration and psychological distress [1]. Diminished social resources frequently co-occur with sleep disturbances and accelerated behavioral dysregulation, such as problematic substance use (alcohol and nicotine) or addictive digital engagements (internet gaming symptoms) [6, 7]. However, historical research has predominantly examined these behavioral pathways in conceptual isolation. By failing to integrate sleep anomalies and diverse addictive behaviors into a mutually adjusted, parallel statistical architecture, prior public health models have been unable to separate secondary behavioral coping artifacts from the core transdiagnostic mechanisms that translate interpersonal isolation into somatic-psychological suffering [3].

Furthermore, exploring these complex socio-behavioral total dependencies requires a strategic bridging of research designs to overcome inherent methodological barriers. Cross-sectional mediation architectures offer exceptional granularity and breadth to evaluate multi-channel behavior concurrent with psychological distress; yet, as extensive econometric and methodological literature cautions, concurrent mediation models are fundamentally incapable of establishing temporal precedence or separating true longitudinal parameter changes from concurrent measurement bias [8, 9]. To validate the public health utility of identified concurrent pathways, they must be structurally triangulated with long-term, population-based prospective cohorts [10, 11]. Within longitudinal sleep epidemiology, most public health research has emphasized short sleep duration, insomnia symptoms, or poor sleep quality as risk markers for psychological distress. Less attention has been given to the prospective meaning of longer

reported sleep-related hours, especially when sleep is assessed repeatedly across multiple survey waves. In population-based cohorts, self-reported sleep hours or sleep-related hours may capture not only sleep duration, but also extended sleep opportunity, fatigue-related withdrawal, illness burden, or behavioral disengagement. Therefore, longer or increasing sleep-related hours may function as a behavioral marker of psychological vulnerability rather than as a straightforward indicator of restorative sleep.

The China Health and Nutrition Survey (CHNS) provides an opportunity to examine this question using repeated pre-2015 sleep-related assessments and a perceived stress outcome measured in 2015. However, the CHNS U324 sleep item varied in wording across survey waves, with earlier waves assessing time spent in bed or lying down and later waves assessing usual sleep hours. This measurement feature requires careful interpretation of longitudinal sleep indicators as broad sleep-related hours measures rather than as harmonized objective sleep-duration estimates. Accordingly, analyses of latest values, long-term means, and multi-wave slopes should be paired with sensitivity analyses addressing measurement heterogeneity.

To address these conceptual and methodological gaps, the present study deployed a dual-lineage complementary design, integrating an original cross-sectional psychometric survey with longitudinal CHNS data. Study 1 used a parallel mediation framework to evaluate subjective sleep problems against alcohol-related problems, nicotine dependence, and internet gaming symptoms as competing statistical pathways linking perceived social support to somatic-psychological symptom burden. Study 2 extended the sleep-related component prospectively by examining whether pre-2015 sleep-related hours indicators, including latest values, long-term means, and higher-density multi-wave slopes, predicted perceived stress scores in 2015. Nonlinear, categorical, and measurement-heterogeneity sensitivity analyses were conducted to clarify whether the prospective association was linear, concentrated in longer reported sleep-related hours categories, and robust to wave-specific wording differences. Age-stratified analyses were treated as exploratory.

We advanced two primary hypotheses matching this dual-cohort infrastructure:

Hypothesis 1

In Study 1, subjective sleep problems will emerge as the structurally predominant and transdiagnostically stable indirect pathway linking lower perceived social support to higher aggregate and disaggregated somatic-psychological symptom burden, consistently outperforming concurrent addictive behavioral routes.

Hypothesis 2

In Study 2, higher latest pre-2015 sleep-related hours and more positive multi-wave sleep-related hours slopes will prospectively predict higher perceived stress scores in 2015, independent of demographic characteristics, anthropometric indicators, lifestyle risk profiles, and pre-2015 chronic somatic

conditions. The association is expected to be predominantly linear and concentrated in longer reported sleep-related hours categories rather than following a conventional U-shaped pattern. Age-stratified analyses will be conducted as exploratory analyses to describe potential subgroup patterns.

Methods

Study Design

This study used a dual-lineage complementary design to examine the interface between psychosocial resources, sleep-related profiles, behavioral indicators, and adult psychological burden. Study 1 comprised a cross-sectional electronic questionnaire survey designed to evaluate mutually adjusted concurrent indirect associations linking perceived social support to somatic-psychological symptom burden through parallel sleep and addictive-behavior indicators. Study 2 extended the sleep-related component prospectively by analyzing longitudinal secondary data from the China Health and Nutrition Survey (CHNS), using repeated pre-2015 sleep-related hours indicators to predict continuous perceived stress scores in 2015. Because the CHNS sleep item differed in wording across survey waves, Study 2 interpreted longitudinal sleep exposures as broad sleep-related hours indicators and included sensitivity analyses addressing measurement heterogeneity.

Study 1: Cross-Sectional Survey

Participants

Study 1 used data from a cross-sectional electronic questionnaire survey administered through Wen Juan Xing, a commercial online survey platform in China. Participants were recruited from the platform's registered panel members from the general public. The delivered dataset included respondents from 29 provincial-level administrative regions across mainland China, with no respondents recorded from Qinghai or Tibet. Because recruitment relied on a non-probability online panel, the sample should not be interpreted as nationally representative. The platform did not provide the research team with the number of panel members invited to participate or the number who viewed the questionnaire; therefore, a conventional response rate could not be calculated. No sampling weights or post-stratification adjustments were applied.

Before data delivery, the platform excluded 290 submissions that did not meet its predefined quality-control criteria, leaving 1,273 anonymized responses available to the research team. The present analysis was restricted to participants aged 18 years or older with a non-missing age value. Fifty records were excluded because age information was missing (n = 25) or indicated an age below 18 years (n = 25), resulting in a final analytic sample of 1,223 adults.

Procedure

The present study analyzed a subset of measures from a broader questionnaire administered through the online survey platform. The study protocol was reviewed and approved by the Ethics Committee of Wenjiang District People's Hospital of Chengdu (Reference No. EC-2020-002). Information regarding the study objectives, voluntary participation, confidentiality, and data-use policies was presented on the introductory page of the electronic questionnaire. Electronic informed consent was obtained from all participants before survey initiation.

According to the platform's standard quality-control procedures, only responses meeting predefined validity criteria were retained. These procedures included mobile-phone verification at registration, restrictions on repeated participation with one submission permitted per participant per project, embedded attention-check items with automatic exclusion of failed cases, IP- and device-based submission limits, and manual spot checks. The research team did not have access to item-level attention-check results and could not independently reproduce the platform-level exclusions.

Measures

Perceived Social Support: Interpersonal psychosocial resources were quantified using the 12-item Multidimensional Scale of Perceived Social Support (MSPSS) [12]. The tool evaluates subjective support derived from three primary targets: family, friends, and significant others [12]. The continuous SS_TOTAL score was utilized as the main independent variable, with higher scores reflecting stronger perceived social integration. Subscale structural reliabilities were extensively cross-verified using Cronbach's alpha coefficients (Supplementary Table S1b).

