Original Article

Snoring is associated with obesity among middle aged Slum-dwelling women in Mysore, India

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ABSTRACT

Background: Globally, rates of obesity have trebled in the past four decades. India has more than 9.8 million men and 20 million women classified as obese. While poor diet and sedentary lifestyles are major causes, growing evidence suggests other factors like sleep-disordered-breathing may also be contributors. **Methods:** A cross-sectional survey was carried out between October 2017 and May 2018 among a nonprobability sample of slum-dwelling women, 40–64 years of age, in government-designated slums in Mysore, India. After the informed consent process, data were collected on sociodemographics, tobacco and alcohol consumption, diet, physical activity, sleep, quality of life, and personal and family history of diagnosed cardiometabolic disorders. Body mass index (BMI) was calculated using anthropometry. The serum was tested for HbA1c and lipid profile. **Results:** In this sample of slum-dwelling women, snoring was associated with obesity. Habitual snorers had more than double the odds (adjusted odds ratio [aOR] 2.05; 95% confidence interval [CI] 1.26–3.33; $P < 0.004$) of obesity I, and seven times the odds (aOR 7.71; CI: 3.58–16.62; $P < 0.001$) of being in the obesity II category compared to nonsnorers after adjustment for age, diabetes, hypertension, hypercholesterolemia, and daytime sleepiness. There was no difference in obesity status among participants reporting abnormal sleep duration, napping, daytime sleepiness, sleep apnea, insomnia, or the use of sleep medication. **Conclusion:** The relationship between snoring and obesity has not been well explored. This study among slum-dwelling Indian women found a significant relationship between snoring and obesity. Future research should explore the underlying mechanisms connecting snoring to BMI.

KEY WORDS: Body mass index, India, obesity, snoring, women

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INTRODUCTION

Globally, rates of overweight and obesity have trebled in the past four decades. In 2016, almost two billion adults were classified as overweight, and 650 million, as obese.[1] Between 1975 and 2014, the share of adults that were overweight or having a body mass index (BMI) ≥25, increased from 40.8% to 69.1%.[2] During the same period,

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age-standardized obesity (BMI ≥ 30 kg/m^2) increased from 3.2% to 10.8% in men; and 6.4% to 14.9% in women.[3] The annual public health cost of obesity is estimated at 3.4 million premature deaths and 4% of both potential years of life lost and disability-adjusted life years worldwide.[4]

Once considered mainly a problem in high-income nations, obesity is now a major public health issue in India. In 1975, for example, about 400,000 men and 800,000 women were obese; by 2014, that had increased to 9.8 million and 20 million, respectively.[3] Across this country of more than a billion people, high rates of being overweight are more frequently associated with age, region, female gender, and being in an urban area as compared to rural ones.[5] Studies suggest that rates among south Indian women are particularly high; one study showed that women living in south Indian states were about 50% more likely to be overweight or obese compared to their peers in northern India.[6]

In addition to substantial evidence that an increasingly sedentary lifestyle and a nutritional transition to processed foods and high-calorie diets are contributing to weight gain globally, a growing body of research also suggests that disordered sleep may also be contributing to obesity.[7] Research suggests a strong link between sleep disorders for instance and metabolic dysfunctions like insulin resistance that have been associated with obesity.[8] Habitual snoring (HS), a sleep-related behavior, has also been associated with glucose and insulin metabolism[9] and obesity.[10] This relationship appears to be bi-directional. On the one hand, obesity and neck circumference have been shown to increase the risk for snoring: Disordered breathing increases negative intraluminal pressure encouraging the collapse of the airway and vibration of pharyngeal soft tissues.[11] In some studies, obesity appeared to be causal in snoring,[12] but this has been increasingly questioned as further research showed that weight reduction had very modest effects on snoring.[13,14] Other research however, suggests that HS may also be linked to weight gain by contributing to metabolic load.[9] HS appears to increase risk factors associated with obesity including sleep fragmentation, impaired circulatory function, hypertension, metabolic syndrome, diabetes, and impaired glucose control.[9,10,15]

The alarming increase in sleep disorders and obesity have led some to describe both as epidemic, but their relationship to each other has not been well characterized. While it is well established that obesity contributes to the development and severity of obstructive sleep apnea (OSA), a growing body of evidence suggests that sleep disorders increase risk for obesity.[16,17] The impact of snoring on obesity, with and without OSA, is even less well understood, but it has been associated with metabolic syndrome, weight gain in pregnant women, hypertension, kidney disease, nocturia,[18] and obesity. This is the first study to our knowledge to explore the prevalence of snoring in slum-dwellers; its relationship to obesity; and interactions between snoring and other sleep parameters that may increase the risk for both obesity and CVD.

METHODS

Overview

A cross-sectional study was carried out between October 2017 and May 2018 among a nonprobability sample of slum-dwelling women in Mysore, India. To be included, women had to be 40–64 years of age, living in a government-designated slum for a minimum of 6 months, and willing to undergo all the study procedures. Women were excluded if they had hemophilia or other medical conditions that put them at risk during sample collection. The research measured knowledge and beliefs about coronary heart disease (CHD), demographics, modifiable risk factors (smoking, use of alcohol, weight, physical activity, healthy diet, blood pressure, serum cholesterol, and blood glucose), and correlates of CHD (defined as previously diagnosed CHD, symptoms on the Rose angina questionnaire, and/or ischemic changes on electrocardiography).

