Sleep and Breathing (2023) 27:1541–1555
https://doi.org/10.1007/s11325-022-02725-9

EPIDEMIOLOGY • ORIGINAL ARTICLE

Metabolic risk factors and psychosocial problems independently explain poor sleep quality and obstructive sleep apnea symptoms among adults in urban India

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Received: 12 July 2022 / Revised: 27 September 2022 / Accepted: 3 October 2022 / Published online: 25 October 2022

Abstract

Study objectives To determine if metabolic risk factors are associated with poor sleep quality and obstructive sleep apnea–like symptoms (OSA symptoms) independent of psychosocial problems and demographic and lifestyle factors in older Indian adults.

Methodology We analyzed baseline data from adults (≥ 50 years) from a population-based cohort, the LoCARPoN study, in India. Variables were grouped as (a) demographic and lifestyle factors such as smoking, alcohol use, and physical activity; (b) psychosocial problems including symptoms of depression, anxiety, and perceived stress; and (c) metabolic risk factors including glycated hemoglobin, high-density lipoprotein, low-density lipoprotein, total cholesterol, body mass index, and hypertension. Variables were examined as predictors of poor sleep quality and OSA symptoms. Groups of variables were added stepwise to a logistic regression. Variance explained by nested models was quantified using McFadden's pseudo R^2, and change was formally tested with the log-likelihood ratio test.

Results Among 7505 adults, the prevalence of poor sleep quality was 16.9% (95% CI: 16.0, 17.7), and OSA symptoms were present in 7.0% (95% CI: 6.4, 7.6). Psychosocial problems had a strong independent association with both poor sleep quality (pseudo R^2 increased from 0.10 to 0.15, $p < 0.001$) and more OSA symptoms (pseudo R^2 increased from 0.08 to 0.10, $p < 0.001$). Metabolic risk factors had a modest independent association with sleep quality (pseudo R^2 increased from 0.14 to 0.15, $p < 0.01$), but a strong association with OSA symptoms (pseudo R^2 increased from 0.08 to 0.10, $p < 0.001$).

Conclusion Psychosocial and metabolic risk factors were independently associated with sleep quality and OSA symptoms. This fact implied that OSA symptoms may affect both mental health and physical health. Our findings have public health implications because the number and proportion of the elderly in India is increasing, while the prevalence of metabolic risk factors and psychosocial problems is high already. These facts have the potential to exacerbate not only the burden of sleep disorders and OSA symptoms but also associated cardiovascular and neurologic sequelae, further stretching the Indian health-care system.

Keywords Sleep · Poor sleep quality · PSQI · OSA symptoms · Prevalence · India · Determinants · Metabolic risk factors · Psychosocial problems · Depression · Anxiety

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Introduction

The contribution of cardiovascular diseases to mortality increased by 34% during the last three decades in India [1]. In this same period, a concomitant rise in underlying risk factors, namely obesity, high blood pressure, fasting blood glucose, and dyslipidemia was noted. These metabolic risk factors along with psychosocial problems tend to become confluent among older adults. In India, almost one in ten (over 139 million) people belong to the elderly age group (60 years or above) in whom high prevalence of chronic diseases, depression, and anxiety constitutes a major public health challenge [2–4].

Sleep is a critical physiological process that maintains the body's circadian rhythm, by not only providing physical rest, but also ensuring internal restorative functions [5]. Inadequate and poor-quality sleep can interrupt the health-promoting functions that occur during sleep, leading to poorer health outcomes [6]. Population-based data on prevalence of subjective poor sleep quality in India are limited, since most studies have beeen conducted in a clinical setting. The reported prevalence of poor sleep quality based on community-based studies was 27% from south India, 43% from urban east India, and 39% from rural east India [7, 8]. Subjective poor sleep quality has been associated with an increased risk of metabolic syndrome including obesity and diabetes [9, 10], higher rates of hypertension [11, 12], and dyslipidemia [10, 13].

The abnormal collapse of the pharyngeal airway during sleep leading to apneic episodes and the resulting repetitive arousals is termed obstructive sleep apnea (OSA) [14]. OSA symptoms, characterized by snoring and sleepiness, are strongly associated with obesity [10], and also with metabolic syndrome, including insulin resistance, and dyslipidemia through inflammatory pathways, as well as with hypertension [15]. OSA symptoms are associated with worsening hypertension, arrhythmias, stroke, and myocardial infarction [12].

In high-income countries, the metabolic and psychosocial problems co-occur with both poor sleep quality [9–13] and OSA symptoms [10, 15–17]. While the association of metabolic risk factors in obesity or cardiovascular diseases is well documented in India, the extent of their association with sleep problems or OSA symptoms remains less clear. Importantly, studies aiming to assess the independent contribution of metabolic risk factors must account for psychosocial problems, in particular symptoms of depression and anxiety, since they exist as common co-morbidities of metabolic dysregulation and sleep problems [8, 18]. However, there is no population-based study among this age group from India that assessed the quality of sleep and OSA symptoms, while considering psychosocial problems and metabolic risk factors together.

The population-based LoCARPoN study of persons aged 50 years and above in India provided an opportunity to describe the pattern of sleep quality and risk of OSA symptoms and their association with metabolic risk factors. Our research question was to determine if metabolic risk factors, independently of psychosocial problems, are associated with poor sleep quality and OSA symptoms. To fulfill this aim, we included common metabolic and frequently occurring psychosocial problems. Since the prevalence of metabolic risk factors is high in all age groups in India, we hypothesized that metabolic risk factors can explain additional variability of poor sleep quality and OSA symptoms independent of psychosocial problems and demographic and lifestyle factors in older Indian adults. As a secondary objective, we also assessed and presented the association of psychosocial factors with poor sleep quality and OSA symptoms, independently of metabolic factors.

Methods

Study population

This was a cross-sectional study using the baseline data of the Longitudinal Cognition and Aging Research on Population of the National Capital Region-LoCARPoN (*Hindi—"dedication-to-people"*) study [19]. The LoCARPoN is a population-based cohort of middle-aged and older adults in New Delhi, India, aimed at studying India-specific risk factors with the onset of stroke, dementia, and mental health.

Between year 2016 and 2019, 8858 participants aged 50 years and above consented and were enrolled from two areas in South Delhi by household visits. A total of 7505 individuals (85%) attended the study center for in-person assessments including cognitive testing and cardiovascular examinations, and provided blood specimens for estimates of blood glucose and lipid profile. We analyzed the data of these 7505 individuals for the present study. The LoCARPoN study was approved by the Institutional Ethics Committee of All India Institute of Medical Sciences, New Delhi, India (reference number: IEC/NP-53/2014 RP-12/2014). Written informed consent was obtained from individual participants.

Exposure assessment

Pre-tested structured questionnaires were used to collect information on (a) socio-demographics age, sex, education

(assessed in continuous scale as *"years of schooling"*), and marital status (marital status was dichotomized to married or divorced/widow/single); (b) *lifestyle factors* smoking, alcohol, and physical activity. For the purpose of the current analysis, both smoking and alcohol were taken as ever smoker and ever alcohol. In the baseline assessment study, these variables were assessed by face-to-face interview questions; physical activity was assessed using the international physical activity questionnaire (IPAQ), and categorized as mild, moderate, and high levels of physical activity. (c) *psycho-social factors* (symptoms of depression, anxiety and perception of social support, and stress) and *cognition*; symptoms of depression, based on the scores of the 30-item geriatric depression scale, were categorized into normal (< 10), mild (10 to < 20), and moderate to severe (20 to 30) [20]. Symptoms of anxiety, based on the 11-item ACS anxiety scale, were categorized into normal (< 2), mild (2 to 5), and moderate to severe (6 to 11) [21]. The 7-item psychosocial stress scale from the INTERHEART study was used to assess levels of stress and categorized as mild normal (< 2) and moderate-to-severe (≥ 2) stress [22]. Social support was categorized into inadequate (< 5) and adequate (≥ 5). These categorizations were done to aid in the comparison with other studies and also to make clinical interpretations. (d) *metabolic factors* included fasting glucose, total cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL), glycated hemoglobin, and the *cardiovascular risk factors* blood pressure (BP) and body mass index (BMI). The cut-offs for BMI (in kg/m^2) were set as underweight (< 18.5), normal (18.5–25), pre-obese (25–30), and obese (> 30), according to the World Health Organization [23]. Overnight fasting blood specimens were used to estimate fasting blood glucose, HDL, LDL, and total cholesterol using an Erba XL-640 Biochemistry Analyser. Glycated hemoglobin (HbA1C) was measured on the same blood specimen using the high-performance liquid chromatography (HPLC) method in a Biorad D-10-HbA1c Analyser. Dyslipidemia for each measure of lipid profile was defined as total cholesterol ≥ 200 mg/dL, LDL ≥ 130 mg/dL, and HDL ≤ 60 mg/dL. These cut-offs were based on the Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III)-NCEP ATP III guidelines, which also recommended that ideal HDL levels should be between 40 and 60 mg/dL [24]. Diabetes mellitus was defined as HbA1c ≥ 6.5% (as per the American Diabetic Association-ADA International Expert Committee report) [25], or currently on medication for diabetes mellitus. High blood pressure was defined as either SBP ≥ 140 mmHg or DBP ≥ 90 mmHg (as per the Seventh Report of the Joint National Committee-JNC on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure) [26] and/or currently on medication for hypertension. Using an electronic blood pressure instrument (OMRON HEM-8712), BP was measured with three readings on the right arm, 5 min apart. The mean of the three readings were included for SBP and DBP. For anthropometry, the mean of three readings was taken for body weight (in kilograms, digital weighing machine) and height (in centimeters, stadiometer with metallic metric tape mounted on a wall). In addition, medication for diabetes mellitus and high blood pressure was self-reported. The Mini Mental Status Examination (MMSE)-Hindi version, was used as a cognitive screening tool.