Subjective Sleep Problems

Subjective sleep quality and sleep-related impairment were evaluated using the Pittsburgh Sleep Quality Index (PSQI) [6]. The continuous PSQI_TOTAL score was computed by aggregating 7 standardized components, with higher aggregate tallies reflecting severe subjective sleep deterioration.

Addictive and Behavioral Indicators

Alcohol-related dependence severity was measured using the 24-item Michigan Alcoholism Screening Test (MAST; continuous ALC_TOTAL score) [13]. Nicotine dependence severity was measured using the 6-item Fagerström Test for Nicotine Dependence (FTND; continuous NIC_TOTAL score) [14]. Internet gaming symptom presentation was captured via the 9-item Internet Gaming Disorder Scale-Short Form (IGDS9-SF; continuous GAM_TOTAL score) [7].

Somatic-Psychological Symptom Burden: Waking psychological distress was captured using the 20-item Somatic Self-rating Scale (SSS) [15]. To systematically prevent structural content inflation and item-level variance overlap with the continuous PSQI sleep mediator, the primary continuous outcome variable (SYM_TOTAL_NOSLEEP) was generated by mathematically subtracting the specific sleep-disturbance item from the SSS grand total score. To explore transdiagnostic invariance, the SSS was further

decompiled into three continuous subscale outcomes: SSS_somatic (9 items), SSS_anxiety (5 items), and SSS_depression (4 items) based on established clinical dimensional mappings (Supplementary Table S2).

Sociodemographic Covariates

Potential confounding was addressed by including continuous chronological age (age_clean) and categorical covariates for sex, occupational classification, marital status, educational attainment, household family structure, and household monthly income modeled as quintile groups.

Statistical Analysis

Multi-variable ordinary least squares (OLS) linear regressions were first executed to confirm covariate-adjusted direct paths linking the predictor and parallel mediators to the outcome metrics. To test Hypothesis 1, a non-parametric parallel mediation model was constructed, defining SS_TOTAL as the independent variable (X), PSQI_TOTAL, ALC_TOTAL, GAM_TOTAL, and NIC_TOTAL as concurrent parallel mediators (M), and SYM_TOTAL_NOSLEEP as the continuous clinical outcome (Y). Point estimates for specific indirect pathways and cumulative total indirect effects were evaluated via non-parametric bootstrap resampling utilizing 5,000 replications via the R boot package. Statistical significance for an indirect path was recognized if its 95% percentile bootstrap confidence interval (CI) strictly excluded zero.

Multi-model sensitivity analyses evaluated the structural invariance of the mediation parameters by sequentially running the parallel architecture against disaggregated outcomes (SSS_somatic, SSS_anxiety, SSS_depression). Methodological artifacts regarding full-sample smoking scores were tested by replacing continuous NIC_TOTAL with a binary current smoking status factor (SMOKE_BINARY), and by re-estimating the parallel framework exclusively within the validated subcohort of current smokers (n = 258).

Given the cross-sectional design of Study 1, mediation results were strictly interpreted as statistical indirect associations rather than evidence of causal mediation, as cross-sectional parameters can yield heavily biased estimates of longitudinal promotional effects when temporal assumptions are violated [8, 9]. To evaluate multicollinearity and model stability, pairwise Spearman correlations among the parallel mediators were inspected, and generalized variance inflation factors were calculated for the main adjusted regression model. Residual and influence diagnostics, including standardized residuals, leverage, and Cook's distance, were also examined. These diagnostic results are reported in Supplementary Tables S5a–S5c. Because all Study 1 measures were self-reported and collected concurrently, the diagnostic and sensitivity analyses were used to assess statistical robustness rather than to establish causal mechanisms.

Study 2: Longitudinal Analysis Using CHNS Data

Data Source and Study Population

Study 2 conducted secondary longitudinal data analysis using the China Health and Nutrition Survey (CHNS)—a large-scale, international open-cohort project designed to monitor socio-economic, lifestyle, and health infrastructure dynamics across the Chinese population [10, 16]. The original CHNS data collection received human subject protection approvals from the Institutional Review Boards of the University of North Carolina at Chapel Hill and relevant Chinese partner institutions, with written informed consent obtained from all active cohort participants. The current secondary analysis was executed exclusively on fully anonymized, de-identified publicly accessible data matrices and involved no direct contact with human subjects. The longitudinal analytic sample was derived from cohort participants who had valid perceived stress total scores in the 2015 CHNS survey wave and provided at least one valid pre-2015 U324 assessment across the 2004, 2006, 2009, or 2011 survey waves. To prevent pediatric developmental confounding in the outcome analysis, all formal regression models were restricted to participants aged 18 years or older at the 2015 follow-up. Model-specific sample sizes were determined by the availability of sleep-related exposure indicators, covariates, and the minimum number of valid waves required for slope estimation.

Outcome: Perceived Stress in 2015

The prospective outcome for Study 2 was perceived stress measured during the 2015 CHNS survey wave. Perceived stress was assessed using 14 items administered to participants aged 18 years or older (items U551–U564). The items asked respondents how often they had experienced specific feelings and thoughts during the previous month. The final analytic dataset contained item scores ranging from 0 to 4, coded so that higher scores consistently indicated greater perceived stress. A total score was calculated only for participants with valid responses to all 14 items by summing the item scores, yielding a possible range of 0 to 56. Higher total scores indicated greater perceived stress. Internal consistency was acceptable in the present sample (Cronbach's $\alpha = 0.747$).

Pre-2015 Sleep-Related Exposure Indicators

The core longitudinal exposure was derived from the self-reported CHNS item U324, recorded as hours per day in the 2004, 2006, 2009, and 2011 survey waves. The wording of U324 differed across waves. In earlier waves, the item assessed time spent in bed or lying down, including nighttime, whereas later waves assessed usual sleep hours, including daytime and nighttime. Therefore, the longitudinal U324 variables were interpreted as broad sleep-related hours indicators rather than as uniform measures of objective sleep duration, sleep quality, sleep efficiency, or time in bed. Responses coded as unknown (-9) and values outside the prespecified plausible range of 3–24 hours per day were recoded as missing.

Three participant-level pre-2015 exposure indicators were derived. Latest pre-2015 sleep-related hours (sleep_latest_pre15) represented the most recent non-missing U324 value before 2015, prioritizing the 2011 wave, followed sequentially by 2009, 2006, and 2004. Mean pre-2015 sleep-related hours (sleep_mean_04_11) represented the within-person mean of all valid U324 values available between

2004 and 2011. Pre-2015 sleep-related hours slope (sleep_slope_04_11) represented the individual linear rate of change in reported sleep-related hours over calendar time. For each participant, repeated U324 values were regressed on centered survey year (2004 = -7, 2006 = -5, 2009 = -2, and 2011 = 0). The resulting unstandardized slope was expressed in hours per day per calendar year, with positive values indicating an increase in reported sleep-related hours over time. To improve the reliability of trajectory estimation, the primary slope analyses required at least three valid pre-2015 measurements.

