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The simplified Chinese version of the Nonrestorative Sleep Scale in Chinese young adults and measurement invariance across language and age

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Abstract

Background To assess the psychometric properties of the simplified Chinese version of the Nonrestorative Sleep Scale (NRSS) in Chinese young adults and examine measurement invariance across language and age.

Methods After cognitive debriefing, the simplified Chinese NRSS was administered to university students in mainland China in this cross-sectional survey (Study 1). The Pittsburgh Sleep Quality Index (PSQI), the Patient Health Questionnaire (PHQ-4), and sociodemographic characteristics were also self-reported. The sample was randomly split into two halves to examine the scale structure using exploratory factor analysis (EFA) and asses the psychometric properties of the identified structure by confirmatory factor analysis (CFA), respectively. Incorporating data from two additional studies (Study 2: a survey of Hong Kong Chinese adults; Study 3: a survey of mainland Chinese adolescents), multigroup CFA models were conducted to examine the measurement invariance across language and age, followed by a t-test to determine group differences once invariance was established.

Results In the 570 participants of Study 1 (28.8% male, age 20.2 ± 1.5 years), the EFA revealed a four-factor structure. The root mean square error of approximation, comparative fit index, and standardized root mean square residual in the CFA model were 0.053, 0.995, and 0.054, respectively. The statistically significant correlations of NRSS with PSQI ($r = -0.61$) and PHQ-4 ($r = -0.53$) demonstrated the convergent validity of NRSS. The internal consistency of the whole scale was 0.84. Measurement invariance was concluded between traditional and simplified Chinese NRSS and between young adults and adolescents with the change of comparative fit index and root mean square error of approximation smaller than 0.010. The effect size (Cohen's d) of difference between mainland Chinese adults and

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Hong Kong Chinese adults ranged from 0.193 to 0.771, while that between mainland Chinese adults and adolescents ranged from 0.027 to 0.345.

Conclusion The simplified Chinese 12-item NRSS is valid and reliable for assessing NRS among Chinese young adults, and it can be used to measure and compare NRS between individuals using simplified Chinese and traditional Chinese, as well as across different age groups within the simplified Chinese user population.

Keywords Confirmatory factor analysis, Exploratory factor analysis, Measurement invariance, Nonrestorative sleep, Reliability, Validity

Background

Adequate sleep is essential to maintain vital activities and basic functions for all individuals. Biological rhythms, physiological functions, cognitive activity, and psychological health could not be carried or restored without sleep [1]. The social-ecological model of sleep puts forward that the "downstream" of insufficient sleep or poor sleep quality covers numerous adverse health outcomes across multiple domains, including general health, cardiovascular health, metabolic health, mental health, immunological health, and human performance [2].

During the last two decades, nonrestorative sleep (NRS) has gained growing attention in addition to other frequently reported sleep-related problems, such as difficulty initiating and maintaining sleep [3–6]. NRS usually refers to an individual's unrefreshed feeling after normal sleep duration [7]. NRS, despite its inconsistent definitions and varied measurements, has been reported to be associated with different health-related problems, such as chronic diseases, psychiatric problems, and increased mental health [8–10]. It would also cause function-related problems like daytime fatigue, decreased daytime performance, and occupational and non-occupational accidents [11]. Studies of Hong Kong Chinese adults found that NRS was prevalent among them, and the association with health-related quality of life revealed that NRS warrants attention [12, 13]. Previous literature also showed that 30.9% of the Chinese population had insomnia symptoms [14], and 19.2% of the Chinese population had poor sleep quality in mainland China [15]. Furthermore, one recent study showed that 43.8% of mainland Chinese young adults stayed up past midnight, 27.4% had sleep efficiency under 85%, 25.7% experienced insomnia, 27.7% reported sleep durations under 7 h, 66.6% had sleep disturbances, and 55.6% showed signs of daytime dysfunction [16]. Therefore, the sleep conditions of mainland Chinese young adults are of significant concern to promote their well-being. However, the NRS among Chinese adults who speak and read simplified Chinese has been underexplored because of the absence of a standardized instrument for measuring it.

For a more comprehensive assessment of NRS, three patient-reported outcome measures (PROMs) were developed because of the "subjective" nature of NRS, namely the Nonrestorative Sleep Scale (NRSS), the Restorative Sleep Questionnaire weekly version (RSQ-W), and the Restorative Sleep Questionnaire daily version (RSQ-D) [17, 18]. The Nonrestorative Sleep Scale (NRSS) is the first standard instrument developed to assess NRS [17]. In 2012, Wilkinson et al. employed a new paradigm inspired by the diagnosis of insomnia to serve as the foundation for the development of NRSS in English, with the aim of encouraging collaboration across disciplines on NRS [17, 19]. This new paradigm identifies NRS as both a symptom of various medical and psychiatric conditions and as a disorder on its own, echoing observations in NRS [17, 19]. For example, NRS has a significant relationship with chronic fatigue syndrome but can manifest independently as well [7].