The study was reviewed and approved by the institutional review boards at Florida International University in the US and Public Health Research Institute of India in India.

Study sites

The study was carried out in six urban slums (*Kesere, Kudaremala, Ekalavya Nagara, Amrutha badavane, KN Pura and Ganeshnagar*) in Mysore City, India. The communities were randomly selected from a sampling frame of 63 Mysore communities designated as slums by the Karnataka Slum Development Board. According to the 2011 census, Mysore City has a population of 920,000, of which 493,762 are females. Approximately 19% of the population live below the poverty line, and about 39,029 residents reside in slums as defined by the Karnataka Slum Act.[19]

Study recruitment

Trained research staff visited study sites 1 day before recruitment and distributed brochures describing the study. If residents expressed interest, staff members explained the purpose of the research, described study activities and conducted a screening process using a standardized script. If potential participants declined to participate, they were asked a brief set of demographic questions to assess any potential systematic biases in participant recruitment.

Interested potential participants were also asked to bring any medical reports or medications for diabetes, high blood pressure, heart disease, or stroke to a pickup point the next day and were transported by van to the study site. Before data collection, potential participants underwent an informed consent process. Study staff explained the study purpose, read the informed consent verbatim, described all study procedures, and solicited and answered any

questions about the study. Women were asked if they understood what they were consenting to, and whether they had any further questions. After any doubts were clarified, participants were required to give written informed consent before data collection.

Data collection

Data were collected from participants in *Kannada* using an interviewer-administered standardized questionnaire adapted from the Centre for Cardiometabolic Risk Reduction in South-Asia (CARRS) surveillance study.[20] Questions solicited information on demographics, socioeconomic status, employment, and residence. Data were also collected on knowledge about cardiovascular disease, willingness to adopt heart healthy behaviors, subjective judgment of general health, tobacco and alcohol consumption, dietary habits, physical activity, sleep, quality of life, and personal and family history of diagnosed cardiometabolic disorders and their risk factors. This included diabetes, heart disease, stroke, chronic obstructive pulmonary disease, angina, peripheral vascular disease, kidney disease, and respiratory diseases. Sleep duration and quality were measured using scales adapted from the National Heart Lung Blood Institute (NHLBI) Sleep Habits Questionnaire. Following data collection, each participant was individually counseled on reducing risk for cardiometabolic diseases and given a brochure outlining how they could alter their existing CHD risk.

Definition of study variables

The primary outcome of this analysis was BMI, calculated as weight in kilograms divided by height in meters squared. BMI was categorized based on the World Health Organization's recommended BMI cutoffs for South Asians.[21] Due to small cell sizes, underweight and normal categories were merged and used as a reference.

The main exposure variable for the study was "frequency of snoring." Categories were based on prior studies with participants defined as "nonsnorers" if they never snored; as "moderate snorers" if they currently snored 1–2 nights per week; and as "habitual snorers" if they currently snored 3–7 nights per week.

Covariates were selected based on the literature. Diabetes, hypertension, hypercholesterolemia (HTC), and anxiety/depression; sleep duration; daytime sleepiness; and frequency of napping, insomnia, and interrupted breathing while sleeping were also included in the analysis. Education was defined as no schooling, primary school (1–7 years), high school (8–12 years), and secondary school or above (12 + years). Marital status was defined as single, married, and "other." Caffeine consumption was defined as "any" consumption of coffee or tea. Physical activity was categorized into levels based on calculated metabolic equivalent (MET)-minutes (met-mins).[22] Diabetes was defined as estimated average glucose >125 mg/dL or taking medication for diabetes. Hypertension was defined as having a systolic blood pressure ≥130 mmHg, diastolic blood pressure ≥80 mmHg, or use of hypertension medication. Hypercholesterolemia (HCL) was defined as low-density lipoprotein cholesterol ≥190 mg/dL or use of cholesterol-lowering medication. Anxiety and depression were evaluated by selection of one of the following statements: "I am not anxious or depressed," "I am moderately anxious or depressed," or "I am extremely anxious or depressed."

Sleep scales were adapted from the US National Heart Lung and Blood Institute's Sleep Heart Health Study. Sleep duration was self-reported for workdays and nonworkdays, and a weighted average was calculated. The frequency of napping was defined as the number of times per week that the participant napped for 5 min or longer. "Frequency of disrupted breathing while sleeping" was defined as rarely if experienced <1 night per week; sometimes if experienced 1–2 nights per week; frequently if experienced 3–5 nights per week; and always or almost always if experienced 6–7 nights per week. Insomnia was assessed using a 6-item scale that measured the frequency of the following sleep symptoms: (1) trouble falling asleep; (2) waking up during the night and having difficulty getting back to sleep; (3) waking up too early in the morning and being unable to get back to sleep; (4) feeling unrested during the day regardless of the number of hours of sleep; (5) not getting enough sleep; and (6) taking sleeping pills or other medication to get to sleep. Monthly frequency of insomnia symptoms was categorized into no (one or more symptoms less than twice per month); rarely (one or more symptoms 2–4 times per month); occasionally (one or more symptoms 5–15 times per month); and frequently (one or more symptoms 16–30 times per month. Daytime sleepiness was measured using the Epworth Sleepiness Scale (ESS)[23] and categorized as normal sleepiness ($0 \leq ESS \leq 6$); average sleepiness ($7 \leq ESS \leq$); and abnormal sleepiness ($9 \leq ESS \leq 24$).