Statistical Analysis

Participant characteristics, model-specific sample sizes, and the distributions of the sleep-related exposure indicators were summarized using descriptive statistics. Sequential multivariable linear regression models were fitted to examine associations between pre-2015 sleep-related hours indicators and perceived stress in 2015. HC3 heteroscedasticity-robust standard errors were used for statistical inference. Model 1 adjusted for age in 2015, sex, and educational attainment. Model 2 additionally adjusted for body mass index. Model 3 further adjusted for pre-2015 smoking and drinking indicators. Model 4 additionally incorporated pre-2015 histories of hypertension and diabetes. Unstandardized regression coefficients, 95% confidence intervals, and p values were reported.

Potential nonlinear associations were evaluated using the latest pre-2015 sleep-related hours indicator. Quadratic models included a mean-centered linear term and its squared term. Categorical models classified reported hours as < 7 h, 7–<8 h, 8–<9 h, or ≥ 9 h, with 7–<8 h as the reference category. Linear and quadratic models were compared using nested-model analysis of variance.

Several sensitivity analyses were conducted to address potential measurement heterogeneity arising from changes in the wording of U324 across survey waves. First, the latest-sleep analyses were repeated after restricting the sample to participants whose most recent pre-2015 U324 assessment was obtained in 2011, when the item specifically assessed usual sleep hours. Second, wave-specific U324 distributions were examined, including within-person changes between the 2006 and 2009 waves. Third, U324 values were standardized within each survey wave before recalculating the longitudinal mean and slope, thereby reducing the influence of wave-level differences in scale location. Fourth, an annualized two-wave change score was calculated using the 2009 and 2011 assessments, which used more comparable item wording. Sensitivity analyses also examined slope estimates based on at least two valid measurements and models excluding extreme sleep-related hours values.

Potential heterogeneity by age was explored using interaction terms between the latest pre-2015 sleep-related hours indicator and age groups defined as 18–39, 40–59, and ≥ 60 years, followed by age-stratified models. Because these analyses were exploratory, evidence of effect modification was based primarily on the formal interaction terms rather than on differences in statistical significance across stratified models.

Missing data were handled using complete-case analysis within each model, resulting in model-specific analytic sample sizes. No imputation was performed. All data preparation and statistical analyses were

conducted using R version 4.x.

Results

Study 1: Cross-Sectional Survey

Participant Characteristics

After platform-level quality-control screening and the exclusion of 50 records with missing age information or an age below 18 years, the final adult analytic sample for Study 1 comprised 1,223 participants. The sample characteristics and descriptive summary of core variables are detailed in Table 1. The mean age of the sample was 30.30 ± 8.24 years, with a relatively balanced sex distribution including 564 males (46.1%) and 659 females (53.9%). In terms of sociodemographic composition, the majority of the participants were married (*n* = 768, 62.8%), held an undergraduate degree (*n* = 852, 69.7%), lived in a nuclear family structure (*n* = 716, 58.5%), and were employed as enterprise or company workers (*n* = 691, 56.5%). For the core psychometric scales, the sample exhibited a mean score of 62.62 ± 11.43 for perceived social support, 5.37 ± 2.63 for sleep problems, 4.49 ± 6.39 for alcohol-related problems, 0.74 ± 1.75 for nicotine dependence, and 21.54 ± 8.45 for internet gaming symptoms. The primary outcome variable, total somatic-psychological symptom burden excluding the sleep-related item to minimize content overlap, yielded a mean score of 28.99 ± 8.46, with the somatic, anxiety, and depressive subscales averaging 12.74 ± 4.00, 7.86 ± 2.38, and 6.61 ± 2.42, respectively.

Table 1

Characteristics of the adult analytic sample in Study 1.

Characteristic	Total (*N* = 1,223)
Analytic sample	
Final adult analytic sample	1223
Sociodemographic characteristics	
Age, years	30.30 ± 8.24
Sex	
Male	564 (46.1%)
Female	659 (53.9%)
Occupation	
Medical/healthcare personnel	23 (1.9%)
Full-time homemaker/caregiver	16 (1.3%)
Teacher	54 (4.4%)
Student	177 (14.5%)
Government/public institution employee	89 (7.3%)
Enterprise/company employee	691 (56.5%)
Self-employed/private business owner	74 (6.1%)
Farmer	2 (0.2%)
Freelance worker	61 (5.0%)
Retired	5 (0.4%)
Worker	12 (1.0%)
Unemployed	7 (0.6%)
Other	12 (1.0%)
Marital status	
Unmarried	449 (36.7%)
Married	768 (62.8%)

Note: Values are presented as mean ± standard deviation or n (%). The symptom-burden outcome was calculated after excluding the sleep-related item from the Somatic Self-rating Scale to reduce content overlap with the PSQI sleep-problem mediator. Household monthly income quintile distribution is reported in Supplementary Table S2a.

Characteristic	Total (*N* = 1,223)
Analytic sample	
Divorced	5 (0.4%)
Widowed	1 (0.1%)
Educational level	
Junior middle school	26 (2.1%)
High school/technical secondary school	81 (6.6%)
Junior college	171 (14.0%)
Undergraduate	852 (69.7%)
Graduate degree or above	93 (7.6%)
Family structure	
Nuclear family	716 (58.5%)
Stem family	318 (26.0%)
Joint/extended family	116 (9.5%)
Other	73 (6.0%)
Core study variables	
Perceived social support	62.62 ± 11.43
Sleep problems	5.37 ± 2.63
Alcohol-related problems	4.49 ± 6.39
Nicotine dependence	0.74 ± 1.75
Gaming symptoms	21.54 ± 8.45
Symptom burden excluding sleep item	28.99 ± 8.46
Somatic symptoms	12.74 ± 4.00
Anxiety symptoms	7.86 ± 2.38
Depressive symptoms	6.61 ± 2.42

Note: Values are presented as mean ± standard deviation or n (%). The symptom-burden outcome was calculated after excluding the sleep-related item from the Somatic Self-rating Scale to reduce content overlap with the PSQI sleep-problem mediator. Household monthly income quintile distribution is reported in Supplementary Table S2a.

Primary Parallel Mediation Models

Covariate-adjusted multivariable linear regression models supported the construction of the parallel indirect-association framework. In the income-quintile-adjusted model, perceived social support remained inversely associated with somatic-psychological symptom burden after accounting for sleep problems, addictive-behavior indicators, and sociodemographic covariates (B = -0.051, 95% CI: -0.087 to -0.015, p = 0.006, N = 1,193). Subjective sleep problems showed the strongest positive association with symptom burden (B = 1.300, 95% CI: 1.142 to 1.457, p < 0.001), followed by gaming symptoms (B = 0.269, 95% CI: 0.219 to 0.319, p < 0.001) and alcohol-related problems (B = 0.167, 95% CI: 0.100 to 0.235, p < 0.001). Nicotine dependence was not statistically significant after mutual adjustment (B = 0.208, 95% CI: -0.037 to 0.454, p = 0.097).