The original English NRSS has undergone translation into several languages, including traditional Chinese for general adults in Hong Kong and simplified Chinese for adolescents in mainland China, with all versions confirming a four-factor structure, while the traditional Chinese version also concluded a bi-factor model [20, 21]. Moreover, studies have identified age as one of the most frequently cited sociodemographic variables affecting NRS, but a consensus has yet to be achieved. Younger adults have been reported to experience more NRS [22]. In contrast, other research has found that NRS is more prevalent among middle-aged adults than among younger or older age groups [23]. Furthermore, the linguistic and written differences in Hong Kong, where Cantonese is spoken and traditional Chinese is used, hinder sleep comparisons of sleep with mainland China. Hong Kong is known as a sleepless city, where sleep problems are highly prevalent among the general population [24]. Therefore, a standardized and reliable tool to measure NRS across age and language would reveal NRS disparities and related factors of it in China, which would facilitate the interventions for NRS.

The direct comparison of scores between different groups requires that the measurement be invariant across different groups. Specifically, measurement invariance determines if an instrument is interpreted equivalently or similarly, such as wording or content, by various individuals with diverse backgrounds [25]. It can be evaluated in multigroup confirmatory factor analysis (CFA) by

progressively testing configural invariance, metric invariance, and scalar invariance with restrictions of equal factor structure, equal factor loadings, and equal intercepts being added to the previous CFA models, respectively [21]. Scalar invariance is adequate for evaluating observed mean differences between groups [21].

Hence, this study aimed to evaluate the psychometric properties of the simplified Chinese version of NRSS in mainland Chinese adults. Second, exploring whether NRSS shows measurement invariance across language and age could facilitate the comparison of NRS across language and age and enhance the understanding of NRS and sleep issues among Chinese populations. Third, to assess the difference in NRS between mainland Chinese adults and Hong Kong Chinese adults and the difference between young adults and adolescents.

Methods

Linguistic validation of the simplified Chinese NRSS

The original simplified Chinese version of NRSS was obtained by the research team using standard forward-backward translation procedures when it was adapted for Chinese adolescents in 2019 [21]. Before cognitive briefing and administering the simplified Chinese NRSS in young adults, a committee meeting with four members who were experienced in scale validation, statistical analysis, and sleep was convened in 2023 to discuss whether the translations and contents were applied to young adults. The experts researched a consensus on the wording and determined the applicability to young adults without major revision. Six university students were then approached to evaluate the scale length, whether the items of the simplified Chinese version were relevant to NRS, and whether the items were clarified enough. All six respondents rated the length as moderate, five of six rated the relevance and clarity of items very high or high, while one rated relevance as moderate. Given the positive feedback, the final version of the simplified Chinese NRSS was finalized without additional modifications.

Sample and procedures

We totally recruited three datasets to investigate the measurement invariance, with two datasets extracted from our previous studies.

Study 1

An internet-based cross-sectional survey of students attending Shenzhen University and Nanjing Medical University was conducted from April 29, 2023 to March 26, 2024. Eligible participants were those who were capable of reading and understanding simplified Chinese and completing the questionnaires according to their true feelings and conditions on their own. Individuals who were taking drugs for sleep problems or diagnosed with mental illness were excluded from this study.

This study adopted convenience sampling, and the potential participants were approached in classes, where they were briefed on the aims, study procedures, inclusion criteria, and exclusion criteria of this study. They were invited in classes and by e-messages to voluntarily complete the self-administered online questionnaires through Wenjuanxing, a widely used electronic survey platform in mainland China. The study procedures were also introduced to potential participants at the beginning of the online questionnaires, including the use of their anonymous data for academic publications. Written informed consent was obtained when they clicked "Next" on the title page before they started the questionnaires. Ethics approval for this study was obtained from the Institutional Review Board of Shenzhen University [No.: PN-202300022] and the Institutional Review Board of Nanjing Medical University [No.: (2023) 585].

The whole sample of Study 1 was randomly split into two halves, with each half used for a factor analysis. Following the guideline suggesting a minimum of 20 subjects per item for factor analysis, we planned to recruit 480 subjects [26].