Outcome assessment

Sleep quality characteristics were assessed using the Pittsburgh Sleep Quality Index (PSQI). The PSQI is a self-rated questionnaire consisting of 19 items grouped into seven components: subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, use of sleeping medication, and any daytime dysfunction. Each component score ranges from 0 to 3 (higher is worse), and the components are summed to get the total score. Participants with a global PSQI score greater than 5 were categorized as having poor sleep quality. Difficulty in initiating sleep was defined as a sleep latency of more than 30 min. Disturbed sleep was also derived from the PSQI and defined as trouble sleeping experienced any time during the past month, with score range 0–3; the summed score was categorized (≥ 1 = disturbed sleep, 0 = no disturbed sleep).

Sleep components: *sleep medication* was defined as the reported use of any prescribed or "over-the-counter" medication to aid sleep at least once a week (yes/no). Sleep latency was defined as the duration it has taken to fall asleep each night, in the past one month (in minutes). *Sleep duration* (in hours) was self-reported, as hours of actual sleep that the person got at night. *Total time in bed* (hours) was calculated as the difference between bedtime and wake time in hours. *Habitual sleep efficiency (HSE)* (in %) was calculated as (sleep duration/total time in bed * 100). Since sleep duration and total time in bed were assessed separately, it may result in implausible high values, but probably represent high HSE. To balance this bias in estimates with loss of precision: values between 100 and 110% were recoded to 100%. *Daytime dysfunction*: self-reported, yes/no, if answered yes to any of the following: trouble staying awake while driving, eating meals, or engaging in social activity at least once a week, *or*, problem in keeping up enough enthusiasm to get things done.

Symptoms of obstructive sleep apnea (OSA) were measured with the Berlin questionnaire (BQ). The questionnaire

consists of eight questions; five items assess symptoms of snoring (category 1), three items assess symptoms of sleepiness (category 2), and a third category consists of either hypertension or BMI ≥ 30 kg/m^2 (category 3). Categories 1 and 2 are considered positive if the score is ≥ 2 points. An individual with a score of 2 and above on the Berlin questionnaire is considered as at high risk of OSA symptoms, while those having a score below 2 are designated as at low risk. Since our objective was to assess the association of metabolic risk factors with the risk of OSA symptoms, we decided not to include the third category in the definition of OSA symptoms. Having the third category, defined by high blood pressure or BMI ≥ 30 kg/m^2, would have resulted in model misspecification if BMI and hypertension were also included as covariates in the model. A similar approach has been used by Peker Y. et al. who developed a modified high-risk (mHR) OSA score by ignoring obesity and hypertension [27].

Hence, we used only category 1 and category 2 to classify individuals at high risk of OSA (total score ≥ 2) so as to allow us to include BMI and hypertension in the model. We could not get any reference where BQ was deployed as mentioned above; hence, we cannot comment on the change in validity of the questionnaire. However, since essentially the outcome variable of OSA symptom reflected the cardinal two symptoms of snoring and sleepiness, which are actually the only two components of BQ specifically for OSA symptoms, we believe that using the BQ excluding the third category will not affect the validity of the instrument to identify those with symptoms of snoring and sleepiness. Use of the BQ was not intended to make a diagnosis of OSA but to enable identification of individuals who are at high risk of OSA symptoms of snoring and sleepiness.

Statistical analysis

We presented a descriptive analysis of participants' characteristics as frequencies and percentages for categorical variables, or as mean (S.D.) for continuous variables. The unadjusted associations between categorical variables were assessed with Pearson's chi-squared test, and those between continuous variables and categorical variables with *t* test or one-way analysis of variance (ANOVA). In model 1, we estimated the association of each covariate with the outcome variables, i.e., separately for sleep quality and OSAS, by binary logistic regression, adjusted for age and sex. We report adjusted odds ratio (AOR) with 95% CI.

Thereafter, we made 3 groups of variables, namely, group 1: demographic (age, sex, marital status, education) and lifestyle factors (smoking, alcohol use, physical activity); group 2: psychosocial problems (symptoms of depression, anxiety, perceived stress, and social support); and group-3: metabolic risk factors (diabetes, BMI, HDL, LDL, total cholesterol, hypertension). To assess the independent association of psychosocial problems and metabolic risk factors with each outcome, we fitted three successive multivariable models as follows: model 2a included two groups of variables, i.e., psychosocial problem and demographic and lifestyle factors; model 2b also had two groups of variables, i.e., metabolic risk factors and demographic and lifestyle factors; and model 3 was the full model which had variables belonging to all 3 groups. Thus, model 2a and 2b were essentially nested models of full model 3. The process was repeated for each outcome.

Independent contribution by nested models was quantified using McFadden's pseudo R^2 for logistic regression. Thus, we compared pseudo R^2 between model 2a and model 3 to assess the independent contribution of metabolic risk factors, and between model 2b and model 3 to assess the independent contribution of psychosocial problems to each outcome. Any observed change in pseudo R^2 was formally tested with a log-likelihood ratio test (LRT), and was considered significant at $p < 0.05$.

Sensitivity analysis after excluding individuals with a past history of stroke A self-reported history of stroke was collected in this study, and a total of 109 (1.5%) of 7505 individuals reported having stroke in the past (males 77, females 32). We conducted a sensitivity analysis to explore if the associations would change, after excluding these 109 individuals. Therefore, after excluding these 109 individuals, we reanalyzed the data and implemented model 1, model 2a, model 2b, and model 3 for both the outcomes that are poor sleep quality and symptoms of obstructive sleep apnea.

For covariates with missing data, multiple imputation was performed with the "*mice*" package, using option "*predictive-mean-matching*." Glycated hemoglobin had the most missing values (22.5%); other missing covariate values did not exceed 2%. Associations with $p < 0.05$ were considered statistically significant in multivariable analysis. All analyses were performed in R.

Power calculation showed that for a 5% level of significance, with a sample size of 7505, we would have a power of 90% to detect an estimated odds ratio of 1.11 for multivariable logistic regression, where R^2 for covariates has been kept at a high of 0.35 considering their syndromic presence. Supplementary file figure-1 provides a graphical representation of the sample sizes as a function of different odds ratios for a given power of 90% for logistic regression. Power calculation was done using G-power software (G*Power Version 3.1.9.6 http://www.gpower.hhu.de/).

Since the incidence of the outcome of interest was common in our study population (> 10%), the adjusted odds ratio derived from the logistic regression may no longer approximate the risk ratio, since, with more frequent outcome, the odds ratio tends to overestimate the risk ratio, if OR > 1, or underestimate it if OR < 1. Hence, we used the formula RR = OR / (1 − Po) + (Po*OR), where Po is the prevalence

in the non-exposed group, suggested by Zhang J. et al. [28] to convert OR derived from logistic regression to RR. We presented the adjusted RR for the fully adjusted model 3 in Table 4 and Table 5.

Results

We analyzed the data of 7505 individuals with a mean age of 64.5 (SD: 9.2) years, ranging 50–99 years; females comprised half of the cohort (50.1%). The demographic, lifestyle, metabolic, and psycho-social characteristics are presented in Table 1.

Prevalence of poor sleep quality and OSA symptoms

The prevalence of poor sleep quality (global PSQI score > 5) was 16.9% (95% CI: 16.0, 17.7), significantly lower among males, 12.3% (95% CI: 11.2, 13.4), than females, 21.0% (95% CI: 19.7, 22.3), and increased with age from 14.0% (50–60 years) to 21.2% (≥ 80 years) (Supplementary Table S1). Table 2 describes the prevalence of each sleep characteristic by age and sex. *A long sleep latency*, i.e., difficulty initiating sleep (> 30 min), was present in 7.5% of participants; this was more common in females (9.9%) than in males (5.0%). The average *sleep duration* was 6.5 ± 1.1 h shorter in females than males, but did change with age. Around 4% of the participants slept < 5 h; almost half slept 7 to 8 h. On an average, the *habitual sleep efficiency* (HSE) was 82%. Overall, *subjective sleep quality* was 0.69 (on a scale of 0—better to 3—poor). Some form of *sleep disturbance* was found in 38% of the participants, most commonly due to "getting up for bathroom" (25%), and "waking up in middle of night" (25%). Sleep disturbances were more common among females (43.1%) than males (32.5%). Overall, 11.4% participants reported experiencing *daytime dysfunction*, which increased with age from 9.1% (50–60 years) to 15.9% (≥ 80 years) by age.