Statistical analysis

Data were presented as frequencies and percentages for categorical variables, and as mean (standard deviation [SD]) and median (first quartile [Q1], third quartile [Q3]) for continuous variables. Differences in sociodemographics, health behaviors, health status, and sleep factors by BMI and by snoring status were assessed using Chi-square tests and analysis of variance (ANOVA) for categorical and continuous variables, respectively. Multinomial logistic regression models, with underweight/normal weight used as the reference category for BMI, were used to assess the adjusted association between BMI and snoring. Factors that were conservatively associated with both BMI and snoring using Chi-square test or ANOVA ($P < 0.20$) were selected *a priori* as covariates to be included in the adjusted models. Variables were excluded from the model if there was little variation in response (i.e., if ≥90% of the sample fell into a single response category) or if variables were highly correlated. Correlation and multicollinearity were assessed using Pearson's correlation coefficients® and variance inflation factors respectively. All analyses used a two-tailed level of significance of alpha of 0.05 and were

carried out using SPSS 22 or higher (SPSS statistics IBM Corp., Armonk, NY, USA). Odds ratios and corresponding confidence intervals (CIs) and *P* values were generated using GENLINMIXED with the covariate (s) as fixed effect (s) and slum as a random effect.

RESULTS

Characteristics of the sample

About 734 women were screened, and 607 were enrolled in the study. There were no significant demographic differences between women who enrolled and those who were excluded or chose not to participate at the time of recruitment. Participants were, on an average, 50 years of age and a majority reported their religion as Hindu (84.2%) [Table 1]. Nearly two of three had no formal schooling (62.8%) and were employed (61.4%). Half were married (51.4%), belonged to a scheduled caste or tribe (47.1%), and 53% lived in a household with a monthly income of 3000–10,000 Indian rupees (1 USD = 66.78 INR). One out of three women were obese (38.7%) and 36% snored. The average BMI of the women in the study was 23.7 kg/m^2 (SD = 5.15; median = 23.0; interquartile range = 7.0).

Association between body mass index and snoring

The prevalence of snoring increased with higher BMI ($P < 0.001$) [Table 2]. Moderate and HS were three times more prevalent among women that were categorized as obese II than underweight/normal-weight women.

Factors associated with body mass index

Women who were overweight or obese were slightly younger ($P = 0.065$) and generally more educated ($P < 0.001$) than underweight/normal-weight women [Table 2]. The proportion of obese women with secondary schooling or above was three times that of underweight/normal-weight women. Current use of smokeless tobacco generally decreased with increasing BMI ($P = 0.001$), while the prevalence of diabetes ($P < 0.001$), hypertension ($P < 0.001$), and abnormal daytime sleepiness ($P = 0.054$) increased with BMI. The proportion of diabetic women classified as obese II was nearly three times that of underweight/normal-weight women. Abnormal daytime sleepiness among obese II women was four times that of underweight/normal-weight women.

Factors associated with snoring

Women who snored were older and had a higher prevalence of diabetes ($P < 0.001$), hypertension ($P < 0.001$) [Table 3]. Abnormal daytime sleepiness ($P < 0.001$) increased with increased frequency of snoring. The prevalence of diabetes among habitual snorers was nearly double that of nonsnorers. The prevalence of abnormal daytime sleepiness among moderate and habitual snorers was triple that of nonsnorers. The prevalence of anxiety/depression ($P = 0.05$) was also higher among snorers compared to nonsnorers.

Table 1: Sociodemographic characteristics of the study sample of slum-dwelling women in Mysore, India (*n*=607)

	n (%)
Age (years)	
Mean (SD)	50.035 (7.318)
Median (Q1-Q3)	50 (44-55)
Education	
No schooling	381 (62.8)
Primary school	61 (10.0)
High school	117 (19.3)
Secondary and above	48 (7.9)
Religion	
Hindu	510 (84.2)
Muslim	76 (12.5)
Christian	20 (3.3)
Caste	
SC/ST	286 (47.1)
Other backward caste	217 (35.7)
General caste	104 (17.1)
Marital status	
Single	7 (1.2)
Married	312 (51.4)
Other	288 (47.4)
Work status	
Employed	373 (61.4)
Housewife	234 (38.6)
Monthly household income (INR)	
<3000	129 (21.3)
3000-10,000	321 (53.0)
>10,000	156 (25.7)
BMI	
Underweight/normal	270 (45.8)
Overweight	91 (15.4)
Obese I	171 (29.0)
Obese II	57 (9.7)
Snoring	
Nonsnorer	374 (63.9)
Moderate snorer	40 (6.8)
Habitual snorer	171 (29.2)

Education: Defined as: No schooling, Primary school (1–7 years), High school (8–12 years), and Secondary school or above (12+years), Marital status: "Other" includes separated, divorced, and widow/widower, BMI: Underweight: <18.5 kg/m^2, Normal weight: 18.5–22.9 kg/m^2, Overweight: 23–4.9 kg/m^2, Obese I: 25–29.9 kg/m^2, Obese II: ≥30 kg/m^2, Snoring: "Nonsnorer" defined as a never snored or a former snorer (used to snore, but no longer snores)."Moderate snorer" defined as a current snorer who snores 1–2 nights per week. "Habitual snorer" defined as a current snorer who snores 3–7 nights per week. Q1: First quartile, Q3: Third quartile, SC/ST: Scheduled caste/scheduled tribe, INR: Indian Rupees, SD: Standard deviation, BMI: Body mass index

Selection of covariates for the multinomial logistic regression models

Three factors were associated with both BMI and snoring ($P < 0.20$) and were included in the regression models: age, diabetes, and hypertension.