Study 2

Data from 500 general adults were successfully approached in the Hong Kong community to complete the traditional Chinese NRSS, which was utilized with data from Study 1 for evaluating the measurement invariance between simplified Chinese and traditional Chinese [13]. The sampling procedure was described in our previous article [13]. The linguistic validation of the traditional Chinese NRSS and the sampling procedure had been described in our earlier study [20].

Study 3

A total of 481 adolescents from secondary and high schools in Nanjing, China, participated in the validation study of the simplified Chinese NRSS [21]. Both the students and their parents/guardians gave written informed consent before the adolescents completed the paper questionnaires [21]. Data from these adolescents on the simplified NRSS were employed with data from Study 1 to examine the measurement invariance across age.

Measures

Nonrestorative sleep scale (NRSS)

The NRSS includes 12 items, which can be grouped into four subscales, including refreshment from sleep (3 items), physical/medical symptoms of NRS (4 items), daytime functioning (3 items), and affective symptoms (2 items) [17]. Items belonging to the physical/medical symptoms of NRS subscale and affective symptoms

subscale are negatively worded, so scores of these items need to be reversed before scoring [17]. The simplified Chinese version administered in this study was scored as the English version [21]. By combining the adjacent answers, the ten items answered using a 1–10 Likert scale were re-coded to form a 1–5 scale with a total score ranging from 12 to 60. Higher scores on the global scale or each subscale indicate less NRS. The details of the simplified Chinese NRSS in adolescents have been reported [21].

Pittsburgh sleep quality index (PSQI)

The PSQI consists of 19 self-rating questions to assess sleep quality over the past month, including seven components: subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disorders, sleep medication use, and daytime dysfunction [27]. The score of each component ranged from 0 to 3, and the global score ranged from 0 to 21, with higher scores indicating worse sleep quality [27]. Both the simplified Chinese and traditional Chinese versions of PSQI have been validated as reliable and valid [28, 29].

Patient health questionnaire-4 (PHQ-4)

The PHQ-4, comprising the PHQ-2 and General Anxiety Disorder-2 (GAD-2), was used to screen for depression and anxiety [30]. PHQ-2 covers two items assessing the frequency of depressive symptoms, while the GAD-2 encompasses two items evaluating core anxiety symptoms in the past two weeks [30]. Validation studies show that both the simplified and traditional Chinese versions of the PHQ-4 are reliable and valid [31, 32]. All items were rated on a Likert 4 scale, ranging from 0 (not at all) to 3 (nearly every day). Higher total scores indicate more severe symptoms of depression [30].

Sociodemographics

Sociodemographic characteristics, including age and gender, were collected.

Statistical analysis

All data analysis was conducted with R-4.3.2. Individuals who completed the NRSS with 50% missing values or less were included in the final data analysis. All the scale scores were summarized using mean ± standard deviation (SD) if normally distributed. The floor and ceiling percentages of NRSS were calculated to examine the scaling properties, indicating the proportions of participants achieving the lowest or highest possible scale scores, respectively [33].

The entire sample of Study 1 was randomly split into two halves, with one half designated as the training sample and the other half as the validation sample. With the training sample, an exploratory factor analysis (EFA) was performed to determine the most appropriate structure of the Chinese NRSS in adults. Specifically, we calculated the Kaiser-Meyer-Olkin (KMO) and conducted Bartlett's Test of Sphericity to assess the appropriateness of EFA with the training sample (requirement: KMO ≥ 0.70 and statistical significance of Bartlett's Test of Sphericity) [34]. Upon confirmation, the number of factors was determined through parallel analysis and scree plot analysis, utilizing factor loadings acquired via minimal residual (MINRES) on the polychoric correlation, followed by oblimin rotation [35]. Oblimin rotation, which is the most commonly used oblique technique, is preferred for factor analysis to allow the factors to correlate and provide an accurate and reproducible solution, especially where correlation among factors was generally expected [35, 36]. A polychoric correlation matrix combined with MINRES estimation is proposed because of its ability to analyze polytomous items with a few graded response categories that do not fulfill the average difficulty and discrimination assumptions [37]. A factor loading of at least 0.4 was considered satisfied [38]. The EFA was conducted under R with the packages "psych" and "GPArotation" [39, 40].

We assessed the factorial validity of the structure identified by EFA and the bifactor model obtained by the traditional Chinese version through CFA using the validation sample [20]. The diagonal weighted least squares (DWLS) estimation was employed to address the ordinal nature of the item responses [41]. We examined the goodness of fit through the root mean square error of approximation (RMSEA), comparative fit index (CFI), and standardized root mean square residual (SRMR) [42]. An acceptable fit for a CFA model was defined as having values of RMSEA at 0.08 or below, CFI at 0.95 or above, and SRMR at 0.08 or below [42].