Nonparametric bootstrap parallel mediation analysis (5,000 resamples; listwise N = 1,193) showed that lower perceived social support was associated with higher symptom burden through multiple behavioral pathways (Fig. 1). The total indirect effect was statistically significant (estimate = -0.0995, 95% CI: -0.1336 to -0.0694), and the total association between perceived social support and symptom burden was also inverse (total effect = -0.1504, 95% CI: -0.1972 to -0.1061). Among the four parallel mediators, subjective sleep problems generated the largest indirect association (indirect effect = -0.0761, 95% CI: -0.1021 to -0.0532). Gaming symptoms also showed a smaller but statistically significant indirect association (indirect effect = -0.0143, 95% CI: -0.0275 to -0.0023), as did alcohol-related problems (indirect effect = -0.0081, 95% CI: -0.0166 to -0.0020). In contrast, nicotine dependence did not show a stable indirect association (indirect effect = -0.0010, 95% CI: -0.0044 to 0.0009). These findings indicate that sleep problems remained the dominant statistical pathway linking lower perceived social support to higher symptom burden, while gaming symptoms and alcohol-related problems contributed smaller parallel indirect pathways.

(A) Parallel indirect-association model. The outcome was symptom burden after excluding the sleep-related item from the Somatic Self-rating Scale. Standardized path coefficients are shown for the main model.

(B) Bootstrap estimates of indirect associations through sleep problems and addictive-behavior indicators. Points represent indirect estimates, and horizontal lines represent 95% bootstrap confidence intervals.

Multi-Model Sensitivity Analyses

Sensitivity analyses across disaggregated symptom outcomes supported the central role of the sleep-problem pathway while clarifying the smaller contributions of addictive-behavior indicators. When the aggregate symptom outcome was separated into somatic, anxiety, and depressive subscales, the indirect association through sleep problems remained significant across all three domains: somatic symptoms (indirect effect = -0.0317, 95% CI: -0.0431 to -0.0213), anxiety symptoms (indirect effect = -0.0165, 95% CI: -0.0230 to -0.0110), and depressive symptoms (indirect effect = -0.0224, 95% CI: -0.0306 to -0.0152; Supplementary Table S5). Gaming symptoms also showed smaller but statistically significant indirect associations across somatic symptoms (indirect effect = -0.0058, 95% CI: -0.0112 to -0.0010),

anxiety symptoms (indirect effect = -0.0037, 95% CI: -0.0070 to -0.0006), and depressive symptoms (indirect effect = -0.0038, 95% CI: -0.0072 to -0.0006). Alcohol-related problems showed significant indirect associations for somatic and anxiety symptoms, but not for depressive symptoms. Nicotine dependence did not show stable indirect associations across the disaggregated outcomes.

Additional sensitivity analyses addressed potential measurement artifacts related to nicotine dependence in a general adult sample. When continuous nicotine dependence was replaced with binary current smoking status in the full sample, the sleep-problem pathway remained the largest indirect association, and alcohol-related problems and gaming symptoms remained smaller but significant pathways; the current-smoking pathway was not significant (Supplementary Table S4a). In the current-smoker-only subset, the sleep-problem pathway remained significant, whereas the alcohol, gaming, and nicotine-dependence pathways were not statistically stable (Supplementary Table S4b). Overall, these sensitivity analyses support the interpretation that subjective sleep problems constituted the dominant statistical bridge between lower perceived social support and higher symptom burden, while alcohol-related problems and gaming symptoms contributed smaller parallel pathways and nicotine-related indicators did not provide a stable indirect pathway after mutual adjustment.

Study 2: Longitudinal Analysis Using CHNS Data

Cohort Attrition and Subsampling Logic

The multi-wave selection protocol and model-specific covariate requirements generated distinct analytic subsamples within the longitudinal CHNS framework (Fig. 2). The initial 2015 outcome sample included 11,069 adults with valid perceived stress total scores. Among them, 8,564 participants provided at least one valid pre-2015 U324 assessment across the 2004, 2006, 2009, or 2011 survey waves. After requiring valid demographic covariates, the latest-sleep-related-hours models included 8,557 individuals. In contrast, the primary slope-based models required at least three valid pre-2015 U324 assessments to support reliable estimation of within-person linear change, resulting in a main slope-model sample of 4,354 participants. Additional complete-case requirements for BMI and other covariates generated smaller model-specific samples, including 7,572 participants for the BMI-adjusted latest-sleep model and 3,940 participants for the BMI-adjusted slope model. This tiered sampling structure reflects the trade-off between retaining sample size for proximate exposure models and requiring higher longitudinal data density for trajectory estimation.

The flowchart summarizes the derivation of CHNS analytic samples for the 2015 perceived-stress outcome and pre-2015 sleep-related hours indicators.

Prospective Associations of Sleep-Related Exposures with Perceived Stress

Pre-2015 sleep-related hours indicators showed positive prospective associations with perceived stress scores in 2015 (Table 2, Fig. 3). For the proximate exposure indicator, each additional hour of the latest

pre-2015 sleep-related hours was associated with a higher perceived stress score in the demographic-adjusted model (B = 0.230, 95% CI: 0.124 to 0.336, $p < 0.001$, N = 8,557). This association remained stable after additional adjustment for BMI (B = 0.195, 95% CI: 0.082 to 0.307, $p < 0.001$, N = 7,572) and in the fully adjusted model incorporating demographic, anthropometric, smoking, and drinking covariates (B = 0.193, 95% CI: 0.080 to 0.306, p = 0.001, N = 7,555).

A similar positive pattern was observed for the multi-wave change indicator. Among participants with at least three valid pre-2015 U324 assessments, a more positive sleep-related hours slope was associated with higher perceived stress in 2015 in the demographic-adjusted model (B = 0.813, 95% CI: 0.043 to 1.584, p = 0.039, N = 4,354). The association remained significant after adjustment for BMI (B = 0.864, 95% CI: 0.057 to 1.670, p = 0.036, N = 3,940) and in the fully adjusted model including demographic, anthropometric, smoking, and drinking covariates (B = 0.853, 95% CI: 0.045 to 1.662, p = 0.039, N = 3,930). In contrast, the long-term mean sleep-related hours indicator showed positive but statistically non-significant associations in the primary models. Together, these findings suggest that recent reported sleep-related hours and higher-density multi-wave increases in sleep-related hours were more informative predictors of later perceived stress than the simple long-term average alone.

Table 2
Associations between pre-2015 sleep-related hours indicators and perceived stress scores in 2015 in Study 2

Exposure indicator	Model / adjustment	N	*B*	95% CI	*p* value
Latest pre-2015 sleep-related hours	Basic	8,557	0.230	0.124 to 0.336	< 0.001
Latest pre-2015 sleep-related hours	+ BMI	7,572	0.195	0.082 to 0.307	< 0.001
Latest pre-2015 sleep-related hours	+ BMI + smoking/drinking	7,555	0.193	0.080 to 0.306	< 0.001
Latest pre-2015 sleep-related hours	+ BMI + smoking/drinking + pre-2015 diseases	7,536	0.197	0.084 to 0.310	< 0.001
Pre-2015 sleep-related hours slope	Basic	4,354	0.813	0.043 to 1.584	0.039
Pre-2015 sleep-related hours slope	+ BMI	3,940	0.864	0.057 to 1.670	0.036
Pre-2015 sleep-related hours slope	+ BMI + smoking/drinking	3,930	0.853	0.045 to 1.661	0.039
Pre-2015 sleep-related hours slope	+ BMI + smoking/drinking + pre-2015 diseases	3,930	0.853	0.044 to 1.662	0.039

Note: B values are unstandardized regression coefficients estimated using HC3 robust standard errors. The basic model adjusted for age in 2015, sex, and educational attainment. The + BMI model additionally adjusted for body mass index. The + BMI + smoking/drinking model further adjusted for pre-2015 smoking and drinking indicators. The + pre-2015 diseases model additionally adjusted for pre-2015 histories of hypertension and diabetes. Latest pre-2015 sleep-related hours refers to the most recent valid U324 value before 2015. The slope indicator was calculated among participants with at least three valid pre-2015 U324 measurements and represents the individual linear rate of change in reported sleep-related hours, expressed as hours per day per calendar year.