Odds of being overweight

After adjustment for covariates, odds of being overweight did not significantly differ between moderate snorers and nonsnorers ($P = 0.163$) or between habitual snorers and nonsnorers ($P = 0.243$) [Table 4]. Age and hypertension, however, were significantly associated with BMI. The odds of being overweight decreased by 5.0% with every

Table 2: Factors associated with body mass index among slum-dwelling women in Mysore, India (*n*=607)

	BMI				*P*
	Underweight/normal (*n*=270), *n* (%)	Overweight (*n*=91), *n* (%)	Obese I (*n*=171), *n* (%)	Obese II (*n*=57), *n* (%)	
Demographics					
Age (years)					
Mean (SD)	50.79 (7.492)	49.21 (7.536)	49.12 (6.900)	49.25 (6.862)	0.065
Median (Q1-Q3)	50 (45-58)	48 (42-55)	48 (43-55)	49 (43-55)	-
Education					
No schooling	196 (72.6)	53 (58.2)	100 (58.5)	24 (42.1)	<0.001
Primary school	24 (8.9)	11 (12.1)	13 (7.6)	9 (15.8)	
High school	39 (14.4)	19 (20.9)	37 (21.6)	17 (29.8)	
Secondary and above	11 (4.1)	8 (8.8)	21 (12.3)	7 (12.3)	
Religion					
Hindu	235 (87.4)	74 (81.3)	146 (85.4)	42 (73.7)	0.115
Muslim	26 (9.7)	15 (16.5)	19 (11.1)	14 (24.6)	
Christian	8 (3.0)	2 (2.2)	6 (3.5)	1 (1.8)	
Caste					
SC/ST	138 (51.1)	40 (44.0)	77 (45.0)	24 (42.1)	0.689
OBC	87 (32.2)	37 (40.7)	62 (36.3)	23 (40.4)	
General caste	45 (16.7)	14 (15.4)	32 (18.7)	10 (17.5)	
Marital status					
Single	4 (1.5)	1 (1.1)	2 (1.2)	-	0.167
Married	126 (46.7)	46 (50.5)	103 (60.2)	27 (47.4)	
Other	140 (51.9)	44 (48.4)	66 (38.6)	30 (52.6)	
Work status					
Employed	165 (61.1)	60 (65.9)	109 (63.7)	30 (52.6)	0.389
Housewife	105 (38.9)	31 (34.1)	62 (36.3)	27 (47.4)	
Monthly household income (INR)					
<3000	67 (24.9)	17 (18.7)	30 (17.5)	12 (21.1)	0.437
3000-10,000	136 (50.6)	47 (51.6)	93 (54.4)	34 (59.6)	
>10,000	66 (24.5)	27 (29.7)	48 (28.1)	11 (19.3)	
Health behaviors					
Smokeless tobacco use					
Never user	217 (80.4)	81 (89.0)	160 (93.6)	48 (84.2)	0.001
Former user	8 (3.0)	2 (2.2)	2 (1.2)	5 (8.8)	
Current user	45 (16.7)	8 (8.8)	9 (5.3)	4 (7.0)	
Alcohol use					
Never used	228 (84.4)	85 (93.4)	158 (92.4)	51 (89.5)	0.054
Former user	8 (3.0)	3 (3.3)	4 (2.3)	2 (3.5)	
Current user	34 (12.6)	3 (3.3)	9 (5.3)	4 (7.0)	
Caffeine consumption					
Never	17 (6.3)	3 (3.3)	12 (7.0)	4 (7.0)	0.837
Yes, but not daily	6 (2.2)	2 (2.2)	6 (3.5)	1 (1.8)	
Yes, daily	247 (91.5)	86 (94.5)	153 (89.5)	52 (91.2)	
Level of physical activity					
Inactive/low	29 (10.7)	7 (7.7)	20 (11.7)	7 (12.3)	0.914
Active	113 (41.9)	40 (44.0)	74 (43.3)	27 (47.4)	
Highly active	128 (47.4)	44 (48.4)	77 (45.0)	23 (40.4)	
Current health status					
Diabetes	64 (23.7)	23 (25.3)	63 (36.8)	36 (63.2)	<0.001
Hypertension	219 (81.1)	86 (94.5)	164 (95.9)	55 (96.5)	<0.001
HCL	16 (5.9)	8 (8.8)	14 (58.2)	2 (3.5)	0.495
Anxiety/depression					
None	46 (17.0)	20 (22.0)	41 (24.0)	10 (17.5)	0.507
Moderate	202 (74.8)	67 (73.6)	121 (70.8)	43 (75.4)	
Extreme	22 (8.1)	4 (4.4)	9 (5.3)	4 (7.0)	
Sleep factors					
Duration of sleep (h/night)					
Weighted average (SD)	7.220 (1.443)	7.183 (1.450)	7.018 (1.485)	7.211 (1.295)	0.531
Median (Q1-Q3)	7.143 (6-8)	7.000 (6-8)	7.000 (6-8)	7.286 (6-8)	-
Napping (times/usual week)					
Mean (SD)	0.715 (1.283)	0.637 (0.837)	0.643 (0.858)	0.825 (0.869)	0.664
Median (Q1-Q3)	0 (0-1)	0 (0-1)	0 (0-1)	1 (0-1)	-
Daytime sleepiness					

Contd...