Symptoms of *snoring* were reported by 46% (95% CI: 44.6, 46.9) of participants and *daytime sleepiness by* 13.7% (95% CI: 12.9, 14.5) (Table 3). Almost one in ten participants reported nodding off at least 3–4 times a week while driving. Of 7505 participants, 525 (overlap category 1 and 2) reported symptoms of both snoring and daytime sleepiness resulting in prevalence of likely OSA as 7.0% (95% CI: 6.4, 7.6), higher among females (8%) than in males (6%); the prevalence of likely OSA decreased with age from 8.3% (50–60 years) to 7.6% (≥ 80 years).

Correlates of poor sleep quality

Age- and sex-adjusted OR of mild and moderate-severe symptoms of depression, anxiety, stress, perception of

Table 1 Characteristics of study participants at baseline of the cohort

	(*n* = 7505)
Demographic characteristics	
Women, *n* (percentage)	3825 (50.1)
Age in years, mean ± SD	64.5 ± 9.2
Age in years, min, max (IQR)	50, 99 (57, 71)
Age group, *n* (percentage)	
50 to < 60 years	2439 (32.5)
60 to < 70 years	2852 (38.0)
70 to < 80 years	1717 (22.9)
≥ 80 years	497 (6.6)
Years of schooling, mean ± SD	15.3 ± 3.4
Height in m, mean ± SD	1.6 ± 0.1
Weight in kg, mean ± SD	71.1 ± 13.0
Lifestyle factors	
Ever smoker, *n* (percentage)	1566 (21.1)
Ever alcohol, *n* (percentage)	2885 (39.3)
Physical activity category, *n* (percentage)	
High	373 (5.0)
Moderate	4864 (64.8)
Low	2268 (30.2)
Metabolic factors	
Body mass index in kg/m^2, mean ± SD	27.5 ± 4.5
Body mass index category, *n* (percentage)	
< 18.5 kg/m^2 (underweight)	69 (0.9)
18.5–24.9 kg/m^2 (healthy weight)	2179 (29.0)
25.0–29.9 kg/m^2 (overweight)	3362 (44.8)
≥ 30.0 kg/m^2 (obese)	1895 (25.2)
Systolic blood pressure in mmHg, mean ± SD	136.7 ± 18.5
Diastolic blood pressure in mmHg, mean ± SD	81.9 ± 10.6
Hypertension, *n* (percentage)	4170 (55.6)
Blood pressure category as per JNC-7, *n* (percentage)	
Normal	1035 (13.8)
Pre-hypertension	3111 (41.5)
Hypertension stage 1	2355 (31.4)
Hypertension stage 2	988 (13.2)
Fasting blood glucose in mg/dL, mean ± SD	106.3 ± 35.8
HbA1C in mmol/mol, mean ± SD	6.3 ± 1.2
Diabetes, *n* (percentage)	1882 (32.4)
Serum lipid profile, *n* (percentage)	
Cholesterol (≥ 200 mg/dL)	2165 (28.9)
HDL (≤ 60 mg/dL)	4532 (60.6)
LDL (≥ 130 mg/dL)	1685 (22.6)
Internal psychopathologic states	
Perceived social support score, mean ± SD	4.5 ± 2.3
Perceived social support, *n* (percentage)	
Inadequate (< 5)	
Adequate (< 5)	
Symptoms of stress, score, mean ± SD	0.70 ± 0.93
Symptoms of stress, *n* (percentage)	
Mild normal (< 2)	6258 (83.4)
Moderate-severe stress (≥ 2)	1247 (16.6)

Table 1 (continued)

	(*n* = 7505)
Symptoms of anxiety, score, mean ± SD	1.6 ± 2.2
Symptoms of anxiety, *n* (percentage)	
No anxiety (< 2)	4204 (56.0)
Mild anxiety (2–5)	2578 (34.3)
Mod-severe anxiety (6–11)	723 (9.6)
Symptoms of depression, score, mean ± SD	3.9 ± 5.0
Symptoms of depression, *n* (percentage)	
No depression (< 10)	7743 (87.4)
Mild depression (10–20)	929 (10.5)
Moderate-severe depression (21–30)	186 (2.1)
Cognition, MMSE score, mean ± SD	28.4 ± 2.1

inadequate social support, hypertension, diabetes, and dyslipidemia were associated with poor sleep quality; higher education, cognition score, and moderate physical activity were associated with lower odds of poor sleep quality (Table 4). In the full model (model 3), demographic characteristics (age, female sex, being divorced/widow(er)/single), psycho-social problems (symptoms of depression and anxiety), and metabolic risk factors (hypertension and low HDL) were independently associated with poor sleep quality, while higher education and moderate physical activity were inversely associated with poor sleep quality. Diabetes mellitus was not significant in the full model. Table S2 shows factors associated with sleep latency and sleep disturbances.

Independent contribution of psychosocial problems and metabolic risk factors to poor sleep quality

Nested models comprising the group of variables pertaining to psychosocial problems and another for metabolic risk factors, each adjusted for demographic and lifestyle factors, were compared with the full model (Table 4). Between models 2a and 3, the pseudo R^2 increased very modestly but significantly from 0.14 to 0.15 (LRT $p < 0.01$, df = 8, chi2 = 25.1) implying a small independent contribution of metabolic risk factors to poor sleep quality. Between models 2b and 3, the pseudo R^2 increased from 0.10 to 0.15 (LRT $p < 0.001$, df = 7, chi2 = 303.4). This implied that psychosocial factors are independently associated with poor sleep quality (Table 4).

Correlates of OSA symptoms

Age- and sex-adjusted OR of mild and moderate-severe symptoms of depression, anxiety, stress, inadequate social support, overweight, and diabetes mellitus were associated with OSA symptoms; higher education and moderate physical activity were associated with lesser odds of OSA symptoms (Table 5). In the full model (model 3), psychosocial problems (symptoms of anxiety and moderate-severe depression), and metabolic risk factor (BMI ≥ 25 kg/m^2), were independently associated with more OSA symptoms, while moderate physical activity was protective. Demographic characteristics were not significant in the full model. Supplementary Table S3 shows factors associated with snoring and sleepiness components.

Independent contribution of psychosocial problems and metabolic risk factors to OSA symptoms

We found an independent contribution of metabolic risk factors on the odds of having OSA symptoms. This is reflected in the increase of the pseudo R^2 from 0.08 to 0.10 between model 2a and model 3 (LRT $p < 0.001$, df = 8, chi2 = 48.2). The psychosocial factors also had an independent effect on OSA symptoms as evident with pseudo R^2 increased from 0.08 to 0.10 between models 2b and 3 (LRT $p < 0.001$, df = 7, chi2 = 70) (Table 5).

In sensitivity analysis, we found that excluding the 109 individuals who reported a history of stroke in the past did not lead to any change in the pattern of associations reported already (Supplementary Table S4 and Supplementary Table S5).

Discussion

We present data from an Indian cohort of older adults to study the frequency and risk factors for subjective poor sleep quality and likelihood of OSA symptoms. The most salient findings were the independent association of metabolic factors with sleep quality and the independent association of psychosocial problems with OSA symptoms.

Prevalence of poor sleep quality

Almost one in six individuals (16%) had poor sleep quality in our study. Comparatively higher prevalence was reported by two community-based studies, with small sample sizes, namely 28% by George et al. [8] (elderly population, *n* = 170, rural southern India) and 43% by Mondal et al. [7] (adults, mean age 38.5 years, urban eastern India). In the absence of representative population-based studies, hospital-based studies are often used to estimate symptom prevalence in India, thus giving a skewed distribution.We argue that the prevalence of 16.9% reported in the present study based on a large community sample of urban adults using a standardized and valid PSQI tool characterizes poor sleep quality in the Indian urban context best.