Robustness and Measurement-Heterogeneity Sensitivity Analyses

Sensitivity analyses addressing potential heterogeneity in U324 wording supported the primary latest-sleep and multi-wave slope findings. The latest pre-2015 U324 value was predominantly derived from the 2011 wave: 88.7% of participants with a valid latest-sleep-related-hours value had their most recent pre-2015 assessment in 2011, whereas 6.1%, 3.3%, and 1.9% came from 2009, 2006, and 2004, respectively. Across survey waves, the mean U324 value decreased gradually from 8.19 hours in 2004 to 7.78 hours in 2011. Among participants with valid values in both 2006 and 2009, the within-person mean change from 2006 to 2009 was modest (-0.168 hours/day), with a median change of 0 and an interquartile range of -1 to 1 hour/day.

Restricting the latest-sleep-related-hours analysis to participants whose most recent pre-2015 U324 assessment was obtained in 2011 yielded results consistent with the primary analysis. In the 2011-only fully adjusted linear model, each additional hour of reported sleep remained associated with a higher perceived stress score (B = 0.208, 95% CI: 0.087 to 0.329, $p < 0.001$, N = 6,761). The quadratic term remained non-significant (B = 0.015, 95% CI: -0.030 to 0.059, p = 0.519), and adding the quadratic term did not improve model fit relative to the linear specification (p = 0.489). In the corresponding categorical model, reported sleep of 8–<9 h and ≥ 9 h remained associated with higher perceived stress relative to the 7–<8 h reference category, whereas < 7 h was not significantly associated with perceived stress.

The multi-wave slope finding was also supported by wave-standardized analyses. After standardizing U324 within each survey wave before calculating longitudinal mean and slope, the slope based on at least three valid pre-2015 measurements remained positively associated with perceived stress in the fully adjusted model (B = 1.023, 95% CI: 0.056 to 1.991, p = 0.038). By contrast, slope estimates based on only two valid measurements were not statistically significant, suggesting that higher longitudinal data density was required for stable trajectory estimation. An annualized two-wave change score based on the 2009 and 2011 assessments was also not statistically significant in the fully adjusted model, although the 2009–2011 mean remained positively associated with perceived stress. These findings indicate that the main slope result was most robust when derived from higher-density multi-wave trajectories rather than from sparse two-wave change estimates.

Evaluation of Nonlinear, Categorical, and Exploratory Age-Stratified Patterns

Nonlinear analyses suggested that the association between latest pre-2015 sleep-related hours and perceived stress was adequately characterized by a linear rather than quadratic function. In the full sample, adding a quadratic sleep term did not significantly improve model fit in either the basic or fully adjusted specifications. The squared sleep term was small and statistically non-significant, and this pattern was replicated in the 2011-only sensitivity analysis. These results do not support a conventional U-shaped association in the present CHNS sample.

Categorical models further indicated that the positive association was concentrated in longer reported sleep-related hours categories. Using 7–<8 h as the reference category, ≥ 9 h was associated with higher perceived stress in the fully adjusted model, whereas < 7 h was not significantly associated with the outcome. The same categorical pattern was observed in the 2011-only sensitivity analysis, in which both 8–<9 h and ≥ 9 h were associated with higher perceived stress relative to 7–<8 h, while < 7 h remained non-significant. Thus, within this analytic sample, longer reported sleep-related hours appeared to carry a clearer prospective signal for later perceived stress than the shorter sleep category.

Age-stratified analyses were interpreted as exploratory. Descriptive comparisons showed that mean latest pre-2015 sleep-related hours differed by age group, with younger adults reporting longer values than middle-aged and older adults. In the 2011-only sensitivity analysis, however, formal age-by-sleep

interaction terms were not statistically significant. Although age-stratified models suggested a positive association among adults aged ≥ 60 years, the absence of robust interaction effects indicates that these subgroup patterns should not be interpreted as definitive evidence of age-related effect modification. Instead, they provide exploratory evidence that may warrant further investigation in future studies with age-specific designs and harmonized sleep measures.

Discussion

This study integrated a concurrent cross-sectional analysis with a long-term prospective cohort framework to examine the interface between psychosocial resources, sleep-related profiles, behavioral indicators, and adult psychological burden. Triangulation of findings yielded three principal insights. First, parallel mediation modeling demonstrated that subjective sleep disturbance served as the primary statistical pathway linking lower perceived social support to greater somatic-psychological symptom burden, consistently outperforming conventional addictive behavioral pathways across multiple symptom domains. Second, longitudinal CHNS analyses showed that higher latest pre-2015 sleep-related hours and more positive multi-wave sleep-related hours slopes were prospectively associated with higher perceived stress scores in 2015. These associations were robust to sequential adjustment for demographic, anthropometric, behavioral, and chronic disease covariates. Third, measurement-heterogeneity sensitivity analyses supported the main latest-sleep and higher-density slope findings, particularly in 2011-only and wave-standardized models. However, age-stratified findings should be interpreted cautiously, as formal age-by-sleep interaction terms were not consistently supported in the 2011-only sensitivity analysis.

The Centrality of Sleep Disturbances in Psychosocial Vulnerability

Our concurrent findings underscore that sleep anomalies function as a transdiagnostic convergence zone where interpersonal deficits manifest as clinical impairments [3]. While empirical literature has historically linked sparse social support networks directly to elevated substance reliance [1] or problematic digital behaviors [7], our parallel framework suggests that the inverse support–symptom association was expressed more strongly through subjective sleep problems than through substance dependence or internet gaming symptoms [4]. Subjective sleep disturbances exerted a stable mediating role across distinct somatic, anxiety, and depressive presentation subscales (Supplementary Table S5).

Neurobiological evidence offers a plausible explanation for this selective operational channel: robust social integration buffers against hypothalamic-pituitary-adrenal (HPA) axis hyperreactivity [5], thereby maintaining the homeostatic equilibrium of the prefrontal-amygdala emotional regulation circuitry during nocturnal rest [17]. Conversely, when social resources are depleted, sustained interpersonal deficits trigger persistent nocturnal hyperarousal [1]. This disruption structurally degrades subsequent emotional processing capacity, escalating subjective distress and functional somatic presentation [15, 18]. In contrast, alcohol-related problems and gaming symptoms contributed smaller but statistically significant

indirect pathways, whereas nicotine dependence did not show a stable indirect association after mutual adjustment. This pattern suggests that addictive-behavior indicators may capture secondary behavioral correlates of distress, but they did not account for the support–symptom association as strongly or consistently as subjective sleep problems.

