Title
Risk of Sleep Apnea Is Associated with Abdominal Obesity Among Asian Americans: Comparing Waist-to-Hip Ratio and Body Mass Index.

Authors
Lee, Sunmin
Ryu, Soomin
Lee, Grace E
et al.

Publication Date
2023

DOI
10.1007/s40615-022-01507-z

Peer reviewed

Journal of Racial and Ethnic Health Disparities
https://doi.org/10.1007/s40615-022-01507-z

Risk of Sleep Apnea Is Associated with Abdominal Obesity Among Asian Americans: Comparing Waist-to-Hip Ratio and Body Mass Index

Sunmin Lee[1] · **Soomin Ryu**[2] · **Grace E. Lee**[1] · **Susan Redline**[3] · **Brittany N. Morey**[4]

Received: 23 August 2022 / Revised: 15 December 2022 / Accepted: 22 December 2022

Abstract

Objective This study examines associations between the risk of sleep apnea and abdominal obesity (assessed by waist-to-hip ratio (WHR)) and general obesity (assessed by body mass index (BMI)) in a sample of Chinese and Korean American immigrants.

Methods The dataset included Chinese and Korean participants aged 50–75 who were recruited from primary care physicians' clinics from April 2018 to June 2020 in the Baltimore-Washington D.C. Metropolitan area ($n = 394$). Abdominal obesity was determined if WHR ≥ 0.9 in men and WHR ≥ 0.85 in women. General obesity was determined if BMI ≥ 30. The risk of sleep apnea was determined by using the Berlin questionnaire. Poisson regression models examined associations between sleep apnea risk and obesity. Models controlled for socio-demographic risk factors.

Results Twelve percent of the study participants were classified as a high risk for sleep apnea, and 75% had abdominal obesity whereas 6.4% had general obesity. High risk of sleep apnea was positively associated with abdominal obesity ($PR = 1.31$, 95% CI: 1.17–1.47) and general obesity ($PR = 2.19$, 95% CI: 0.90–5.32), marginally significant at $p < 0.1$).

Conclusions Chinese and Korean immigrants living in the USA who are at high risk of sleep apnea have higher abdominal obesity, even after accounting for sociodemographic characteristics. Abdominal obesity may be a better indicator than general obesity when examining the risk of sleep apnea among Asian Americans.

Information on Clinical Trial Name: Screening To Prevent ColoRectal Cancer (STOP CRC) among At-Risk Asian American Primary Care Patients
NCT Number: NCT03481296;
Date of registration: March 29, 2018
URL: https://clinicaltrials.gov/ct2/show/NCT03481296?term=Sunmin+Lee&draw=2&rank=1

Keywords Abdominal obesity · Sleep apnea · Asian Americans

✉ Sunmin Lee
sunminl7@hs.uci.edu

1 Department of Medicine, School of Medicine, University of California-Irvine, 1001 Health Sciences Road, Bldg835, Ste 231, Irvine, CA, USA

2 Department of Epidemiology, School of Public Health, University of Michigan, Ann Arbor, MI, USA

3 Department of Medicine, Harvard Medical School, Brigham and Women's Hospital, Boston, MA, USA

4 Department of Health, Society, & Behavior, Program in Public Health, University of California, Irvine, CA, USA

Introduction

Studies on obstructive sleep apnea—a common condition characterized by the collapse of the upper airways resulting in oxygen desaturation and fragmented sleep [1]—reveal that ethnic/racial obstructive sleep apnea disparities exist [2, 3]. While comparisons of obstructive sleep apnea prevalence across racial/ethnic groups in the USA remain limited [3], according to a 2015 cross-sectional analysis of the Multi-Ethnic Study of Atherosclerosis (MESA) data, 14.9% of non-Hispanic Blacks, 17.7% of Hispanics, and 17.8% of Chinese Americans had severe sleep apnea compared to 12.4% of non-Hispanic Whites [3]. Moreover, racial/ethnic minoritized populations have a higher rate of undiagnosed and untreated sleep apnea compared to their non-Hispanic White counterparts, with the same 2015 MESA study revealing that Chinese populations were 49% less likely to report a prior diagnosis of obstructive sleep apnea compared to non-Hispanic White populations despite their higher rates of obstructive sleep apnea via multiple objective measurements [3]. These observed disparities in obstructive sleep apnea are of particular concern because sleep apnea has been implicated in the pathogenic pathways of multiple conditions including diabetes [4], obesity [5], stroke [6], cardiovascular diseases [7], and all-cause mortality [8]. In particular, sleep apnea can increase the risk of developing obesity by potentially predisposing individuals to increased body fat percentages through leptin-mediated disrupted metabolism [9] and dysregulation in glucose levels [10]. Sleep apnea may also lead to changes in appetite-regulating orexin neuron activity, leading to increased food intake and reduced physical activity, which increase weight gain [11, 12].