Prevalence of OSA symptoms

The probability of clinically relevant OSA symptoms was 7% in our study. Studies from India among the general

Table 2 Components of sleep quality measured by the Pittsburgh Sleep Quality Index, by sex and age group

Sleep quality components	*n*	Total	Male	Female	*p* value	50–59 yrs	60–69 yrs	70–79 yrs	≥ 80 yrs	*p* value
Subjective sleep quality[#], mean ± SD	7499	0.69 ± 0.62	0.63 ± 0.60	0.75 ± 0.64	2.20E − 16	0.64 ± 0.63	0.69 ± 0.62	0.75 ± 0.62	0.75 ± 0.61	1.53E − 07
Sleep latency, *n* (%)	7444									
≤ 15 min		4164 (55.9)	2178 (60.0)	1986 (52.3)	2.20E − 16	1414 (58.7)	1578 (55.7)	921 (53.9)	251 (50.7)	0.002
> 15–30 min		2721 (36.6)	1282 (35.2)	1439 (37.9)		845 (35.1)	1027 (36.2)	645 (37.7)	204 (41.2)	
> 30 min		559 (7.5)	184 (5.0)	375 (9.9)		148 (6.1)	228 (8.0)	143 (8.4)	40 (8.0)	
Sleep duration, mean ± SD (h)		6.5 ± 1.1	6.6 ± 1.0	6.4 ± 1.1	6.38E − 10	6.5 ± 1.1	6.5 ± 1.1	6.4 ± 1.1	6.5 ± 1.1	0.07
Sleep duration, *n* (%)	7419									
< 5 h		290 (3.9)	115 (3.2)	175 (4.6)	5.21E − 05	81 (3.4)	112 (4.0)	77 (4.5)	20 (4.0)	0.1005
5–6 h		3342 (4.5)	1577 (4.3)	1765 (46.6)		1053 (43.9)	1244 (44.0)	807 (47.4)	238 (48.2)	
7–8 h		3652 (4.9)	1869 (5.1)	1783 (47.1)		1214 (50.7)	1423 (50.4)	789 (46.3)	226 (45.7)	
> 8 h		135 (1.8)	72 (2.0)	63 (1.7)		48 (2.0)	47 (1.7)	30 (1.8)	10 (2.0)	
Habitual sleep efficiency[$], *n* (%)	7367									
≥ 80%		6061 (82.3)	3068 (85.1)	2993 (79.6)	5.49E − 09	1998 (84.3)	2314 (82.3)	1356 (80.0)	393 (79.9)	0.01
60–80%		1079 (14.6)	450 (12.5)	629 (16.7)		300 (12.7)	416 (14.8)	280 (16.5)	83 (16.9)	
< 60%		227 (3.1)	89 (2.5)	138 (3.7)		71 (3.0)	8 (2.8)	60 (3.5)	16 (3.3)	
Sleep disturbances[±] (any), *n* (%)	7500									
Yes		2842 (37.9)	1194 (32.5)	1648 (43.1)	2.20E − 16	779 (32.0)	779 (32.0)	779 (32.0)	779 (32.0)	2.20E − 16
No		4658 (62.1)	2482 (67.5)	2176 (56.9)		1658 (68.0)	1658 (68.0)	1658 (68.0)	1658(68.0)	
Use of sleep medication[Ψ], *n* (%)	7500									
Yes		275 (3.7)	111 (3.0)	164 (9.6)	4.21E − 03	55 (2.3)	92 (3.2)	100 (5.8)	28 (5.7)	2.04E − 09
No		7225 (96.3)	3565 (97.0)	3660 (4.3)		2382 (97.7)	2758 (96.8)	1617 (94.2)	468 (94.3)	
Daytime dysfunction[&] (any), *n* (%)	7500									
Yes		853 (11.4)	346 (9.4)	507 (13.3)	1.91E − 07	221 (9.1)	292 (10.2)	261 (15.2)	79 (15.9)	3.64E − 11
No		6647 (88.6)	3330 (90.6)	3317 (86.7)		2216 (90.9)	2558 (89.8)	1456 (84.8)	417 (84.1)	

[#]Score ranges from 0 to 3; a higher score indicates poor subjective sleep quality

[$]Derived as hours of sleep / (get up time − usual bedtime) * 100%

[±]Derived from PSQI items 5b–5j; each score ranges from 0 to 3, a higher score indicates more sleep disturbances

[Ψ]Reported as use of any medication to aid in sleep at least once a week (yes/no)

[&]PSQI items 8 and 9

Table 3 Prevalence of symptoms of obstructive sleep apnea, using the Berlin questionnaire

Characteristics	Numbers $n=7505$	Proportion (%) (95% CI)
High risk for category 1 symptoms (*snoring*)	3434	45.7 (44.6, 46.9)
Snoring—yes	4330	57.7 (56.6, 58.8)
Snoring louder than talking/very loud	315	4.2 (3.8, 4.7)
Snoring almost every day/3–4 times a week	3206	42.7 (41.6, 43.8)
Snoring bothers other people	1628	21.7 (20.8, 22.6)
Quit breathing during sleep, every day/3–4 times a week	191	2.5 (2.2, 2.9)
High risk for category 2 symptoms (*sleepiness*)	1029	13.7 (12.9, 14.5)
Tired after sleeping—almost every day/3–4 times a week	1242	16.6 (15.7, 17.4)
Tired during wake time—almost every day/3–4 times a week	1075	14.3 (13.5, 15.1)
Ever nodded off or fallen asleep while driving	1229	16.4 (15.5, 17.2)
Falls asleep every day/3–4 times a week while driving	486	6.5 (5.9, 7.1)
High risk of symptoms of obstructive sleep apnea (OSA)	525	7.0 (6.4, 7.6)
High risk of symptoms of OSA, by sex		
Male ($n=3680$)	219	6.0 (5.2, 6.8)
Female ($n=3825$)	306	8.0 (7.2, 8.9)
High risk of symptoms of OSA, by age group		
50–60 yrs ($n=2439$)	202	8.3 (7.2, 9.5)
60–70 yrs ($n=2852$)	175	6.4 (5.3, 7.1)
70–80 yrs ($n=1717$)	110	6.4 (5.3, 7.7)
≥ 80 yrs ($n=497$)	38	7.6 (5.5, 10.4)

High risk: if there are 2 or more categories where the score is positive; *low risk*: if there is only 1 or no category where the score is positive

population have reported similar prevalence estimates of 8.7% in rural [29] and 9.3% in urban areas [30]. We used the Berlin questionnaire but restricted the categorization to snoring and sleepiness, while excluding the third category, which is characterized by high BMI and hypertension, as obesity is a known risk factor of OSA symptoms [31]. Globally, prevalence of OSA reportedly varies widely from 6·5 to 17% in women, and between 17 and 34% in men [14, 31]. A systematic review of 10 community studies from Asia that used sleep questionnaires reported the prevalence of OSA symptoms between 4.9 and 27.3% [32]. The review, where most of the studies were from Japan, China, and Singapore, further found that male sex, older age, a higher BMI and waist-to-hip ratio, arterial hypertension, and smoking were associated with OSA. Asians are, on an average, less obese than the population in high-income western countries and may have a lower prevalence. The prevalence reported in our study confirms previous reports that the prevalence of OSA symptoms in Asians is similar to that in populations from North America, Europe, and Australia [33]. Comparable prevalence of OSA symptoms despite relatively lower prevalence of obesity may indicate the contribution of other risk factors in a population. We discuss an independent association of psychosocial factors with OSA symptoms in our study below.

Independent contribution of psychosocial and metabolic risk factors to poor sleep quality

Psychosocial problems, mainly symptoms of anxiety and depression, had a strong independent association with poor quality sleep, sleep latency, and disturbed sleep. Our findings were consistent with studies conducted in India [8, 34, 35], China [18], Korea [36], Turkey [37], USA [38], and Europe [39] as well as other populations [40].

Potvin et al. reported anxiety symptoms to be independently related to short sleep duration, daytime sleepiness, and sleep disturbances [41]. A cross-sectional survey among Korean adults (19–69 years) also found anxiety and depression to be more common among those with insomnia [42]. The relation between sleep quality and depression has been shown to be bidirectional [43]. Maladaptive emotional response is postulated as one of the paths through which inadequate sleep leads to depression [44]. Recently, it has also been shown that poor sleep quality affects the connectivity pathways involving the amygdala and the frontal cortex [45]. In the present cross-sectional design, we cannot infer the direction of the association, which needs to be explored further as the LoCARPoN-Cohort matures. Nonetheless, these findings reiterate the importance of screening for emotional disorders, irrespective of gender, in people presenting with sleep disorders in the Indian context.