Following confirmation of the factor structure of the simplified Chinese NRSS with Study 1 data, we additionally utilized data from Study 2 and data from Study 3 to examine the measurement invariance across language and age, respectively, through multigroup CFA models. The standard configural invariance, metric invariance, and scalar invariance were progressively evaluated [43]. Invariance was determined if the associated change in CFI was smaller than 0.010 and the change in RMSEA was smaller than 0.015 in each step [43]. The CFA models were analyzed under R with the package "lavaan" [44].

Considering the fact that NRS was associated with sleep quality and depression, Spearman's rank correlation coefficients between NRSS and PSQI, as well as PHQ-4, were calculated to examine the convergent validity of the Chinese version of NRSS [20]. In addition, internal consistency was examined via the values of Cronbach's α.

After the validity and reliability of the simplified Chinese in adults and measurement invariance across

Table 1 Global and subscales scores of simplified Chinese NRSS ($n = 570$)

Scales (No. of items)	Mean (SD)	% Floor	% Ceiling
Refreshment from sleep	10.7 (2.5)	0	7
Physical/medical symptoms of NRS	15.0 (3.4)	0	12
Daytime functioning	10.3 (2.3)	1	4
Affective symptoms of NRS	6.3 (1.7)	1	4
Global score	42.4 (7.2)	0	0

NRS: nonrestorative sleep; NRSS: Nonrestorative Sleep Scale; SD: standardized deviation

Table 2 Factor loadings by exploratory factor analysis and internal reliability of the simplified Chinese NRSS ($n = 275$)

	Factor loadings				Internal reliability
Item	F1	F2	F3	F4	Corrected Item-total correlation (subscales)
Q1:…rate the quality of your sleep			0.84		0.62 (0.68)
Q2:…sleep is restoring or refreshing?			0.70		0.52 (0.60)
Q3:…felt rested if you've slept for your usual amount of time?			0.43		0.49 (0.54)
Q4:…had physical sensations or unusual feelings?		0.61			0.39 (0.52)
Q5:…one or more of the following: headaches, body pain, numbness or tingling…?		0.52			0.48 (0.52)
Q6: physical or medical problems are dragging you down?		0.87			0.62 (0.68)
Q7:… have a sense of panic, or physical symptoms of panic…?		0.67			0.46 (0.58)
Q8:…memory and concentration…?	0.78				0.55 (0.73)
Q9:…level of daytime energy?	0.83				0.59 (0.78)
Q10:…alert during the daytime?	0.85				0.60 (0.74)
Q11:…depressed or down if you didn't sleep well…?				0.48	0.29 (0.39)
Q12:…irritable or gotten the blahs" if you didn't sleep well.				0.88	0.44 (0.39)

NRSS: Nonrestorative sleep scale

language and age were established, the independent t-test was applied to compare the scores of NRSS between different groups. The effect size of Cohen's d was obtained for each comparison to indicate the magnitude of the difference [45]. For all data analysis, a two-tailed *P*-value smaller than 0.05 was deemed statistically significant.

Results

Demographic characteristics and NRS status

A total of 570 (28.8% male) students with an average age of 20.2 (SD: 1.5, range: 18–30) years answered the simplified Chinese questionnaires and were included in the analysis. The mean global score of the NRSS of the overall sample ($n = 570$) was 42.4 (SD = 7.2). The floor and ceiling rates of the scale scores were 0–1% and 1–12%, respectively (Table 1). The mean age of the adolescents who answered the simplified Chinese version was 16 years old (SD: 1; range: 13–18) [21], while that of the adults who answered the traditional Chinese version was 39 years old (SD: 12; range: 18–80) [13].

Exploration of scale structure

With the training sample, the KMO yielded a value of 0.82, indicating high sampling adequacy, and Bartlett's Test of Sphericity demonstrated statistical significance ($P < 0.001$). Four factors were identified from parallel analysis and the scree plot, which explained 71.2% of the total variance. The factor structure is inconsistent with the English version. Table 2 shows the rotated factor loadings corresponding to the parallel analysis and the corrected item-scale correlation.

Confirmation of the factor structure

In order to test whether the four-factor model derived from the EFA was reasonable, CFA models were performed using the validation sample. The bifactor model of the traditional Chinese version was compared with the four-factor model. The fitting indexes of the four-factor model (RMSEA = 0.053, CFI = 0.995, SRMR = 0.054) were better than those of the bifactor model (Table 3). The standardized factor loadings of the four-factor model were all above 0.4, and the standardized coefficients of the four-factor model are shown in Fig. 1.