With the increasing number of studies implicating obesity as an outcome of sleep apnea [13] as well as a causal pathway between sleep apnea and cardiometabolic disease risk [5], it is important to note that Asians have higher health risks at lower weight categories compared to other racial and ethnic groups [14]. In the USA, only 17.4% of Asian Americans are considered obese, compared to 49.6% of Blacks, 44.8% of Hispanics, and 42.2% of non-Hispanic Whites [15]. However, body mass index (BMI)—the most commonly used metric of obesity in the USA—is not an accurate indicator of obesity among Asian populations because they are known to develop obesity-related illnesses (e.g., cardiovascular disease, diabetes, and metabolic syndrome) at a much lower BMI [16]. Despite having lower obesity prevalence, rates of diabetes and metabolic syndrome among Asians are similar to or slightly higher than for non-Hispanic White populations in every BMI category [17]. A growing body of literature suggests that measuring abdominal fat may be a better indicator of obesity among Asians. Measuring abdominal fat is particularly critical for Asians (Chinese, Indians, Indonesians, and Malays) who have 3 to 5% higher body fat percentages than European White populations at the same BMI [18]. Asian American women furthermore have larger amounts of visceral adipose tissue compared to European American women [19]. Another study also suggested that visceral and liver fat were much greater among Japanese Americans compared to Hispanic, non-Hispanic Black, non-Hispanic White, and Native Hawaiian Americans [20]. This higher intra-abdominal fat may contribute to larger upper airway soft tissues among Asian Americans, which can lead to sleep apnea [21]. Recent studies reported that abdominal obesity is correlated with tongue fat—which may play a more proximate role in obstructive sleep apnea pathogenesis than fat elsewhere [22, 23]. Notably, waist-to-hip ratio (WHR) provides a measure of both subcutaneous and intra-abdominal adipose tissue [24], which has been associated with several well-established metabolic risk factors including diabetes [25, 26], high blood pressure [25, 27], and high cholesterol [25] in various East Asian populations. Therefore, it is important to consider WHR in addition to BMI as the measure of obesity and corresponding cardiometabolic disease risk among Asian Americans.

While existing evidence points to sleep apnea being associated with increased abdominal obesity, no study to our knowledge has examined these associations for Asian Americans. This is especially important to examine because initial evidence shows that sleep apnea is more prevalent and severe among Americans from East Asia, compared to Americans of European or African descent, even at similar BMIs [28]. This discrepancy may be because Asians have narrower cranial base dimensions than Europeans, causing reduced pharyngeal airflow and an increased risk of sleep apnea [29]. Existing studies of sleep apnea, WHR, and BMI have focused on populations of mostly non-Hispanic White participants in the USA and populations from Asian countries. A US-based study found that patients with obstructive sleep apnea had a significant weight gain of approximately 7 kg greater than similarly obese controls without obstructive sleep apnea in the year preceding obstructive sleep apnea diagnosis [30]. Two studies in Asian countries also suggested similar findings. Using 838 community participants of the Korean Genome Epidemiology study, Kim and colleagues found that individuals with sleep apnea had a 1.57 increased odds of having visceral obesity, which was defined as having a visceral fat area (VFA) greater than or equal to 100 cm^2 as measured by CT scan [28]. Another study involving 120 patients undergoing regular check-ups at the National Taiwan University Hospital found that sleep-disordered breathing was associated with 1.10 increased odds of central obesity as defined as having a waist circumference greater than or equal to 90 cm in men and greater than or equal to 80 cm in women, even after adjustment for BMI [31].