Table 2: Contd...

	BMI				*P*
	Underweight/normal (*n*=270), *n* (%)	Overweight (*n*=91), *n* (%)	Obese I (*n*=171), *n* (%)	Obese II (*n*=57), *n* (%)	
Normal sleepiness	257 (95.2)	82 (90.1)	156 (91.2)	47 (82.5)	0.054
Average sleepiness	7 (2.6)	7 (7.7)	10 (5.8)	5 (8.8)	
Abnormal sleepiness	6 (2.2)	2 (2.2)	5 (2.9)	5 (8.8)	
Snoring					
Nonsnorer	199 (75.7)	59 (67.0)	96 (58.2)	13 (25.0)	<0.001
Moderate snorer	12 (4.6)	7 (8.0)	13 (7.9)	7 (13.5)	
Habitual snorer	52 (19.8)	22 (25.0)	56 (33.9)	32 (61.5)	
How often do you stop breathing while sleeping					
Never	242 (91.3)	79 (89.8)	152 (90.5)	50 (89.3)	0.728
Rarely	9 (3.4)	2 (2.3)	5 (3.0)	2 (3.6)	
Sometimes	8 (3.0)	6 (6.8)	7 (4.2)	3 (5.4)	
Frequently	5 (1.9)	-	4 (2.4)	1 (1.8)	
Always or almost always	1 (0.4)	1 (1.1)	-	-	
Insomnia					
No	118 (43.7)	43 (47.3)	85 (49.7)	35 (61.4)	0.530
Rarely	25 (9.3)	9 (9.9)	13 (7.6)	4 (7.0)	
Occasionally	49 (18.1)	14 (15.4)	23 (13.5)	5 (8.8)	
Frequently	78 (28.9)	25 (27.5)	50 (29.2)	13 (22.8)	
Ever use of sleep medication	10 (3.7)	4 (4.4)	8 (4.7)	4 (7.0)	0.765

Snoring: "Nonsnorer" defined as a never snored or a former snorer (used to snore, but no longer snores). "Moderate snorer" defined as a current snorer who snores 1–2 nights per week. "Habitual snorer" defined as a current snorer who snores 3–7 nights per week. Education: No schooling, Primary school (1–7 years), High school (8–12 years), and Secondary school or above (12+years). Marital status: "Other" includes separated, divorced, and widow/widower. Caffeine consumption: Defined as consumption of coffee or tea. Level of physical activity: "Inactive/low" defined as <600 met-min. "Active" defined as 600–1200 met-min. "Highly active" defined as >1200 met-min. BMI: Underweight <18.5 kg/m^2, Normal weight 18.5–22.9 kg/m^2, Overweight: 23–24.9 kg/m^2, Obese I: 25–29.9 kg/m^2, Obese II ≥30 kg/m^2. Diabetes: Defined as eAG>125 mg/dL or use of medication for diabetes. Hypertension: Defined as systolic BP ≥130 mmHg, diastolic BP ≥80 mmHg, or use of medication for elevated BP. HCL: Defined as LDL-C≥190 mg/dL or use of cholesterol lowering medication. Anxiety/depression: Self-reported history of anxiety and/or depression. Napping: Defined as napping for at least 5 min. Daytime sleepiness: "Normal sleepiness" defined as 0 ≤ESS ≤6. "Average sleepiness" defined as 7 ≤ESS ≤8. "Abnormal sleepiness" defined as 9 ≤ESS ≤24. How often do you stop breathing while sleeping: "Rarely" defined as <1 night per week. "Sometimes" defined as 1–2 nights per week. "Frequently" defined as 3–5 nights per week. "Always or almost always" defined as 6–7 nights per week. Insomnia: "No" defined as <2 nights per month. "Rarely" defined as 2–4 nights per month. "Occasionally" defined as 5–15 nights per month. "Frequently" defined as 16–30 nights per month. If a subject had more than one of the five symptoms of insomnia, insomnia was categorized based on the most frequent symptom. SD: Standard deviation, Q1: First quartile, Q3: Third quartile, SC/ST: Scheduled caste/scheduled tribe, BMI: Body mass index, eAG: Estimated average glucose, BP: Blood pressure, INR: Indian Rupees, HCL: Hypercholesterolemia, ESS: Epworth Sleep Scale, LDL-C: Low-density lipoprotein cholesterol

1-year increase in age ($P = 0.006$) and was nearly four times higher among women with hypertension compared to those without hypertension ($P = 0.002$).

Odds of being obese I

After adjusting for covariates, odds of being obese I among moderate and habitual snorers was more than double that of nonsnorers (adjusted odds ratio: 2.42; 95% CI: 1.01–5.82, $P = 0.048$ and 2.10; 95% CI: 1.31–3.39, $P = 0.002$, respectively) [Table 5]. Age, diabetes, and hypertension were also significantly associated with BMI. The odds of being obese I decreased by 5.9% with every 1-year increase in age ($P < 0.001$). The odds of being obese I was nearly double among people with diabetes compared to nondiabetics ($P = 0.011$). The odds of being obese I was more than five times higher among women with hypertension compared to those without hypertension ($P < 0.001$).

Odds of being obese II

After adjusting for all covariates, the odds of being obese II (compared to underweight/normal weight) were nearly nine times higher among moderate snorers and eight times higher among habitual snorers compared to nonsnorers ($P < 0.001$and$P < 0.001$,respectively) [Table 6]. Age and diabetes were also significantly associated with BMI. The odds of being obese II decreased by 8.8% with every 1-year increase in age ($P < 0.001$) and was nearly five times higher among diabetics compared to nondiabetics ($P < 0.001$). Although nonsignificant, the odds of being obese II was more than six times higher among women with hypertension compared to those without ($P = 0.060$).