Table 4 Factors associated with poor sleep quality measured using the Pittsburgh Sleep Quality Index (PSQI)

Variable	Model 1: age and sex adj		Model 2a		Model 2b		Model 3		Model 3
	AOR[#] (95% CI)	*p* value	AOR (95% CI)	*p* value	AOR (95% CI)	*p* value	AOR (95% CI)	*p* value	RR^ (95% CI)
Demographic and lifestyle factors									
Age[$]	1.03 (1.02, 1.04)	< 0.001	1.03 (1.02, 1.03)	< 0.001	1.02 (1.01, 1.03)	< 0.001	1.02 (1.02, 1.03)	< 0.001	1.02 (1.01, 1.03)
Sex—males (reference)[$]									
Females	2.07 (1.82, 2.35)	< 0.001	1.71 (1.42, 2.05)	< 0.001	2.03 (1.69, 2.45)	< 0.001	1.90 (1.57, 2.30)	< 0.001	1.65 (1.42, 1.92)
Education	0.95 (0.93, 0.96)	< 0.001	0.96 (0.94, 0.98)	< 0.001	0.95 (0.93, 0.97)	< 0.001	0.96 (0.94, 0.98)	< 0.001	0.97 (0.96, 0.98)
Marital status—married (reference)									
Divorced/widow/single	1.30 (1.11, 1.53)	< 0.01	1.21 (1.01, 1.44)	0.03	1.31 (1.10, 1.55)	0.002	1.21 (1.02, 1.44)	0.03	1.16 (1.02, 1.32)
Ever smoker (yes)	1.07 (0.88, 1.30)	0.48	1.04 (0.84, 1.29)	0.72	1.02 (0.83, 1.26)	0.84	1.03 (0.83, 1.27)	0.82	1.02 (0.86, 1.2)
Ever alcohol (yes)	1.02 (0.87, 1.19)	0.84	1.03 (0.85, 1.29)	0.78	1.09 (0.91, 1.30)	0.34	1.03 (0.86, 1.24)	0.71	1.03 (0.89, 1.18)
Physical activity—low (reference)									
Moderate	0.70 (0.61, 0.80)	< 0.001	0.83 (0.72, 0.96)	0.01	0.77 (0.67, 0.89)	< 0.001	0.84 (0.73, 0.97)	0.02	0.88 (0.79, 0.98)
High	0.72 (0.52, 0.99)	0.05	0.93 (0.66, 1.28)	0.65	0.82 (0.58, 1.13)	0.23	0.98 (0.69, 1.36)	0.89	0.98 (0.76, 1.27)
Psychosocial problems									
Symptoms of depression—normal (ref)									
Mild depression	2.64 (2.24, 3.10)	< 0.001	1.47 (1.21, 1.79)	< 0.001			1.50 (1.23, 1.82)	< 0.001	1.36 (1.17, 1.57)
Mod-severe depression	4.75 (3.48, 6.45)	< 0.001	2.03 (1.39, 2.95)	< 0.001			2.08 (1.42, 3.03)	< 0.001	1.69 (1.31, 2.18)
Symptoms of anxiety—normal (reference)									
Mild anxiety	2.25 (1.96, 2.59)	< 0.001	2.18 (1.87, 2.55)	< 0.001			2.18 (1.87, 2.54)	< 0.001	1.8 (1.61, 2.01)
Mod-severe anxiety	4.62 (3.82, 5.57)	< 0.001	3.27 (2.55, 4.18)	< 0.001			3.22 (2.51, 4.13)	< 0.001	2.31 (1.97, 2.7)
Symptoms of stress—mild normal (ref)									
Mod-severe stress (≥ 2)	1.64 (1.40, 1.91)	< 0.001	1.12 (0.94, 1.33)	0.19			1.12 (0.94, 1.33)	0.19	1.09 (0.96, 1.24)
Social support—inadequate (reference)									
Adequate	1.69 (1.45, 1.96)	< 0.001	0.99 (0.82, 1.19)	0.92			0.99 (0.83, 1.19)	0.95	1 (0.87, 1.15)
Cognition (MMSE scores)	0.96 (0.93, 0.98)	< 0.01	1.01 (0.97, 1.04)	0.71			1.00 (0.97, 1.04)	0.84	1 (0.98, 1.03)
Metabolic risk factors									
BMI—healthy weight (18.5–25) (ref)									
Underweight (< 18.5)	1.08 (0.57, 1.93)	0.81			1.22 (0.62, 2.26)	0.54	1.06 (0.53, 2.01)	0.85	1.05 (0.63, 1.73)
Overweight (25–30)	0.94 (0.81, 1.09)	0.41			0.91 (0.78, 1.07)	0.25	0.94 (0.80, 1.11)	0.44	0.95 (0.84, 1.08)
Obese (≥ 30)	1.04 (0.87, 1.24)	0.65			0.93 (0.78, 1.12)	0.47	0.92 (0.76, 1.12)	0.41	0.94 (0.81, 1.09)
Hypertension—yes	1.23 (1.08, 1.40)	< 0.01			1.20 (1.04, 1.37)	0.01	1.17 (1.02, 1.35)	0.03	1.13 (1.01, 1.26)
Diabetes—yes	1.21 (1.06, 1.37)	< 0.01			1.11 (0.97, 1.27)	0.13	1.09 (0.95, 1.26)	0.21	1.07 (0.96, 1.19)

Table 4 (continued)

Variable	Model 1: age and sex adj		Model 2a		Model 2b		Model 3		Model 3
	AOR[#] (95% CI)	*p* value	AOR (95% CI)	*p* value	AOR (95% CI)	*p* value	AOR (95% CI)	*p* value	RR^ (95% CI)
Fasting blood glucose in mg/dL	1.00 (1.00, 1.00)	0.60							
HbA1C (%)	1.03 (0.98, 1.08)	0.26							
Lipid—cholesterol < 200 mg/dL (reference)									
≥ 200 mg/dL	0.81 (0.70, 0.93)	< 0.01			0.82 (0.66, 1.02)	0.07	0.80 (0.64, 1.00)	0.05	0.85 (0.71, 1.00)
Lipid—HDL > 60 mg/dL (reference)									
≤ 60 mg/dL	1.25 (1.10, 1.43)	< 0.001			1.16 (1.00, 1.34)	0.05	1.22 (1.05, 1.42)	0.009	1.17 (1.04, 1.31)
Lipid—LDL < 130 mg/dL (reference)									
≥ 130 md/dL	0.90 (0.77, 1.05)	0.19			1.09 (0.87, 1.38)	0.44	1.13 (0.90, 1.43)	0.29	1.10 (0.92, 1.31)

Poor-quality sleep is defined as a "Global PSQI" score of > 5. Diabetes is defined as HbA1c ≥ 6.5% or currently on medication for diabetes. Hypertension is defined as either SBP ≥ 140 or DBP ≥ 90 mmHg and/or currently on medication for hypertension

Adj adjusted, *AOR* adjusted odds ratio, *BMI* body mass index, *MMSE* Mini Mental State Exam, *HDL* high-density lipoprotein, *LDL* low-density lipoprotein, *HbA1C* glycated hemoglobin

[#]Model 1: binary logistic regression, adjusted for age and sex; model 2a, 2b, and 3 are multivariable binary logistic regression models; model 2a: demographic-lifestyle factors and psychosocial factors; model 2b: demographic-lifestyle factors and metabolic risk factors; model 3: fully adjusted. Variance explained (McFadden's pseudo-R^2) for model 2a was 0.14, model 2b was 0.10, and model 3 was 0.15; for model 3 vs model 2a, likelihood ratio test (LRT) ($p < 0.01$, df = 8, chi2 = 25.1) implies independent effect of metabolic risk factors; for model 3 vs model 2b LRT $p < 0.001$, df = 7, chi2 = 303.4 and implies independent effect of psychosocial problems to poor sleep quality

[$]In model 1, the estimates of age and sex were adjusted for each other

[^]Adjusted RR is provided for model 3 coefficients derived using formula RR = OR / (1 − Po) + (Po * OR), where Po is prevalence in the non-exposed group

Metabolic risk factors (hypertension and dyslipidemia—low HDL) were independently associated with poor sleep quality. Poor sleep quality has been associated with an increased risk of metabolic syndrome, including an adverse lipid profile [9, 10], but in some studies, this association was explained by BMI and sleep apnea [46, 47]. However, there is a limited number of studies that explored the association of different metabolic risk factors while adjusting for diverse psychosocial problems among community-dwelling individuals. Kiwan et al. [48] assessed the sleep characteristics and metabolic profile of medicated and non-medicated mentally ill patients compared with a control group. They found the effect size of the association of metabolic risk factors poor sleep quality was similar in both medicated and non-medicated mentally ill patients, perhaps indicating its independent effect.

Gender as a risk factor for poor sleep quality and OSA symptoms

Females were more likely to have poor sleep quality in our study than males. The gender difference in poor sleep quality, with more affected females, has been attributed to hormonal transitions, vasomotor symptoms, stress, depression, anxiety, maladjustment to night-shift work, an overactive bladder, and comorbid conditions, and cognitively females being more perceptive of sleep problems [49, 50]. Our study suggests that accounting for psychosocial and metabolic risk factors does not reduce the female preponderance for poor sleep quality.

While predominantly males are affected more by OSA, the prevalence of OSA symptoms was higher among females in our study [16]. This sex difference was observed although females reported less snoring. A study from south India also reported a higher prevalence among females (11.7%) than males (7.4%) [29]. The association of females with OSA symptoms in our study persisted after adjusting for psychosocial problems (model 2a) and metabolic risk factors (model 2b), but it was no longer significantly associated in the fully adjusted model. This suggests that the apparent association was confounded by an unequal distribution of psychosocial and metabolic risk factors between the two sexes.