The current study fills critical gaps in sleep disparities research by clarifying the associations between the risk of sleep apnea and obesity among Asian Americans, comparing measures of WHR and BMI. To our knowledge, our study is the first to examine these associations between the risk of sleep apnea, WHR, and BMI in a sample of Chinese and Korean Americans. Based on the findings of previous studies, we aim to examine the separate associations between the risk of sleep apnea and obesity measured using WHR and measured using BMI, to investigate if there are any differences in these associations for Asian Americans. As the first hypothesis, we expect a positive association between sleep apnea risk and obesity measured using WHR. Secondly, we expect a positive but weaker or non-existent association between sleep apnea risk and BMI (hypothesis 2).

Methods

Sample

We used data from a randomized controlled trial to increase colorectal cancer screening among 400 Chinese and Korean Americans (200 Chinese and 200 Korean Americans) living in the Baltimore-Washington D.C. Metropolitan area. Study participants were between the ages of 50 and 75, and they were recruited from primary care physicians' clinics in Baltimore, Maryland, Northern Virginia, and Washington D.C. We used the baseline survey data collected from August 2018 to June 2020. After signing informed consent forms, 400 participants completed the survey either in-person or by phone in their preferred language (Mandarin, Korean, or English). Ninety-two percent of the participants (155 Chinese and 200 Korean Americans) completed a self-administered questionnaire in person, and 8% of the participants (45 Chinese Americans) completed a research assistant-led phone survey because of the COVID-19 outbreak in March 2020. This study was approved by the Institutional Review Boards of the University of Maryland, College Park, and the University of California, Irvine.

We have two analytic samples based on two obesity-related measures. For the participants who completed in-person baseline meetings ($n = 355$), trained research assistants measured height, weight, and waist and hip circumferences. For those who completed phone-based baseline meetings ($n = 45$), self-reported weight and height were collected during the 6-month follow-up phone survey. Two out of 355 participants refused to measure weight and height during the in-person baseline meeting, while four out of 45 participants were not responsive to our phone call for a 6-month follow-up survey where we asked about their weight and height. Therefore, our analytic sample for the outcome of BMI was 394. Information on the waist and hip circumferences was not collected for those who completed a phone-based baseline meeting ($n = 45$), and three participants refused to measure waist and hip circumferences during in-person baseline meetings, resulting in an analytic sample of $n = 352$ for the outcome of WHR.

Waist to Hip Ratio (WHR)

We assessed abdominal obesity using WHR. The WHR was generated by dividing waist circumference by hip circumference (measured in cm). The measurements of WHR were rounded to two decimal places. Having a high WHR was defined as WHR ≥ 0.9 in men and ≥ 0.85 in women, based on clinical cut points that have been determined to be associated with an increased risk of chronic conditions [32, 33]. Based on this definition, we created a binary variable: high (≥ 0.9 in men and ≥ 0.85 in women) and low (< 0.9 in men and < 0.85 in women) WHR.

Obesity

To assess obesity, we used BMI which is generally used to determine obesity. We calculated BMI by dividing weight in pounds (l b) by height in inches (in) squared and multiplying by a conversion factor of 703, according to the guideline of the Centers for Disease Control and Prevention [34]. For the main analysis, we used obesity as a binary variable based on standard criteria for BMI (non-obese: BMI < 30, obese: BMI ≥ 30) [35]. As a sensitivity analysis, we used a binary obesity variable based on lower BMI recommendations in Asian populations, referred to as Asian BMI (non-obese: BMI < 27, obese: BMI ≥ 27) [36].