DISCUSSION

In this sample of slum-dwelling women, snoring was associated with obesity and cardio-metabolic disorders. In an adjusted model, habitual snorers had more than double the odds of having obesity I and seven times the odds of having obesity II compared to nonsnorers. Moderate snoring was significantly associated with obesity I and obesity II after adjusting for age, diabetes, hypertension, HCL, and daytime sleepiness. Obesity was not associated with short sleep duration, napping, daytime sleepiness,

Table 3: Factors associated with snoring among slum-dwelling women in Mysore, India (n=607)

	Snoring			*P*
	Nonsnorer (*n*=374), *n* (%)	Moderate snorer (*n*=40), *n* (%)	Habitual snorer (*n*=171), *n* (%)	
Demographics				
Age (years)				
Mean (SD)	49.18 (7.23)	49.37 (7.37)	51.77 (7.23)	0.001
Median (Q1-Q3)	48 (43-55)	50 (42-54.5)	52 (45-58)	-
Education				
No schooling	243 (65.0)	19 (47.5)	103 (60.2)	0.330
Primary school	37 (9.9)	4 (10.0)	19 (11.1)	
High school	65 (17.4)	12 (30.0)	37 (21.6)	
Secondary and above	29 (7.8)	5 (12.5)	12 (7.0)	
Religion				
Hindu	316 (84.7)	30 (75.0)	142 (83.0)	0.590
Muslim	46 (12.3)	8 (20.0)	22 (12.9)	
Christian	11 (2.9)	2 (5.0)	7 (4.1)	
Caste				
SC/ST	172 (46.0)	21 (52.5)	80 (46.8)	0.618
OBC	138 (36.9)	16 (40.0)	61 (35.7)	
General caste	64 (17.1)	3 (7.5)	30 (17.5)	
Marital status				
Single	3 (0.8)	2 (5.0)	2 (1.2)	0.215
Married	194 (51.9)	24 (60.0)	83 (48.5)	
Other	177 (47.3)	14 (35.0)	86 (50.3)	
Work status				
Employed	237 (63.4)	26 (65.0)	99 (57.9)	0.434
Housewife	137 (36.6)	14 (35.0)	72 (42.1)	
Monthly household income (INR)				
<3000	79 (21.1)	5 (12.5)	41 (24.1)	0.080
3000-10,000	209 (55.9)	24 (60.0)	76 (44.7)	
>10,000	86 (23.0)	11 (27.5)	53 (31.2)	
Health behaviors				
Smokeless tobacco use				
Never user	328 (87.7)	32 (80.0)	143 (83.6)	0.399
Former user	36 (9.6)	5 (12.5)	23 (13.5)	
Current user	10 (2.7)	3 (7.5)	5 (2.9)	
Alcohol use				
Never used	334 (89.3)	37 (92.5)	145 (84.8)	0.239
Former user	9 (2.4)	2 (5.0)	6 (3.5)	
Current user	31 (8.3)	1 (2.5)	20 (11.7)	
Caffeine consumption				
Never	18 (4.8)	4 (10.0)	13 (7.6)	0.127
Yes, but not daily	6 (1.6)	3 (7.5)	5 (2.9)	
Yes, daily	350 (93.6)	33 (82.5)	153 (89.5)	
Level of physical activity				
Inactive/low	39 (10.4)	4 (10.0)	18 (10.5)	0.999
Active	164 (43.9)	18 (45.0)	73 (42.7)	
Highly active	171 (45.7)	18 (45.0)	80 (46.8)	
Current health status				
BMI (kg/m^2)				
Mean (SD)	22.478 (4.77)	24.687 (5.26)	26.007 (5.06)	<0.001
Median (Q1-Q3)	22 (19-25)	25 (21.5-27)	26 (22-29)	-
BMI				
Underweight/normal	119 (54.2)	12 (30.8)	52 (32.1)	<0.001
Overweight	59 (16.1)	7 (17.9)	22 (13.6)	
Obese I	96 (26.2)	13 (33.3)	56 (34.6)	
Obese II	13 (3.5)	7 (17.9)	32 (19.8)	
Diabetes	96 (25.7)	10 (25.0)	77 (45.0)	<0.001
Hypertension	319 (85.3)	36 (90.0)	166 (97.1)	<0.001
HCL	26 (7.0)	3 (7.5)	12 (7.0)	0.992
Anxiety/depression				
None	82 (21.9)	6 (15.0)	27 (15.8)	0.053
Moderate	264 (70.6)	29 (72.5)	138 (80.7)	
Extreme	28 (7.5)	5 (12.5)	6 (3.5)	
Sleep factors				
Duration of sleep (h/night)				
Weighted average (SD)	7.180 (1.49)	6.911 (1.12)	7.284 (1.35)	0.319

Contd...

Table 3: Contd...