Measurement invariance across language and age groups

Table 4 shows the assessment of configural, metric, and scalar invariances between simplified Chinese and traditional Chinese in adults and between young adults and adolescents with simplified Chinese versions. The model fit indices were all in an acceptable range, with all

Table 3 Model fit indices in confirmatory factor analysis of the Chinese NRSS ($n = 295$)

Model	χ^2 statistic	Degrees of freedom	RMSEA (95%CI)	CFI	SRMR
Four-factor	87.67	48	0.053 (0.035, 0.070)	0.995	0.054
Bifactor	88.86	42	0.062 (0.044, 0.079)	1.000	0.057

NRSS: Nonrestorative Sleep Scale; RMSEA: root mean square error of approximation; CFI: comparative fit index; SRMR: standardized root mean square residual

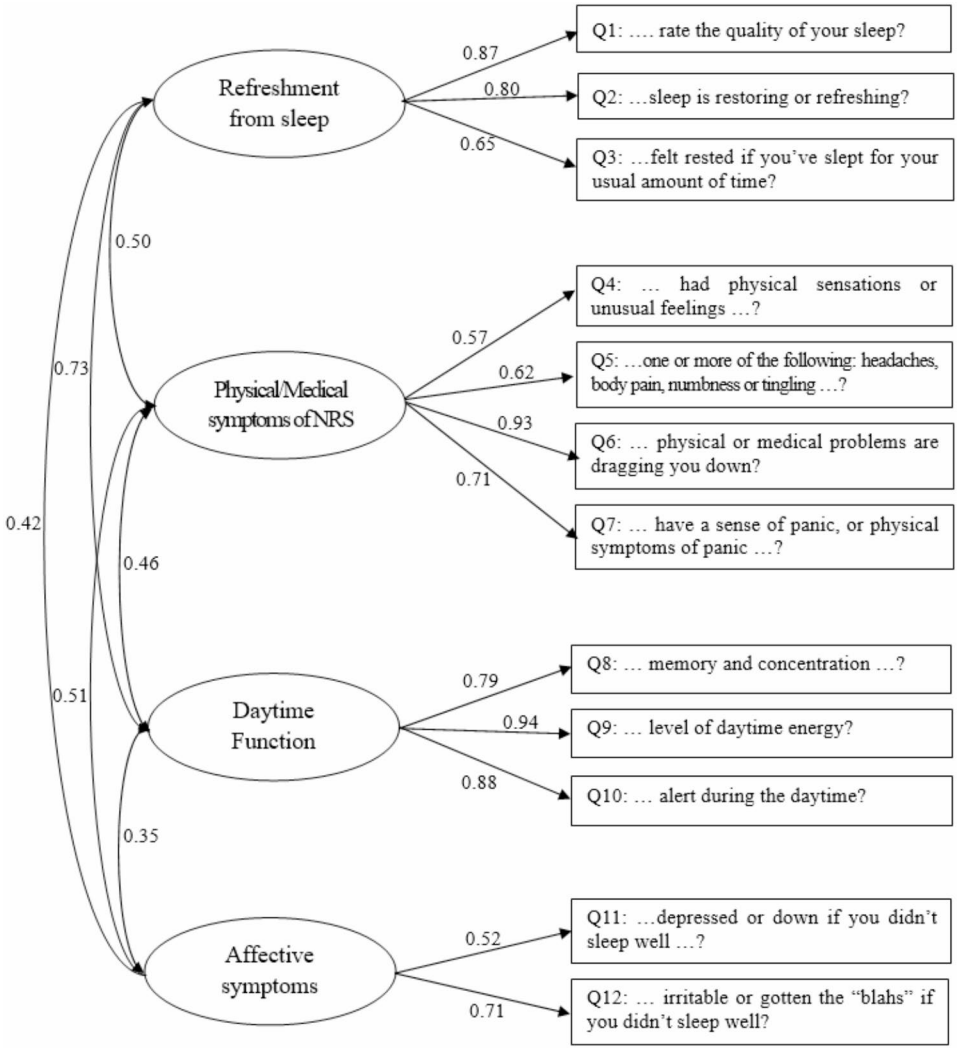

Fig. 1 Standardized coefficients of a four-factor structure for the 12-item Chinese NRSS ($n = 295$)