Sleep Apnea

To identify the risk of having sleep apnea, the Berlin questionnaire was used [37], a valid clinical screening test and epidemiological tool to identify people with the risk of sleep apnea [37–40]. As the Berlin sleep apnea scale includes questions about obesity, which is one of the dependent variables in this study, we used a modified high-risk obstructive sleep apnea score [41]. Three subcategories were used from the questionnaire: *subcategory 1*, snoring patterns, *i.e.*, snoring intensity and snoring frequency provided a positive score when the response was "louder than talking" or "3–4 times a week or almost every day"; *subcategory 2*, breathing pauses provided a positive score when the response was "3–4 times a week" or "almost every day"; and *subcategory 3*, feeling tired or fatigued in the morning and/or daytime, provided a positive score when the response was "3–4 times a week" or "almost every day." Participants were classified as high-risk obstructive sleep apnea when they scored positive on 2 or more subcategories, and the participants who did not score positive in any or only 1 subcategory were categorized as low-risk obstructive sleep apnea. The risk of having sleep apnea was used as a binary variable (high risk versus low risk) in the analysis. We did not use hypertension information included in the Berlin questionnaire to minimize bias by having underlying cardiovascular diseases.

Covariates

Sociodemographic characteristics included age, sex, Asian subgroup, marital status, education, income, and employment status. Age was a continuous variable in years, and sex was categorized as male and female. The Asian subgroup was categorized as Chinese and Korean. Marital status was recoded into a binary variable: married, cohabiting, or not currently married. Education was classified as follows: less than high school, high school graduate/GED, some college/vocational school, college graduate, and higher than a college degree. Household income was categorized as < $20,000, $20,000-$39,999, $40,000–$59,999, and ≥ $60,000. Employment status was recoded into three categories: full-time, part-time, and not employed (which includes people who were unable to work or on disability, students, keeping house, or retired).

Potential Effect Modifiers

We tested age, sex, Asian subgroup (Chinese vs. Korean), and marital status (married or live with a partner vs. not currently married) as potential effect modifiers of the associations between sleep apnea risk, WHR, and obesity.

Statistical Analysis

First, descriptive analysis was conducted for the entire sample and by the risk of sleep apnea. We report the mean and standard error for continuous age and frequencies and percentages for all other categorical variables. We calculated differences in these variables by sleep apnea risk using t-test and chi-square tests. Second, we conducted Poisson regression models to estimate associations between sleep apnea risk and high WHR or obesity. Poisson regression models were used as the preferred method to estimate prevalence ratios instead of logistic models that may overestimate the associations using odds ratios in cross-sectional studies [42, 43]. For each outcome, three regression models were conducted. The first model estimated the association between sleep apnea risk and each outcome variable without any covariates. The second model added age, sex, Asian subgroup, and marital status to the first model, while the third model added education, household income, and employment status to the second model. Finally, we examined interaction terms to test for effect modification by age, sex, Asian subgroup, and marital status for the association between sleep apnea risk and high WHR and obesity. All statistical analyses were computed using Stata, version 15.1.

Results

Table 1 reports the descriptive characteristics. Out of 394 participants, 345 (87.6%) respondents were classified as low risk of sleep apnea, while 49 (12.4%) were classified as high risk. There were statistically significant differences between the two sleep apnea risk groups for WHR[1] and sex at the $p < 0.05$ level. There were moderate differences between the two sleep apnea risk groups for obesity at the $p < 0.1$ level. A higher proportion of individuals in the high-risk sleep apnea group had high WHR ($n = 41$, 93.2%) compared to those in the low-risk group ($n = 222$, 72.1%). The high-risk group had a larger proportion of obese participants ($n = 6$, 12.2%) than the low-risk group ($n = 19$, 5.5%). Additionally, the high-risk group had a greater proportion of males ($n = 31$, 63.3%) compared to the low-risk group ($n = 155$, 44.9%).

Table 2 displays the adjusted prevalence ratio (aPR) and 95% confidence intervals (CIs) for Poisson regression models to estimate associations between sleep apnea risk and high WHR. In all models, we found that a high risk of sleep apnea was significantly associated with a high WHR (all p-values < 0.01). In the first model, without adjusting any potential confounders, participants who are in the high-risk group had 1.29 (95% CI: 1.16–1.44) times the prevalence of having high WHR compared to those in the low-risk group. This positive association was maintained in the second model (aPR: 1.29; 95% CI:1.16–1.45), where age, sex, Asian subgroup, and marital status were controlled for. In model 3, which further adjusted education, income, and employment status, individuals with a high risk of sleep apnea had a 1.31 prevalence of having high WHR compared to those with a low risk of sleep apnea (95% CI: 1.17–1.47).