The male-to-female ratio of the prevalence of OSA symptoms is less in population-based studies compared to that of hospital-based studies indicating a clinical under-recognition of OSA among females attending hospitals [51]. Moreover, the Berlin questionnaire used to assess OSA symptoms in the present study may overestimate OSA symptoms in

Table 5 Factors associated with symptoms of obstructive sleep apnea assessed using the Berlin questionnaire

Variable	Model 1: age and sex adj		Model 2a		Model 2b		Model 3		
	AOR[#] (95% CI)	*p* value	AOR (95% CI)	*p* value	AOR (95% CI)	*p* value	AOR (95% CI)	*p* value	RR^ (95% CI)
Demographic and lifestyle factors									
Age[$]	1.00 (0.99, 1.01)	0.67	1.00 (0.99, 1.01)	0.96	1.00 (0.99, 1.01)	0.62	1.01 (0.99, 1.02)	0.29	1.01 (0.99, 1.02)
Sex—males (reference)[$]									
Females	1.37 (1.14, 1.64)	< 0.001	1.32 (1.03, 1.69)	0.03	1.31 (1.01, 1.70)	0.04	1.22 (0.94, 1.60)	0.13	1.2 (0.94, 1.53)
Education	0.97 (0.94, 0.99)	0.008	0.97 (0.95, 1.00)	0.06	0.97 (0.94, 0.99)	0.03	0.98 (0.95, 1.01)	0.13	0.98 (0.96, 1)
Marital status—married (reference)									
Divorced/widow/single	1.16 (0.91, 1.47)	0.21	1.03 (0.79, 1.32)	0.82	1.10 (0.85, 1.42)	0.45	1.03 (0.79, 1.32)	0.85	1.02 (0.81, 1.29)
Ever smoker (yes)	1.1 (0.85, 1.43)	0.46	1.00 (0.75, 1.33)	0.99	1.02 (0.77, 1.36)	0.87	1.02 (0.77, 1.36)	0.88	1.02 (0.79, 1.32)
Ever alcohol (yes)	1.21 (0.96, 1.51)	0.10	1.23 (0.96, 1.57)	0.10	1.22 (0.95, 1.56)	0.11	1.19 (0.92, 1.52)	0.18	1.17 (0.93, 1.46)
Physical activity—low (reference)									
Moderate	0.7 (0.58, 0.85)	< 0.01	0.74 (0.61, 0.91)	0.003	0.71 (0.58, 0.87)	< 0.01	0.77 (0.63, 0.94)	< 0.01	0.79 (0.65, 0.94)
High	1.1 (0.74, 1.61)	0.61	1.23 (0.96, 1.57)	0.10	1.16 (0.77, 1.72)	0.46	1.30 (0.86, 1.93)	0.19	1.27 (0.89, 1.82)
Psychosocial problems									
Symptoms of depression—normal (ref)									
Mild depression	1.86 (1.47, 2.33)	< 0.001	1.21 (0.91, 1.60)	0.19			1.25 (0.94, 1.66)	0.12	1.22 (0.95, 1.58)
Mod-severe depression	3.48 (2.34, 5.04)	< 0.001	1.71 (1.04, 2.75)	0.03			1.76 (1.07, 2.85)	0.02	1.65 (1.08, 2.52)
Symptoms of anxiety—normal (ref)									
Mild anxiety	1.52 (1.25, 1.86)	< 0.001	1.41 (1.13, 1.75)	< 0.01			1.41 (1.13, 1.75)	< 0.01	1.36 (1.12, 1.65)
Mod-severe anxiety	3.05 (2.37, 3.9)	< 0.001	2.25 (1.60, 3.14)	< 0.001			2.22 (1.57, 3.11)	< 0.001	2.03 (1.51, 2.73)
Symptoms of stress—mild normal (ref)									
Mod-severe stress (≥ 2)	1.5 (1.2, 1.85)	< 0.01	1.12 (0.88, 1.42)	0.33			1.12 (0.88, 1.42)	0.35	1.11 (0.89, 1.37)
Social support—inadequate (reference)									
Adequate	1.42 (1.14, 1.76)	< 0.01	1.02 (0.79, 1.31)	0.86			1.03 (0.80, 1.33)	0.81	1.03 (0.82, 1.3)
Cognition (MMSE scores)	0.97 (0.93, 1.01)	0.12	1.00 (0.95, 1.04)	0.86			0.99 (0.95, 1.04)	0.64	0.99 (0.95, 1.03)
Metabolic risk factors									
BMI—healthy weight (18.5–25) (ref)									
Underweight (< 18.5)	0.3 (0.02, 1.39)	0.23			0.01 (0.01, 0.09)	0.96	0 (0, 0.11)	0.96	0 (0, 0.11)
Overweight (25–30)	1.63 (1.28, 2.08)	< 0.001			1.65 (1.29, 2.14)	< 0.001	1.71 (1.33, 2.22)	< 0.001	1.62 (1.29, 2.02)
Obese (≥ 30)	2.18 (1.68, 2.84)	< 0.001			2.09 (1.58, 2.76)	< 0.001	2.11 (1.60, 2.80)	< 0.001	1.95 (1.53, 2.49)
Hypertension—yes	1.14 (0.95, 1.37)	0.15			1.02 (0.84, 1.24)	0.88	0.99 (0.81, 1.21)	0.91	0.99 (0.83, 1.18)
Diabetes—yes	1.25 (1.04, 1.5)	0.01			1.15 (0.95, 1.40)	0.15	1.14 (0.94, 1.39)	0.18	1.13 (0.95, 1.35)
Fasting blood glucose in mg/dL	1 (1, 1)	0.23							
HbA1C (%)	1.08 (1.01, 1.16)	0.02							
Lipid—cholesterol < 200 mg/dL (ref)									

Table 5 (continued)

Variable	Model 1: age and sex adj		Model 2a		Model 2b		Model 3		
	AOR[#] (95% CI)	*p* value	AOR (95% CI)	*p* value	AOR (95% CI)	*p* value	AOR (95% CI)	*p* value	RR^ (95% CI)
≥ 200 mg/dL	0.91 (0.75, 1.11)	0.38			0.85 (0.62, 1.15)	0.29	0.84 (0.61, 1.14)	0.26	0.85 (0.64, 1.13)
Lipid-HDL > 60 mg/dL (ref)									
≤ 60 mg/dL	1.18 (0.97, 1.43)	0.09			1.06 (0.86, 1.30)	0.61	1.07 (0.87, 1.33)	0.51	1.07 (0.88, 1.29)
Lipid-LDL < 130 mg/dL (reference)									
≥ 130 md/dL	1.07 (0.86, 1.31)	0.54			1.27 (0.92, 1.75)	0.14	1.29 (0.94, 1.78)	0.12	1.26 (0.94, 1.67)

Symptoms of OSA high risk: if the score is positive for both category 1 and 2; low risk: if there is only 1 or no category where the score is positive. Diabetes is defined as HbA1c ≥ 6.5% or currently on medication for diabetes. Hypertension is defined as either SBP ≥ 140 or DBP ≥ 90 mmHg and/or currently on medication for hypertension

Adj adjusted, *AOR* adjusted odds ratio, *BMI* body mass index, *MMSE* Mini Mental State Exam, *HDL* high-density lipoprotein, *LDL* low-density lipoprotein, *HbA1C* glycated hemoglobin

[#]Model 1: binary logistic regression, adjusted for age and sex; model 2a, 2b, and 3 are multivariable binary logistic regression models; model 2a: demographic-lifestyle factors and psychosocial factors; model 2b: demographic-lifestyle factors and metabolic factors; model 3: fully adjusted. variance explained (McFadden's pseudo-R^2) for model 2a was 0.08; model 2b was 0.08, and model 3 was 0.10; for model 3 vs model 2a, a likelihood ratio test (LRT) ($p < 0.001$, df = 8, chi2 = 48.2) implies independent effect of metabolic risk factors; for model 3 vs model 2b, LRT $p < 0.001$, df = 7, chi2 = 70 and implies independent effect of psychosocial problems to OSA symptoms

[$]In model 1, the estimates of age and sex were adjusted for each other

[^]Adjusted RR is provided for model 3 coefficients derived using formula RR = OR / (1 − Po) + (Po * OR), where Po is prevalence in the non-exposed group

females [52]. On the other hand, OSA may well be under-reported and underdiagnosed in females, as they are less likely to report snoring due to social awkwardness [49]. This may also have biased the assessment in our study. However, our findings highlight that health-care professionals in India need to ask women of all ages about their sleep to try to identify occult OSA symptoms.