Longer Sleep-Related Hours as Prospective Markers of Psychological Burden

A major finding from the longitudinal analysis was that higher latest pre-2015 sleep-related hours and increasing multi-wave sleep-related hours slopes prospectively predicted higher perceived stress scores. This pattern was observed despite sequential control for demographic characteristics, BMI, smoking, drinking, and pre-2015 chronic disease indicators. Importantly, the association was not better characterized by a conventional U-shaped pattern. Both the full-sample and 2011-only sensitivity analyses indicated that the quadratic term did not improve model fit, whereas categorical analyses showed that the prospective signal was concentrated in longer reported sleep-related hours, especially the ≥ 9 h category.

These findings should not be interpreted as evidence that longer sleep itself is necessarily harmful. The CHNS U324 item captured self-reported sleep-related hours, and its wording varied across waves, with earlier waves assessing time spent in bed or lying down and later waves assessing usual sleep hours. Therefore, prolonged sleep-related hours may reflect a heterogeneous behavioral profile, including extended sleep opportunity, prolonged time in bed, fatigue-related withdrawal, subclinical illness burden, or psychological avoidance. In epidemiological settings, longer reported sleep duration or sleep-related hours has often been interpreted as a marker of underlying vulnerability rather than a purely restorative behavior.

The measurement-heterogeneity sensitivity analyses strengthen this interpretation. Most latest pre-2015 U324 values were obtained in 2011, and the 2011-only model replicated the positive linear association between reported sleep hours and later perceived stress. Similarly, the wave-standardized slope analysis showed that the higher-density multi-wave slope remained positively associated with perceived stress after reducing the influence of wave-level differences in U324 distributions. In contrast, two-wave change estimates were not statistically stable, indicating that reliable longitudinal signal detection required denser repeated measurements. Thus, the most defensible interpretation is that longer or increasing sleep-related hours functioned as prospective behavioral markers of later psychological burden, rather than as direct evidence that prolonged sleep opportunity causally increased stress.

Exploratory Age-Stratified Patterns

Age-stratified analyses provided exploratory context for the longitudinal sleep-related findings but did not establish definitive age-related effect modification. Descriptive results indicated that reported sleep-related hours varied across age groups, and stratified models suggested that the positive association between longer sleep-related hours and perceived stress was most evident among older adults.

However, formal age-by-sleep interaction terms were not statistically significant in the 2011-only sensitivity analysis. Therefore, the present findings should not be interpreted as evidence that age robustly moderates the sleep-related hours–stress association.

The exploratory age-stratified pattern may still be useful for hypothesis generation. Older adults may show stronger links between longer reported sleep-related hours and psychological burden because extended sleep or sleep-related hours can coincide with somatic decline, reduced activity engagement, social withdrawal, or fatigue-related behavioral restriction. By contrast, the weaker association observed among middle-aged adults may reflect greater heterogeneity in work schedules, family demands, and health profiles rather than a true protective mid-life effect. Because these mechanisms were not directly measured, they should be tested in future studies using harmonized sleep measures, age-specific designs, and richer assessments of health status, work-family context, and daily activity patterns.

Public Health Implications and Limitations

From a public health perspective, the present findings suggest that sleep-related profiles may provide useful behavioral signals of psychological burden in adult populations. In Study 1, subjective sleep problems emerged as the strongest indirect statistical pathway linking lower perceived social support to higher somatic-psychological symptom burden. In Study 2, longer latest pre-2015 sleep-related hours and increasing multi-wave sleep-related hours slopes prospectively predicted higher perceived stress scores. These findings suggest that screening frameworks should not focus exclusively on sleep restriction or insomnia-like symptoms, but should also consider unusually long or increasing sleep-related hours as potential markers of underlying psychological or somatic vulnerability.

Several limitations should be acknowledged. First, the cross-sectional architecture of Study 1 precludes formal verification of temporal precedence or causal directionality among social support, sleep quality, behavioral indicators, and symptom burden. Accordingly, the mediation results should be interpreted as statistical indirect associations rather than as evidence of causal mediation. In addition, Study 1 relied on self-reported questionnaires collected within a single survey session, and the instruments differed in their reference periods; therefore, associations among social support, sleep problems, addictive-behavior indicators, and symptom burden may partly reflect shared method variance or recall-window mismatch [19]. Study 1 also relied on a non-probability online panel without sampling weights or post-stratification adjustment; despite broad geographic coverage, the sample may not be representative of the general adult population in China.

Second, Study 2 relied on self-reported CHNS sleep-related hours indicators rather than objective sleep measures. The wording of CHNS item U324 also changed across survey waves: earlier waves assessed time spent in bed or lying down, whereas later waves assessed usual sleep hours. Although 2011-only and wave-standardized sensitivity analyses supported the primary latest-sleep and higher-density slope findings, the longitudinal mean and slope indicators should still be interpreted as broad sleep-related hours measures rather than as uniform assessments of sleep duration, sleep quality, sleep efficiency, or time in bed.

Third, although sequential regression models adjusted for demographic characteristics, BMI, smoking and drinking indicators, and pre-2015 histories of hypertension and diabetes, residual confounding remains possible. Potential sources include unmeasured health conditions, medication use, work schedules, depressive symptoms prior to 2015, genetic factors, and other social or environmental determinants. Fourth, missing data were handled using complete-case analysis within each model, which may introduce selection bias if participants with complete longitudinal sleep and covariate data differed systematically from those excluded because of missingness. Finally, age-stratified analyses were exploratory. Because formal age-by-sleep interaction terms were not consistently supported in sensitivity analyses, the present study cannot establish robust age-related effect modification.

Conclusions

Across a cross-sectional survey and longitudinal CHNS analysis, sleep-related indicators were consistently associated with adult psychological burden. In Study 1, subjective sleep problems were the main statistical pathway linking lower perceived social support to higher somatic-psychological symptom burden, while alcohol-related problems and internet gaming symptoms showed smaller indirect associations. In Study 2, longer latest pre-2015 sleep-related hours and increasing multi-wave sleep-related hours were associated with higher perceived stress in 2015.

These findings suggest that sleep-related measures may help identify adults with greater psychological burden in public health research and screening contexts. However, the results should be interpreted cautiously because sleep measures were self-reported, CHNS sleep-item wording varied across waves, and the observational design does not support causal inference.

Abbreviations

BMI: Body mass index
CHNS: China Health and Nutrition Survey
CI: Confidence interval
FTND: Fagerström Test for Nicotine Dependence
HC3: Heteroscedasticity-consistent standard error type 3
IGDS9-SF: Internet Gaming Disorder Scale–Short Form
MAST: Michigan Alcoholism Screening Test
MSPSS: Multidimensional Scale of Perceived Social Support
OLS: Ordinary least squares
PSQI: Pittsburgh Sleep Quality Index
SSS: Somatic Self-rating Scale

Declarations

Human ethics and consent to participate

For Study 1, all procedures involving human participants were approved by the Ethics Committee of Wenjiang District People's Hospital of Chengdu (Reference No. EC-2020-002). Electronic informed consent was obtained from all participants prior to survey initiation. All methods were conducted in accordance with the ethical standards of the approving institutional committee and with the Declaration of Helsinki.