Table 4 Model fit indices in confirmatory factor analysis of the Chinese NRSS

Level of measurement invariance	χ^2 statistic	Degrees of freedom	CFI	RMSEA (95% CI)	SRMR	△CFI	△RMSEA
Language ($n = 1070$, simplified Chinese: $n = 570$; traditional Chinese: $n = 500$)							
Configural	269.945	96	0.993	0.058 (0.050, 0.067)	0.053		
Metric	302.739	104	0.992	0.060 (0.052, 0.068)	0.056	0.001	0.002
Scalar	445.059	136	0.987	0.065 (0.059, 0.072)	0.053	0.005	0.005
Age ($n = 1051$, Adolescents: $n = 481$; Adults: $n = 570$)							
Configural	209.309	96	0.995	0.047 (0.039, 0.056)	0.046		
Metric	275.275	104	0.992	0.056 (0.048, 0.064)	0.052	0.003	0.009
Scalar	396.643	136	0.988	0.060 (0.054, 0.067)	0.048	0.004	0.004

NRSS: Nonrestorative Sleep Scale; CFI: comparative fit index; CI: confidence interval; RMSEA: root mean square error of approximation; SRMR: standardized root mean square residual

Table 5 Correlations between Chinese NRSS scores and global scores of other subjective scales ($n=232$)

Subscales of NRSS	PSQI	PHQ-4
Refreshment from sleep	−0.60**	−0.34**
Physical/Medical symptoms of NRS	−0.40**	−0.42**
Daytime function	−0.44**	−0.42**
Affective symptoms	−0.42**	−0.40**
Global score	−0.61**	−0.53**

NRSS: Nonrestorative Sleep Scale; PSQI: Pittsburgh Sleep Quality Index; PHQ-4: Patient Health Questionnaire-4; NRS: nonrestorative sleep

**: $P<0.01$

Table 6 Scale-scale correlations of the simplified Chinese NRSS ($n=570$)

Subscales of NRSS	Global score	Refreshment from sleep	Physical/Medical symptoms of NRS	Daytime function
Refreshment from sleep	0.76**	-	-	-
Physical/Medical symptoms of NRS	0.79**	0.38**	-	-
Daytime function	0.73**	0.60**	0.36**	-
Affective symptoms	0.55**	0.29**	0.35**	0.25**

NRSS: Nonrestorative Sleep Scale; NRS: nonrestorative sleep

**: $P<0.01$

Table 7 Comparison of NRSS between different populations

	Difference[a] (95% CI)	Cohen's d	*P*-value	Difference[b] (95% CI)	Cohen's d	*P*-value
Refreshment from sleep	−0.46 (−0.74, −0.17)	0.193	0.002**	0.88 (0.67, 1.19)	0.345	<0.001**
Physical/Medical symptoms of NRS	0.76 (0.37, 1.15)	0.232	<0.001**	−0.23 (−0.65, 0.18)	0.068	0.271
Daytime function	0.43 (0.17, 0.69)	0.195	0.001**	−0.07 (−0.36, 0.23)	0.027	0.660
Affective symptoms	1.32 (1.11, 1.52)	0.771	<0.001**	−0.33 (−0.56, −0.10)	0.178	0.005**
Global score	2.05 (1.22, 2.88)	0.296	<0.001**	0.25 (−0.65, 1.15)	0.034	0.583

Difference[a]: Difference between Hong Kong Chinese adults (n = 500) and mainland Chinese adults ($n=570$)

Difference[b]: Difference between young adults ($n=570$) and adolescents ($n=481$)

NRSS: Nonrestorative Sleep Scale; NRS: nonrestorative sleep

**: $P<0.01$

the △CFI and △RMSEA values smaller than 0.010 and 0.015, respectively. Hence, scalar invariance was established between the simplified Chinese and the traditional Chinese and between young adults and adolescents.

Convergent validity

Table 5 shows that the scores of the global scale and its four subscales were moderately associated with the PSQI and PHQ-4, with correlation coefficients ranging from −0.61 to −0.34 (all $P<0.01$).

Scale-scale correlations and internal consistency

The global score of the simplified Chinese version of NRSS demonstrated strong associations with its subscales, with coefficients of Spearman's rank correlation ranging between 0.55 and 0.79. The subscales were moderate with each other, with scale-scale correlations in the range of 0.25 to 0.60 (Table 6). The Cronbach's α for the global scale, the refreshment from sleep, physical/medical symptoms of NRS, daytime functioning, and affective symptoms subscales were 0.84, 0.77, 0.77, 0.87, and 0.55, respectively.