Table 3 reports aPR and 95% CIs for Poisson regression models to assess associations between sleep apnea risk and obesity (BMI ≥ 30). Across all models, the associations between the high risk of sleep apnea and the prevalence of obesity were only marginally significant ($p < 0.1$) with wide confidence intervals. Without any potential confounders, individuals with a high risk of sleep apnea had 2.22 (95% CI: 0.93–5.30) times the prevalence of obesity as those with low risk. This positive association was similar in models 2 and 3, after including age, sex, Asian subgroup, marital status, education, household income, and employment status as covariates (aPR in model 2: 2.19; 95% CI: 0.91–5.23; aPR in model 3: 2.19; 95% CI: 0.90–5.32).

In a sensitivity analysis, we examined an association between sleep apnea risk and the prevalence of obesity

[1] The mean and standard errors for waist-hip ratio are based on a sample of $n = 352$.

Table 1 Characteristics of the study participants ($n = 394$)

	Total	Sleep apnea		p-value
		Low risk	High risk	
	(100%)	$n = 345$ (87.6%)	$n = 49$ (12.4%)	
WHR[1], *n* (%)				
Low	89 (25.3)	86 (27.9)	3 (6.8)	0.003
High	263 (74.7)	222 (72.1)	41 (93.2)	
WHR, mean (SE)	0.902 (0.003)	0.898 (0.003)	0.928 (0.008)	0.003
Obesity, *n* (%)				
Non-obese	369 (93.7)	326 (94.5)	43 (87.8)	0.070
Obese	25 (6.4)	19 (5.5)	6 (12.2)	
BMI, mean (SE)	24.6 (0.2)	24.5 (0.2)	25.4 (0.6)	0.110
Age, mean (SE)	58.4 (0.3)	58.3 (0.3)	58.8 (0.9)	0.580
Sex, *n* (%)				
Male	186 (47.2)	155 (44.9)	31 (63.3)	0.016
Female	208 (52.8)	190 (55.1)	18 (36.7)	
Asian subgroup, *n* (%)				
Chinese	194 (49.2)	174 (50.4)	20 (40.8)	0.208
Korean	200 (50.8)	171 (49.6)	29 (59.2)	
Marital status, *n* (%)				
Married or living with a partner	336 (85.3)	295 (85.5)	41 (83.7)	0.735
Not currently married	58 (14.7)	50 (14.5)	8 (16.3)	
Education, *n* (%)				
< HS	42 (10.7)	35 (10.1)	7 (14.3)	0.230
HS grad/GED	88 (22.3)	78 (22.6)	10 (20.4)	
Some college/vocational school	67 (17.0)	57 (16.5)	10 (20.4)	
College grad	101 (25.6)	85 (24.6)	16 (32.7)	
College +	96 (24.4)	90 (26.1)	6 (12.2)	
Income, *n* (%)				
< $20	61 (15.5)	51 (14.8)	10 (20.4)	0.616
$20 K–39,999	61 (15.5)	55 (15.9)	6 (12.2)	
$40 K–59,999	84 (21.3)	72 (20.9)	12 (24.5)	
> $60 K	188 (47.7)	167 (48.4)	21 (42.9)	
Employment, *n* (%)				
Full-time	229 (58.1)	200 (58.0)	29 (59.2)	0.683
Part-time	81 (20.6)	73 (21.2)	8 (16.3)	
Not employed	84 (21.3)	72 (20.9)	12 (24.5)	

[1]The mean and standard errors for waist-to-hip ratio are based on smaller sample ($n = 352$)

WHR, waist-hip ratio; *low*, WHR < 0.9 for men, WHR < 0.85 for women; high, WHR ≥ 0.9 for men, WHR ≥ 0.85 for women

Non-obese, BMI < 30; obese, BMI ≥ 30

using Asian BMI (Appendix). Although the findings suggest that a high risk of sleep apnea may be associated with a greater prevalence of obesity based on Asian BMI, none of the associations was statistically significant ($p > 0.1$).