Independent contribution of psychosocial problems to OSA symptoms

In line with prior studies, we found that metabolic risk factors (BMI ≥ 25 kg/m^2), psychosocial problems (symptoms of anxiety and moderate-severe depression), and the absence of moderate physical activity were all associated with OSA symptoms [16, 17, 53]. While a link between metabolic risk factors and OSA is established, recent systematic reviews have reported that symptoms of OSA are higher among patients with depressive disorders and anxiety [54]. The underlying temporal direction of the association between OSA symptoms and psychosocial problems is still being investigated. Two cohort studies reported a prospective association between OSA and subsequent development of depressive disorders [55, 56]. Mostly, results on the co-occurrence of different psychosocial problems and OSA symptoms were obtained in clinical populations; studies in the general population are scarce. The present study is one of the largest population-based studies that have assessed an exhaustive list of both metabolic risk factors and psychosocial problems.

Moreover, in our study, dyslipidemia (low HDL) and hypertension were also associated with the occurrence of snoring. In fact, the deleterious effect of OSA on cardiovascular symptoms has been attributed to the high LDL/HDL ratio [57]. In the SYNAPSE study of 834 elderly persons, low HDL levels were related to the severity of OSA [58].

Our finding has public health implications. First, given the concomitant rise in the prevalence of metabolic syndrome and obesity in India, there is a presumable increase in the occurrence of OSA. As a corollary, preventive efforts targeted at BMI are urgently needed to accrue benefits against OSA and related consequences. Second, our findings underscore an opportunity for cross-diagnosis of OSA symptoms and psychosocial problems, and the need to sensitize psychiatrists and sleep care providers. As the prevalence of psychosocial problems is rising fast in India, it is important to introduce screening for OSA in primary care settings, in particular in women.

Strengths and limitations

This is one of the few large-scale epidemiological studies with a clearly defined primary population base (based on voting and population register) exploring the determinants of subjective sleep quality as well as OSA symptoms. Furthermore, we considered multiple psychosocial problems lifestyle factors and metabolic risk factors. A standardized and validated assessment tool and a large sample size increased the internal validity and reliability of our study.

However, several limitations must also be discussed. We used PSQI for sleep quality assessment, rather than the gold standard polysomnography. The latter requires overnight evaluation, is expensive, and is not suitable for population-level estimations in low- or middle-income countries. The PSQI is a widely used, validated tool to assess sleep disturbances. Likewise, we used the Berlin questionnaire to assess OSA symptoms, instead of using the apnea–hypopnea index cut-off for logistical reasons. Finally, the cross-sectional nature of the analysis limits any temporal interpretation of the associations. Nonetheless, our results are valid for pointing to associations with relevance for public health prevention and control.

Conclusion

In older Indian adults, metabolic risk factors and psychosocial problems were associated independently with both subjective sleep quality and OSA symptoms. Our findings have public health implications because the proportion of people of elderly age in India is increasing rapidly, while the prevalence of metabolic risk factors is already high in this age group. This risk pattern has the potential to exacerbate the occurrence of sleep disorders and OSA, and their associated cardiovascular and neurologic sequelae, further straining the Indian health-care system.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11325-022-02725-9.

Funding The LoCARPoN cohort study was funded by the Department of Biotechnology, Ministry of Science and Technology (grant number BT/IN/Netherland/03/KP/2012 dated 14/02/2014), and the Department of Health Research, Ministry of Health and Family Welfare, government of India (grant number R.11012/15/2018-HR, dated 09/08/2018). Technical support and training were provided by the Department of Epidemiology, Erasmus University Medical Centre, the Netherlands. The Erasmus component was funded through the Erasmus Medical Centre, Rotterdam, the Netherlands, and the Erasmus University, Rotterdam. MAI and HT received further support from Alzheimer Nederland (WE.15–2014-09).

Data availability The data underlying this article cannot be shared publicly due to the privacy of individuals that participated in the study. However, interested researchers may contact the corresponding author with reasonable request for data sharing.

Declarations

Ethics approval The study was approved by the Institutional Ethics Committee of the All India Institute of Medical Sciences, New Delhi, India (reference number: IEC/NP-53/2014 RP-12/ 2014, dated 15 May 2014). Written informed consent was obtained from both the community leaders and the participants for assessment. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Conflict of interest The authors declare no competing interests.

Preprint repositories None.

References

1. Arokiasamy P (2018) India's escalating burden of non-communicable diseases. Lancet Glob Health 6:e1262–e1263. https://doi.org/10.1016/S2214-109X(18)30448-0
2. Jana A, Chattopadhyay A (2022) Prevalence and potential determinants of chronic disease among elderly in India: rural-urban perspectives. PLoS one 17:e0264937. https://doi.org/10.1371/journal.pone.0264937
3. Sinha P, Hussain T, Boora NK et al (2021) Prevalence of common mental disorders in older adults: results from the National Mental Health Survey of India. Asian J Psychiatry 55:102463. https://doi.org/10.1016/j.ajp.2020.102463
4. Sahni B, Bala K, Kumar T, Narangyal A (2020) Prevalence and determinants of geriatric depression in North India: a cross-sectional study. J Fam Med Prim Care 9:2332–2336. https://doi.org/10.4103/jfmpc.jfmpc_357_20
5. Medic G, Wille M, Hemels ME (2017) Short- and long-term health consequences of sleep disruption. Nat Sci Sleep 9:151–161. https://doi.org/10.2147/NSS.S134864
6. Zielinski MR, McKenna JT, McCarley RW (2016) Functions and mechanisms of sleep. Aims Neurosci 3:67–104. https://doi.org/10.3934/Neuroscience.2016.1.67
7. Mondal comparison of perceived sleep quality among urban and rural adult population by Bengali Pittsburgh Sleep Quality Index. https://www.aihbonline.com/article.asp?issn=2321-8568;year=2018;volume=8;issue=1;spage=36;epage=40;aulast=Mondal. Accessed 6 Feb 2022
8. George S, Paul G, Paul N (2018) Study on sleep quality and associated psychosocial factors among elderly in a rural population of Kerala, India. Int J Community Med Public Health 5:526–531. https://doi.org/10.18203/2394-6040.ijcmph20180114
9. Mesas AE, Guallar-Castillón P, López-García E et al (2014) Sleep quality and the metabolic syndrome: the role of sleep duration and lifestyle. Diabetes Metab Res Rev 30:222–231. https://doi.org/10.1002/dmrr.2480
10. Koren D, Dumin M, Gozal D (2016) Role of sleep quality in the metabolic syndrome. Diabetes Metab Syndr Obes Targets Ther 9:281–310. https://doi.org/10.2147/DMSO.S95120
11. Lo K, Woo B, Wong M, Tam W (2018) Subjective sleep quality, blood pressure, and hypertension: a meta-analysis. J Clin Hypertens 20:592–605. https://doi.org/10.1111/jch.13220
12. Yang Z, Heizhati M, Wang L et al (2021) Subjective poor sleep quality is associated with higher blood pressure and prevalent hypertension in general population independent of sleep disordered breathing. Nat Sci Sleep 13:1759–1770. https://doi.org/10.2147/NSS.S329024
13. Geovanini GR, Lorenzi-Filho G, de Paula LK et al (2019) Poor sleep quality and lipid profile in a rural cohort (The Baependi Heart Study). Sleep Med 57:30–35. https://doi.org/10.1016/j.sleep.2018.12.028
14. Heinzer R, Vat S, Marques-Vidal P et al (2015) Prevalence of sleep-disordered breathing in the general population: the HypnoLaus study. Lancet Respir Med 3:310–318. https://doi.org/10.1016/S2213-2600(15)00043-0
15. Bangash A, Wajid F, Poolacherla R et al (2020) Obstructive sleep apnea and hypertension: a review of the relationship and