Comparison of NRSS between different populations

Upon measurement invariance was concluded, and the mean between the young adults and the Hong Kong Chinese adults and adolescents were compared. Independent t-test showed that Hong Kong Chinese adults reported significantly better NRS conditions than the mainland Chinese young adults except for refreshment from sleep subscale (Table 7). The young adults reported better refreshment from sleep than adolescents while worse affective symptoms than adolescents (Table 7). The values of Cohen's d ranged from 0.193 to 0.771 in terms of the difference between Hong Kong Chinese adults and mainland Chinese adults and ranged from 0.027 to 0.345 in terms of the difference between mainland Chinese adults and adolescents. The linear regression showed that age was only associated with the score of affective symptoms, while language was associated with refreshment from sleep, physical/medical symptoms of NRS, and affective symptoms (Table 8).

Discussion

This study examined the reliability and validity of the simplified Chinese version of NRSS in Chinese young adults and the measurement invariance across language

Table 8 The association of age and Language with NRSS subscales ($n = 1551$)

Variables	Refreshment from sleep		Physical/Medical symptoms of NRS		Daytime function		Affective symptoms	
	Adjusted β[a]	*P*	Adjusted β[a]	*P*	Adjusted β[a]	*P*	Adjusted β[a]	*P*
Age	0.01	0.351	0.00	0.686	0.01	0.415	0.02	< 0.001***
Language (Ref: traditional Chinese)	−0.61	0.005**	0.68	0.024*	0.32	0.117	0.85	< 0.001***

NRSS: Nonrestorative Sleep Scale; NRS: nonrestorative sleep

*: $P < 0.05$; **: $P < 0.01$; ***: $P < 0.001$

and age. Both the exploratory and confirmatory factor analyses showed that the simplified Chinese NRSS had good structural validity, and measurement invariance was concluded across language and age.

The EFA identified a four-factor model, which was in line with the structure of the original English version [17]. The corrected item-total correlation of Item 11 was marginally smaller than 0.3. However, the factor loading obtained by EFA and the standardized coefficient obtained by CFA were both greater than 0.4, and the model fit was satisfactory in the CFA. Therefore, this item was retained to ensure better alignment with the original version. Notably, although the bifactor model of 12-item NRSS showed a satisfactory model fit in this sample, the coefficient of the explained common variance was around 0.5, which was smaller than the cut-off values and couldn't support the bifactor model [46]. Therefore, the bifactor model was not established.

The scalar level invariance between the simplified Chinese NRSS and the traditional Chinese version in adults, as well as that of the simplified Chinese version between young adults and adolescents, was established. Establishing metric and scalar invariance is crucial and sufficient when the research focus is on comparing observed mean differences between groups [47]. Hence, the raw scores of the Chinese NRSS across languages and age groups could be compared to identify whether there would be any significant difference between various groups.

As hypothesized, the observed associations of the simplified Chinese NRSS with the PSQI and PHQ-4 demonstrated its convergent validity [17]. NRS was found to be more frequent among poor sleepers [48]. Moreover, sleep quality and depression were found to be related to NRS [49]. Thus, relieving depression symptoms and improving sleep quality may help reduce the level of NRS [49].

The four subscales of the simplified Chinese NRSS were moderately associated with each other, with correlation coefficients ranging from 0.25 to 0.60, showing that these subscales measured essentially different aspects of NRS [21]. The correlation coefficient between the refreshment from sleep and daytime functioning subscales reached 0.60, reflecting results from prior English and Chinese validations [17, 20, 21]. As proposed before, people are anticipated to perform better if they feel more refreshed after sleep [50]. Hence, the stronger correlation between the two subscales than the others is reasonable. Hereto, the simplified Chinese NRSS is demonstrated to be valid and reliable for measuring NRS in mainland Chinese adults, and the measurement invariance was established across language and age.

Comparison of NRS between mainland Chinese young adults and Hong Kong Chinese adults showed that Hong Kong Chinese adults reported significantly better NRS conditions than mainland Chinese young adults except for the refreshment from sleep subscale, with coefficients of the effect size ranging from 0.193 to 0.771. Previous studies showed that middle-aged adults reported more NRS than either the younger or older adults measured by asking "refreshment from sleep" [23, 51]. The average ages were 20 and 39 for the mainland Chinese young adults and Hong Kong Chinese adults, respectively. However, the linear regression preliminarily showed that age was only associated with the score of affective symptoms. Specifically, the older people showed less affective symptoms of NRS than the younger group. The difference between the other three subscales and the overall scale might be due to risk variables that were not covered in this study. In addition, language contributed to the difference in refreshment from sleep, physical/medical symptoms of NRS, and affective symptoms. Potential rationale should be considered holistically, such as differences in sleep culture, lifestyle, and other variables that might be associated with NRS, especially since the evidence showed that Hong Kong was one of the most sleep-deprived places in the world [24]. For example, Hong Kong Chinese adults are more influenced by Western cultures and consume more coffee, which was demonstrated to help daytime function and potential protective influence on affective symptoms [52, 53]. Moreover, previous research indicates that elevated room temperatures and high humidity levels contribute to increased awakenings and reduced sleep efficiency. The climatic conditions, including temperature and humidity, differed between Hong Kong and Nanjing [23]. Therefore, more comprehensive studies involving potential associated factors and confounders with an adequate sample should be conducted to identify the possible influencing factors, and in-depth studies, such as laboratory studies on the