Additionally, none of the interaction tests revealed any significant effect modifications by age, sex, Asian subgroup, or marital status.

Discussion

To the best of our knowledge, the present study is the first to examine the relationship between sleep apnea risk, abdominal obesity, and obesity among Chinese and Korean Americans from a general population sample. First, our study found a significant positive association between sleep apnea risk and

Table 2 Poisson regression analysis: association between sleep apnea and high waist-to-hip ratio (*n* = 352)

	Model 1 PR (95% CI)	Model 2 PR (95% CI)	Model 3 PR (95% CI)
High risk of sleep apnea (ref: low risk)	1.29** (1.16–1.44)	1.29** (1.16–1.45)	1.31** (1.17–1.47)
Age		1.01* (1.00–1.02)	1.01 (1.00–1.02)
Sex (ref: male)			
Female		1.10 (0.97–1.24)	1.10 (0.96–1.26)
Asian subgroup (ref: Korean)			
Chinese		0.93 (0.82–1.06)	0.90 (0.79–1.02)
Marital status (ref: married/cohabit)			
Not currently married		0.90 (0.74–1.08)	0.88 (0.73–1.07)
Education (ref: graduate/professional)			
< HS			1.06 (0.86–1.31)
HS graduate/GED			1.01 (0.82–1.23)
Some college/vocational school			1.08 (0.90–1.30)
College grad			0.92 (0.76–1.12)
Household income (ref: > $60 K)			
< $20			0.99
$20 K-39,999			(0.81–1.20)
			1.06
$40 K-59,999			(0.91–1.25)
			0.88
			(0.74–1.05)
Employment status (ref: full-time)			
Part-time			0.99 (0.85–1.16)
Not employed			1.02 (0.87–1.21)
Constant	0.72** (0.67–0.77)	0.39** (0.22–0.69)	0.45* (0.23–0.88)

†$p < 0.10$; *$p < 0.05$; **$p < 0.01$

Model 1: sleep apnea

Model 2: model 1 + age, sex, Asian subgroup, marital status

Model 3: model 2 + education, household income, employment status

PR, prevalence ratio; *CI*, confidence interval

low, WHR < 0.9 for men, WHR < 0.85 for women; high, WHR ≥ 0.9 for men, WHR ≥ 0.85 for women

high WHR. Specifically, individuals with a high risk of sleep apnea were more likely to have unhealthy WHR compared to those with a low risk of sleep apnea. These associations were evident in unadjusted models and in models adjusted for demographic and socio-economic variables that could be potential confounders. Second, we also found that individuals in the high risk of sleep apnea group may be more likely to be obese than those in the low-risk group, but the 95% confidence intervals were too wide to draw conclusions for both regular and Asian BMI cutoff values.

Table 3 Poisson regression analysis: association between sleep apnea and obesity ($n = 394$)

	Model 1 PR (95% CI)	Model 2 PR (95% CI)	Model 3 PR (95% CI)
High risk of sleep apnea (ref: low risk)	2.22† (0.93–5.30)	2.19† (0.91–5.23)	2.19† (0.90–5.32)
Age		1.01 (0.94–1.08)	1.00 (0.93–1.08)
Sex (ref: male)			
Female		0.67 (0.30–1.49)	0.59 (0.27–1.33)
Asian subgroup (ref: Korean)			
Chinese		1.65 (0.74–3.68)	1.82 (0.80–4.13)
Marital status (ref: married/cohabit)			
Not currently married		0.55 (0.13–2.29)	0.59 (0.13–2.62)
Education (ref: graduate/professional)			
< HS			0.53 (0.11–2.61)
HS graduate/GED			1.09 (0.34–3.45)
Some college/vocational school			0.70 (0.18–2.67)
College grad			0.86 (0.30–2.44)
Household income (ref: > $60 K)			
< $20			1.27 (0.30–5.43)
$20 K-39,999			1.71 (0.50–5.90)
$40 K-59,999			2.43† (0.92–6.40)
Employment status (ref: full-time)			
Part-time			0.91 (0.29–2.93)
Not employed			1.55 (0.65–3.68)
Constant	0.06** (0.04–0.09)	0.03 (0.00–2.00)	0.04 (0.00–4.48)