pathogenic association. Cureus 12:e8241. https://doi.org/10.7759/cureus.8241
16. Maspero C, Giannini L, Galbiati G et al (2015) Obstructive sleep apnea syndrome: a literature review. Minerva Stomatol 64:97–109
17. Abbasi A, Gupta SS, Sabharwal N et al (2021) A comprehensive review of obstructive sleep apnea. Sleep Sci 14:142–154. https://doi.org/10.5935/1984-0063.20200056
18. Yu J, Rawtaer I, Fam J et al (2016) Sleep correlates of depression and anxiety in an elderly Asian population. Psychogeriatr Off J Jpn Psychogeriatr Soc 16:191–195. https://doi.org/10.1111/psyg.12138
19. Prasad K, Dwivedi SN, Kant S et al (2022) Cohort profile: the LoCARPoN-a population-based prospective cohort study in middle-aged and older adults in India. Int J Epidemiol 51:29–30m. https://doi.org/10.1093/ije/dyab078
20. Yesavage JA, Brink TL, Rose TL et al (1982) Development and validation of a geriatric depression screening scale: a preliminary report. J Psychiatr Res 17:37–49. https://doi.org/10.1016/0022-3956(82)90033-4
21. Yadav AK (2020) Designing and validation of evidence-based questionnaire in English and Hindi for a population-based cohort study in North India. PhD thesis. Department of neurology. ll India Institute of Medical Sciences
22. Rosengren A, Hawken S, Ounpuu S et al (2004) Association of psychosocial risk factors with risk of acute myocardial infarction in 11119 cases and 13648 controls from 52 countries (the INTERHEART study): case-control study. Lancet Lond Engl 364:953–962. https://doi.org/10.1016/S0140-6736(04)17019-0
23. WHO Expert Consultation (2004) Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet Lond Engl 363:157–163. https://doi.org/10.1016/S0140-6736(03)15268-3
24. Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (2001) Executive summary of the third report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, And Treatment of High Blood Cholesterol In Adults (Adult Treatment Panel III). Jama 285:2486–2497. https://doi.org/10.1001/jama.285.19.2486
25. International Expert Committee (2009) International Expert Committee report on the role of the A1C assay in the diagnosis of diabetes. Diabetes Care 32:1327–1334. https://doi.org/10.2337/dc09-9033
26. Chobanian AV, Bakris GL, Black HR et al (1979) (2003) Seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. Hypertens Dallas Tex 42:1206–1252. https://doi.org/10.1161/01.HYP.0000107251.49515.c2
27. Peker Y, Celik Y, Arbatli S et al (2021) Effect of high-risk obstructive sleep apnea on clinical outcomes in adults with coronavirus disease 2019: a multicenter, prospective, observational clinical trial. Ann Am Thorac Soc 18:1548–1559. https://doi.org/10.1513/AnnalsATS.202011-1409OC
28. Zhang J, Yu KF (1998) What's the relative risk? A method of correcting the odds ratio in cohort studies of common outcomes. Jama 280:1690–1691. https://doi.org/10.1001/jama.280.19.1690
29. Pinto AM, Devaraj U, Ramachandran P et al (2018) Obstructive sleep apnea in a rural population in South India: feasibility of health care workers to administer level III sleep study. Lung India Off Organ Indian Chest Soc 35:301–306. https://doi.org/10.4103/lungindia.lungindia_433_17
30. Reddy EV, Kadhiravan T, Mishra HK et al (2009) Prevalence and risk factors of obstructive sleep apnea among middle-aged urban Indians: a community-based study. Sleep Med 10:913–918. https://doi.org/10.1016/j.sleep.2008.08.011
31. Peppard PE, Young T, Barnet JH et al (2013) Increased prevalence of sleep-disordered breathing in adults. Am J Epidemiol 177:1006–1014. https://doi.org/10.1093/aje/kws342
32. Mirrakhimov AE, Sooronbaev T, Mirrakhimov EM (2013) Prevalence of obstructive sleep apnea in Asian adults: a systematic review of the literature. Bmc Pulm Med 13:10. https://doi.org/10.1186/1471-2466-13-10
33. Punjabi NM (2008) The epidemiology of adult obstructive sleep apnea. Proc Am Thorac Soc 5:136–143. https://doi.org/10.1513/pats.200709-155MG
34. Majumdar A, Ramya S, Ramakrishnan J (2019) Depression, anxiety, and bodily pain independently predict poor sleep quality among adult women attending a primary health center of Puducherry, India. J Fam Med Prim Care 8:1182–1188. https://doi.org/10.4103/jfmpc.jfmpc_118_19
35. Gambhir IS, Chakrabarti SS, Sharma AR, Saran DP (2014) Insomnia in the elderly—A hospital-based study from North India. J Clin Gerontol Geriatr 5:117–121. https://doi.org/10.1016/j.jcgg.2014.05.005
36. Chang KJ, Son SJ, Lee Y et al (2014) Perceived sleep quality is associated with depression in a Korean elderly population. Arch Gerontol Geriatr 59:468–473. https://doi.org/10.1016/j.archger.2014.04.007
37. Orhan FO, Tuncel D, Taş F et al (2012) Relationship between sleep quality and depression among elderly nursing home residents in Turkey. Sleep Breath Schlaf Atm 16:1059–1067. https://doi.org/10.1007/s11325-011-0601-2
38. Huang Y, Zhu M (2020) Increased global PSQI score is associated with depressive symptoms in an adult population from the United States. Nat Sci Sleep 12:487–495. https://doi.org/10.2147/NSS.S256625
39. Jansson M, Linton SJ (2006) The role of anxiety and depression in the development of insomnia: cross-sectional and prospective analyses. Psychol Health 21:383–397. https://doi.org/10.1080/14768320500129015
40. Palagini L, Baglioni C, Ciapparelli A et al (2013) REM sleep dysregulation in depression: state of the art. Sleep Med Rev 17:377–390. https://doi.org/10.1016/j.smrv.2012.11.001
41. Potvin O, Lorrain D, Belleville G et al (2014) Subjective sleep characteristics associated with anxiety and depression in older adults: a population-based study. Int J Geriatr Psychiatry 29:1262–1270. https://doi.org/10.1002/gps.4106
42. Oh C-M, Kim HY, Na HK et al (2019) The effect of anxiety and depression on sleep quality of individuals with high risk for insomnia: a population-based study. Front Neurol 10:849. https://doi.org/10.3389/fneur.2019.00849
43. Kahn M, Sheppes G, Sadeh A (2013) Sleep and emotions: bidirectional links and underlying mechanisms. Int J Psychophysiol Off J Int Organ Psychophysiol 89:218–228. https://doi.org/10.1016/j.ijpsycho.2013.05.010
44. O'Leary K, Bylsma LM, Rottenberg J (2017) Why might poor sleep quality lead to depression?: a role for emotion regulation. Cogn Emot 31:1698–1706. https://doi.org/10.1080/02699931.2016.1247035
45. Klumpp H, Hosseini B, Phan KL (2018) Self-reported sleep quality modulates amygdala resting-state functional connectivity in anxiety and depression. Front Psychiatry 9:220. https://doi.org/10.3389/fpsyt.2018.00220
46. Bos MM, Noordam R, van den Berg R et al (2019) Associations of sleep duration and quality with serum and hepatic lipids: The Netherlands Epidemiology of Obesity Study. J Sleep Res 28:e12776. https://doi.org/10.1111/jsr.12776
47. Petrov MER, Kim Y, Lauderdale D et al (2013) Longitudinal associations between objective sleep and lipids: the CARDIA study. Sleep 36:1587–1595. https://doi.org/10.5665/sleep.3104

48. Kiwan N, Mahfoud Z, Ghuloum S et al (2019) Relationships between sleep patterns and metabolic profile in patients maintained on antipsychotics: a cross-sectional comparative study. Neuropsychiatr Dis Treat 15:2035–2047. https://doi.org/10.2147/NDT.S207987
49. Mallampalli MP, Carter CL (2014) Exploring sex and gender differences in sleep health: a Society for Women's Health research report. J Womens Health 23:553–562. https://doi.org/10.1089/jwh.2014.4816
50. Pengo MF, Won CH, Bourjeily G (2018) Sleep in women across the life span. Chest 154:196–206. https://doi.org/10.1016/j.chest.2018.04.005
51. Quintana-Gallego E, Carmona-Bernal C, Capote F et al (2004) Gender differences in obstructive sleep apnea syndrome: a clinical study of 1166 patients. Respir Med 98:984–989. https://doi.org/10.1016/j.rmed.2004.03.002
52. Pataka A, Kotoulas S, Kalamaras G et al (2020) Gender differences in obstructive sleep apnea: the value of sleep questionnaires with a separate analysis of cardiovascular patients. J Clin Med 9:130. https://doi.org/10.3390/jcm9010130
53. Young T, Palta M, Dempsey J et al (1993) The occurrence of sleep-disordered breathing among middle-aged adults. N Engl J Med 328:1230–1235. https://doi.org/10.1056/NEJM199304293281704
54. Garbarino S, Bardwell WA, Guglielmi O et al (2020) Association of anxiety and depression in obstructive sleep apnea patients: a systematic review and meta-analysis. Behav Sleep Med 18:35–57. https://doi.org/10.1080/15402002.2018.1545649
55. Kim J-Y, Ko I, Kim D-K (2019) Association of obstructive sleep apnea with the risk of affective disorders. Jama Otolaryngol Neck Surg 145:1020–1026. https://doi.org/10.1001/jamaoto.2019.2435
56. Chen Y-H, Keller JK, Kang J-H et al (2013) Obstructive sleep apnea and the subsequent risk of depressive disorder: a population-based follow-up study. J Clin Sleep Med JCSM Off Publ Am Acad Sleep Med 9:417–423. https://doi.org/10.5664/jcsm.2652
57. Kawano Y, Tamura A, Kadota J (2012) Association between the severity of obstructive sleep apnea and the ratio of low-density lipoprotein cholesterol to high-density lipoprotein cholesterol. Metabolism 61:186–192. https://doi.org/10.1016/j.metabol.2011.06.004
58. Roche F, Sforza E, Pichot V et al (2009) Obstructive sleep apnoea/hypopnea influences high-density lipoprotein cholesterol in the elderly. Sleep Med 10:882–886. https://doi.org/10.1016/j.sleep.2008.07.017