underlying mechanism of specific dimensions, could be applied to help explore the differences between different populations [54].

Compared to adolescents, mainland Chinese young adults exhibited better sleep refreshment but worse affective symptoms. However, the effect sizes were smaller than 0.2 except for that of refreshment from sleep (0.345), which was medium. Academic stress among Chinese adolescents is known to be high because of competitive examinations, and they frequently suffer from sleep deprivation and poor sleep quality [55]. Therefore, they might feel less refreshed from sleep than the university students who have overcome the pressure of the national college entrance examination. However, university students might be more vulnerable to emotional problems since they begin to contact the complex society, face more sources of stress, and undergo the transition to adulthood despite primary study and examination during adolescence [56]. Furthermore, university students usually are far away from family and parents, which may make them less emotionally supported [56]. Moreover, previous studies reported that young adults had poor sleep habits, such as staying up late due to increased mobile phone use [16]. However, these variations might result from factors beyond the scope of this study, suggesting that future research should consider exploring influences like lifestyle and sleep practice.

To our knowledge, this study made the first effort to assess the psychometric properties of the simplified Chinese NRSS among mainland Chinese young adults, while simultaneously examining its cross-linguistic applicability (i.e., simplified Chinese vs. traditional Chinese) and age-group generalizability (i.e., adults and adolescents). Second, this study revealed significant disparities in NRSS patterns between mainland Chinese adults and their Hong Kong counterparts, as well as between adult and adolescent populations within mainland China. These empirical findings not only advance our understanding of cross-cultural and developmental variations in NRS but also provide crucial directions for future research to identify potential underlying factors contributing to these observed differences. However, several limitations of the study are worth noting. First, due to the anonymous sampling limitation, the test-retest reliability of the simplified Chinese NRSS in adults could not be verified. It would be preferable to gather a new sample to assess test-retest reliability. Second, some researchers suggest that a minimum of three items per factor be maintained for factorial validity. Whether additional items should be incorporated into the scale could be investigated in future studies. Nevertheless, the total score is recommended as the primary measure for NRS. Third, report bias is unavoidable as all questionnaires were voluntarily self-reported by students. Although some studies have tried to investigate whether specific objective parameters would indicate the condition of NRS, no gold standard has been verified. Future studies involving instruments such as polysomnography or electroencephalograms are worth the attention of sleep specialists. Lastly, expanding invariance testing would be valuable for facilitating meaningful comparisons across cultural, demographic, and temporal contexts, contributing to a deeper understanding of the underlying mechanisms of NRS. In addition, once longitudinal invariance is established, longitudinal studies could explore the potential "upstream" factors of NRS, thereby enhancing NRS intervention approaches.

Conclusions

To conclude, the 12-item simplified Chinese NRSS is a reliable and valid tool to evaluate NRS among Chinese young adults, and the score could be compared between the simplified Chinese NRSS and traditional Chinese NRSS and between adolescents and young adults with the simplified Chinese version to enhance our understanding of sleep problems in these ethnic groups.

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Author contributions

Daniel Yee Tak Fong, Sha Li, and Zheng Lin contributed to the conception and design of the study. Material preparation and data collection were performed by Yanzhe Wang, Weijie Gong, Daniel Yee Tak Fong, Ziyuan Yu, Ruiheng Nong, and Sha Li. Sha Li and Xingchen Shang performed data analysis. The first draft of the manuscript was written by Yanzhe Wang, Weijie Gong, and Sha Li. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability

The datasets generated and/or analyzed during the current study are not publicly available due to confidentiality.

Declarations

Ethics approval

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Institutional Review Board of Shenzhen University [No.: PN-202300022] and the Institutional Review Board of Nanjing Medical University [No.: (2023) 585].

Informed consent

Informed consent was obtained from all individual participants included in the study.

Consent for publication
Not applicable.

Competing interests
The authors have no relevant financial or non-financial interests to disclose.

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