	Snoring			*P*
	Nonsnorer (*n*=374), *n* (%)	Moderate snorer (*n*=40), *n* (%)	Habitual snorer (*n*=171), *n* (%)	
Median (Q1-Q3)	7.143 (6-8)	7 (6-8)	7.714 (6.64-8)	-
Napping (times/usual week)				
Mean (SD)	0.62 (1.15)	0.75 (0.89)	0.83 (0.91)	0.091
Median (Q1-Q3)	0 (0-1)	0.50 (0-1)	1 (0-1)	-
Daytime sleepiness				
Normal sleepiness	359 (96.0)	34 (85.0)	146 (85.4)	<0.001
Average sleepiness	9 (2.4)	4 (10.0)	15 (8.8)	
Abnormal sleepiness	6 (1.6)	2 (5.0)	10 (5.8)	
How often do you stop breathing while sleeping				
Never	337 (91.6)	34 (85.0)	151 (90.4)	0.470
Rarely	10 (2.7)	1 (2.5)	6 (3.6)	
Sometimes	15 (4.1)	4 (10.0)	5 (3.0)	
Frequently	4 (1.1)	1 (2.5)	5 (3.0)	
Always or almost always	2 (0.5)	-	-	
Insomnia				
No	179 (47.9)	18 (45.0)	83 (48.5)	0.477
Rarely	27 (7.2)	4 (10.0)	20 (11.7)	
Occasionally	62 (16.6)	9 (22.5)	22 (12.9)	
Frequently	106 (28.3)	9 (22.5)	46 (26.9)	
Ever use of sleep medication	15 (4.0)	3 (7.5)	8 (4.7)	0.587

Snoring: "Nonsnorer" defined as a never snored or a former snorer (used to snore, but no longer snores). "Moderate snorer" defined as a current snorer who snores 1–2 nights per week. "Habitual snorer" defined as a current snorer who snores 3–7 nights per week. Education: No schooling, Primary school (1–7 years), High school (8–12 years), and Secondary school or above (12+years). Marital status: "Other" includes separated, divorced, and widow/widower. Caffeine consumption: Defined as consumption of coffee or tea. Level of physical activity: "Inactive/low" defined as<600 met-min. "Active" defined as 600–1200 met-min. "Highly active" defined as >1200 met-min. BMI: Underweight <18.5 kg/m^2, Normal weight 18.5–22.9 kg/m^2, Overweight: 23–24.9 kg/m^2, Obese I: 25–29.9 kg/m^2, Obese II ≥30 kg/m^2. Diabetes: Defined as eAG >125 mg/dL or use of medication for diabetes. Hypertension: Defined as systolic BP≥130 mmHg, diastolic BP ≥80 mmHg, or use of medication for elevated BP. HCL: Defined as LDL-C ≥190 mg/dL or use of cholesterol lowering medication. Anxiety/depression: Self-reported history of anxiety and/or depression. Napping: Defined as napping for at least 5 min. Daytime sleepiness: "Normal sleepiness" defined as 0 ≤ESS ≤6. "Average sleepiness" defined as 7 ≤ESS ≤8. "Abnormal sleepiness" defined as 9≤ESS≤24. How often do you stop breathing while sleeping: "Rarely" defined as <1 night per week. "Sometimes" defined as 1–2 nights per week. "Frequently" defined as 3-5 nights per week. "Always or almost always" defined as 6–7 nights per week. Insomnia: "No" defined as<2 nights per month. "Rarely" defined as 2–4 nights per month. "Occasionally" defined as 5–15 nights per month. "Frequently" defined as 16–30 nights per month. If a subject had more than one of the five symptoms of insomnia, insomnia was categorized based on the most frequent symptom. SD: Standard deviation, Q1: First quartile, Q3: Third quartile, SC/ST: Scheduled caste/scheduled tribe, BMI: Body mass index, eAG=Estimated average glucose, BP: Blood pressure, INR: Indian Rupees, HCL: Hypercholesterolemia, ESS: Epworth Sleep Scale, LDL-C: Low-density lipoprotein cholesterol

Table 4: Odds of being overweight versus underweight/normal weight among slum-dwelling women in Mysore, India (*n*=607)

	Unadjusted		Adjusted	
	OR (95% CI)	*P*	aOR (95% CI)	*P*
Age (years)	0.971 (0.939-1.003)	0.079	0.950 (00.916-0.986)	0.006
Diabetes	1.089 (0.627-1.890)	0.762	0.961 (0.527-1.753)	0.898
Hypertension	4.005 (1.542-10.402)	0.004	4.843 (1.815-12.927)	0.002
Snoring				
Nonsnorer	Reference	-	Reference	-
Moderate snorer	1.967 (0.738-5.245)	0.176	2.056 (0.747-5.661)	0.163
Habitual snorer	1.427 (0.799-2.547)	0.229	1.429 (0.784-2.606)	0.243

BMI: Underweight<18.5 kg/m^2, Normal weight 18.5–22.9 kg/m^2, Overweight: 23–24.9 kg/m^2, Obese I: 25–29.9 kg/m^2, Obese II ≥30 kg/m^2. Diabetes: Defined as eAG >125 mg/dL or use of medication for diabetes. Hypertension: Defined as systolic BP ≥130 mmHg, diastolic BP ≥80 mmHg, or use of medication for elevated BP. Snoring: "Nonsnorer" defined as a never snored or a former snorer (used to snore, but no longer snores). "Moderate snorer" defined as a current snorer who snores 1–2 nights per week. "Habitual snorer" defined as a current snorer who snores 3–7 nights per week. OR: Odds ratio, aOR: Adjusted OR, CI: Confidence interval, BMI: Body mass index, eAG: Estimated average glucose, BP: Blood pressure

sleep apnea, insomnia, or sleep medication. HS was less common among normal/underweight women, compared to women who were overweight or obese. These findings are consistent with previous studies showing that self-reported HS in women was strongly associated with age and BMI.[24]