For Study 2, the China Health and Nutrition Survey was approved by the Institutional Review Boards of the University of North Carolina at Chapel Hill and the Chinese partner institutions responsible for the CHNS. Written informed consent was obtained from all CHNS participants. The present study used de-identified secondary data from the publicly available CHNS database and involved no additional contact with participants.

Clinical trial number

Not applicable.

Trial registration

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The China Health and Nutrition Survey (CHNS) datasets used in Study 2 are available from the official CHNS data portal and Dataverse. The present analysis used public-use individual- and household-level datasets, which can be accessed through the CHNS website subject to the data-use requirements specified by the CHNS.

The cross-sectional survey data generated and analyzed in Study 1 are not publicly available because the ethics approval and participant consent did not permit unrestricted public sharing of participant-level questionnaire data. De-identified data may be made available from the corresponding author upon reasonable request, subject to approval by the relevant ethics committee and completion of an appropriate data-use agreement.

The analysis code and derived variable-construction scripts are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

MQ conceptualized the study, contributed to methodology and investigation, drafted and critically revised the manuscript, and coordinated project administration. YG contributed to methodology, data curation, formal analysis, visualization, manuscript drafting, and manuscript revision. YG led the Study 2 CHNS longitudinal sleep-related analysis, including the construction and verification of pre-2015 sleep-related exposure indicators, main regression models, sensitivity analyses, figure preparation, and interpretation of the Study 2 findings. XL contributed to data curation, methodology, formal analysis, and manuscript revision. XL conducted Study 1 data cleaning, variable construction, and mediation analyses, and contributed to CHNS variable screening and data extraction. YW contributed to data curation, formal analysis, visualization, and manuscript revision. YW prepared and modeled pre-2015 smoking and drinking indicators and organized extended CHNS model outputs for sequential comparison and figure preparation. LF and HW critically reviewed and edited the manuscript. SL supervised the study, contributed to manuscript review and editing, and acquired funding. All authors read and approved the final manuscript.

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Figures

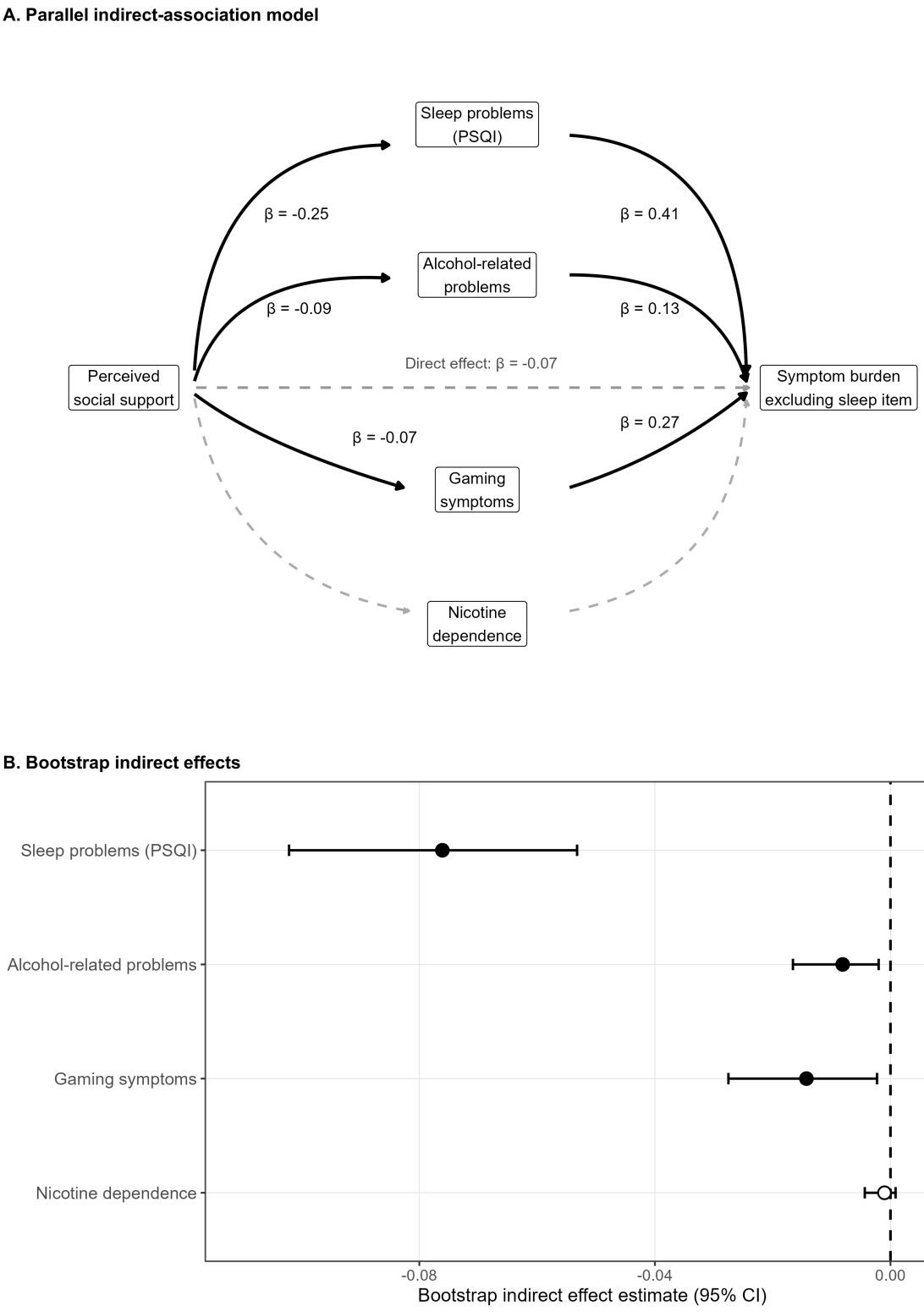
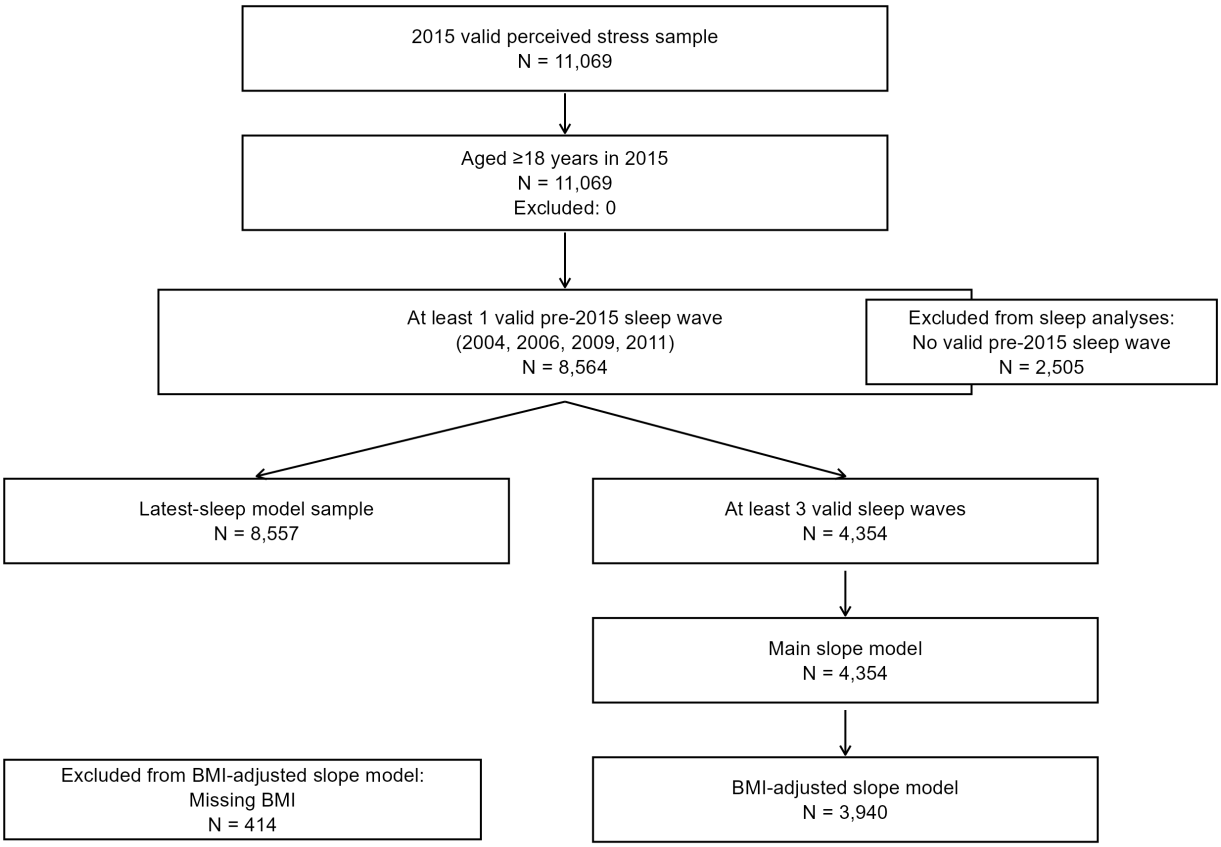