Growing evidence suggests that the relationship between snoring and obesity may be bi-directional. Adiposity has been shown to enhance the risk for snoring,[25] while snoring appears to increase risk for metabolic disorders, diabetes, poor sleep quality, and daytime sleepiness.[26] Lauderdale *et al*. also demonstrated that snoring moderated the association between sleep duration and BMI.[27] In a longitudinal model, persons who reported snoring also gained more weight. While the mechanisms underlying these associations are still little understood, some research suggests that sleep-disordered breathing may influence systemic inflammation, insulin resistance, and appetite with reciprocal and bi-directional effects.[28]

Study results are consistent with other research showing that snoring is associated with cardio-metabolic disorders

Table 5: Odds of being Obese I versus underweight/normal weight among slum-dwelling women in Mysore, India (*n*=607)

	Unadjusted		Adjusted	
	OR (95% CI)	*P*	aOR (95% CI)	*P*
Age (years)	0.969 (0.943-0.995)	0.021	0.941 (0.913-0.970)	<0.001
Diabetes	1.878 (1.234-2.858)	0.003	1.829 (1.152-2.903)	0.011
Hypertension	5.456 (2.409-12.359)	<0.001	5.625 (2.407-13.146)	<0.001
Snoring				
Nonsnorer	Reference	-	Reference	-
Moderate snorer	2.246 (0.984-5.124)	0.055	2.424 (1.009-5.824)	0.048
Habitual snorer	2.232 (1.422-3.505)	0.001	2.105 (1.305-3.396)	0.002

BMI: Underweight <18.5 kg/m^2, Normal weight 18.5–22.9 kg/m^2, Overweight: 23–24.9 kg/m^2, Obese I: 25–29.9 kg/m^2, Obese II ≥30 kg/m^2. Diabetes: Defined as eAG >125 mg/dL or use of medication for diabetes. Hypertension: Defined as systolic BP ≥130 mmHg, diastolic BP ≥80 mmHg, or use of medication for elevated BP. Snoring: "Nonsnorer" defined as a never snored or a former snorer (used to snore, but no longer snores). "Moderate snorer" defined as a current snorer who snores 1–2 nights per week. "Habitual snorer" defined as a current snorer who snores 3–7 nights per week. OR: Odds ratio, aOR: Adjusted OR, CI: Confidence interval, BMI: Body mass index, eAG: Estimated average glucose, BP: Blood pressure

Table 6: Odds of being Obese II versus underweight/normal weight among slum-dwelling women in Mysore, India (*n*=607)

	Unadjusted		Adjusted	
	OR (95% CI)	*P*	aOR (95% CI)	*P*
Age (years)	0.971 (0.933-1.011)	0.154	0.912 (0.868-0.959)	<0.001
Diabetes	5.518 (3.001-10.145)	<0.001	5.786 (2.843-11.777)	<0.001
Hypertension	6.404 (1.507-27.218)	0.012	7.385 (0.915-59.574)	0.060
Snoring				
Nonsnorer	Reference	-	Reference	-
Moderate snorer	8.928 (2.992-26.642)	<0.001	9.909 (2.995-32.785)	<0.001
Habitual snorer	9.419 (4.602-19.277)	<0.001	8.259 (3.836-17.782)	<0.001

BMI: Underweight <18.5 kg/m^2, Normal weight 18.5–22.9 kg/m^2, Overweight: 23–24.9 kg/m^2, Obese I: 25–29.9 kg/m^2, Obese II ≥30 kg/m^2. Diabetes: Defined as eAG >125 mg/dL or use of medication for diabetes. Hypertension: Defined as systolic BP ≥130 mmHg, diastolic BP ≥80 mmHg, or use of medication for elevated BP. Snoring: "Nonsnorer" defined as a never snored or a former snorer (used to snore, but no longer snores). "Moderate snorer" defined as a current snore. OR: Odds ratio, aOR: Adjusted OR, CI: Confidence interval, BMI: Body mass index, eAG: Estimated average glucose, BP: Blood pressure

such as insulin resistance, hypertension, metabolic syndrome, and type-2 diabetes.[29] Current evidence suggests that snoring may play a role in fragmenting sleep, an important modulator of metabolic homeostasis.[30]

There were limitations to our study. The design was cross-sectional, and hence, we are unable to determine the temporality of the relationship between snoring and obesity. Sleep variables were self-reported and subject to recall and information bias. It is possible that some of the association between snoring and obesity reflects undiagnosed sleep apnea, which has previously been associated with obesity. Although we adjusted for potential confounders, residual confounding remains a possibility, as in all observational studies. Finally, due to low cell counts, we were unable to provide precise estimates of the effect size for some of the variables. Despite these limitations, the study also has strengths. They include recruitment of a community-based sample likely to be free of the referral biases that may occur in studies with clinic-based samples. The study was designed to minimize measurement error. Data were collected using validated and standardized instruments and questionnaires administered by well-trained staff following highly structured protocols.

This study, in a sample of slum-dwelling Indian women, found a significant relationship between snoring and obesity. In contrast to previous studies that found a consistent correlation between sleep duration and BMI, we found little association between the length of night-time sleep and BMI except among those who reported snoring. Further research is needed to understand the underlying mechanisms connecting sleep-disordered breathing and BMI.

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Conflicts of interest

There are no conflicts of interest.

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