Figure 1

Indirect associations linking perceived social support to symptom burden in Study 1.
(A) Parallel indirect-association model. The outcome was symptom burden after excluding the sleep-related item from the Somatic Self-rating Scale. Standardized path coefficients are shown for the main model.
(B) Bootstrap estimates of indirect associations through sleep problems and addictive-behavior

indicators. Points represent indirect estimates, and horizontal lines represent 95% bootstrap confidence intervals.

Figure 2. Flowchart of analytic samples for sleep exposure models



Note. The 2015 outcome sample included participants with valid perceived stress total scores. All formal models were restricted to participants aged ≥18 years in 2015. The latest-sleep models required at lea

Figure 2

Flowchart of the analytic samples for Study 2.

The flowchart summarizes the derivation of CHNS analytic samples for the 2015 perceived-stress outcome and pre-2015 sleep-related hours indicators.

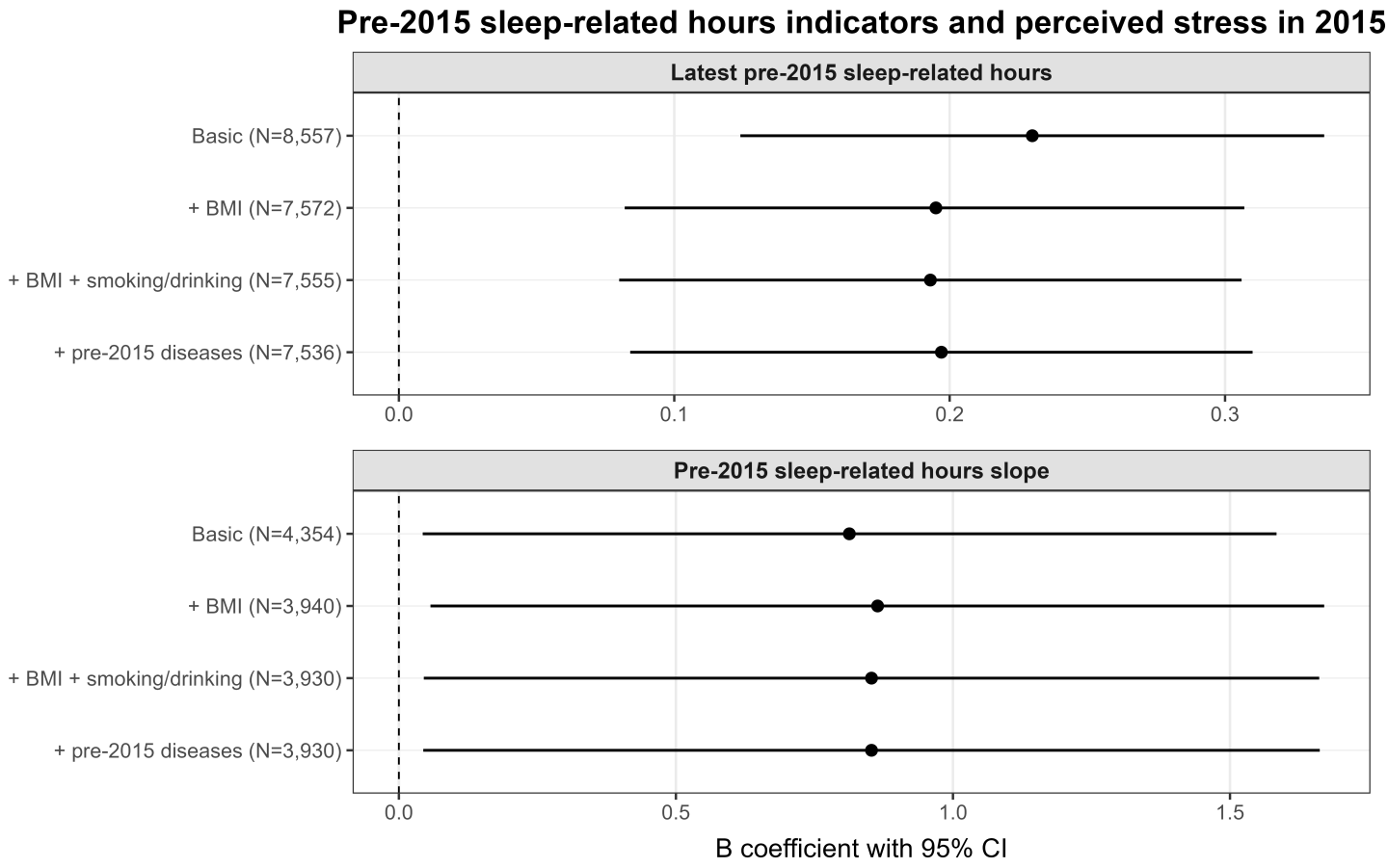


Figure 3

Associations between pre-2015 sleep-related hours indicators and perceived stress in Study 2. Points represent unstandardized regression coefficients, and horizontal lines represent 95% confidence intervals across sequential model specifications.

Supplementary Files

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- Additionalfile1SupplementaryTablesandFigures.docx