†$p < 0.10$; *$p < 0.05$; **$p < 0.01$

Model 1: sleep apnea

Model 2: model 1 + age, sex, Asian subgroup, marital status

Model 3: model 2 + education, household income, employment status

PR, prevalence ratio; *CI*, confidence interval

Non-obese, BMI < 30; obese, BMI ≥ 30

Our findings are consistent with previous studies in Asian countries. In a representative adult cohort in Korea ($n = 838$), individuals with sleep apnea had higher waist circumference and abdominal visceral fat measured by CT scanning compared to individuals without sleep apnea [28]. In that study, the association between sleep apnea and visceral fat remained, even after adjusting for BMI and other covariates. Similar to our current analysis, a case–control study in China ($n = 120$) demonstrated through logistic regression analysis that participants with sleep-disordered breathing had significantly higher waist circumferences but not significantly greater BMI compared to those without sleep-disordered breathing, after accounting for control variables [31]. Our current study of Chinese and Korean Americans builds on this literature conducted in China and Korea to demonstrate that the association between sleep apnea risk and WHR appeared to be more precise and stronger than the association between sleep apnea risk and obesity measured using BMI. Altogether, these findings indicate that for Chinese and Korean Americans, abdominal obesity may be a better indicator of poor health than obesity measured using BMI. This is confirmed by other studies that show that Asian Americans tend to carry more visceral fat around their abdomen than non-Hispanic Whites Canadians of European origin [19, 44]. Furthermore, studies have found that Asian Americans tend to have more chronic diseases associated with high abdominal obesity measured using WHR as compared to obesity measured using BMI [45].

Overall, our findings align with growing evidence that sleep apnea has a pathophysiologic mechanism linked to high WHR and obesity. Sleep apnea increases sleep deprivation, daytime somnolence, and disrupted metabolism [11, 46]. Some studies have revealed that individuals with sleep apnea have gained weight in the year preceding the diagnosis and have higher levels of leptin—a hormone that helps in inhibiting hunger when the body does not need energy—than expected based on their percentage of body fat [47, 48], compared to similarly obese controls. These findings indicate that sleep apnea is associated with higher resistance to the weight-reducing effects of leptin [11]. Additionally, intervention studies have found that treatment of sleep apnea led to decreases in levels of ghrelin—a hormone that stimulates hunger and increases fat storage [49, 50]—which could decrease food intake and result in lowering overall body fat [51, 52]. Emerging findings also indicated a correlation between abdominal obesity and tongue fat, which may play a role in obstructive sleep apnea pathogenesis [22]. Furthermore, sleep apnea may result in behavioral changes due to daytime somnolence [46], including a reduction of physical activity and an increase in unhealthy eating habits [11]. Studies have found associations between increased sleep apnea severity and decreases in objectively measured as well as in self-reported physical activity [12, 53].

Our study has some limitations. First, we assessed the risk of sleep apnea using self-reports of the Berlin questionnaire. Although the Berlin questionnaire has been evaluated as a valid clinical screening test and epidemiological tool to identify people with a risk of sleep apnea [37–40], it does not indicate a clinical diagnosis of sleep apnea. Second, we used self-reported weight and height to calculate BMI for 45 of the original 400 participants who completed a phone-based survey due to the onset of the COVID-19 pandemic, which may lead to some reporting bias. Third, the cross-sectional study design did not enable us to examine temporal ordering or causal mechanisms between sleep apnea risk and WHR and obesity. Fourth, although we adjusted for several socio-demographic covariates, there is a possibility of unmeasured confounding, which could distort the associations. Finally, the study was limited to Chinese and Korean Americans aged 50 to 75 years living in the Washington D.C. Metropolitan area. Thus, our findings may not be generalizable to Asian Americans outside of this age range, with origins from Asian countries other than China and Korea, or who live elsewhere in the USA.

Despite these limitations, our findings have important implications. First, we found that Chinese and Korean Americans ages 50 to 75 years with a high risk of sleep apnea were more likely to have high abdominal obesity. The association between sleep apnea risk with WHR appeared to be stronger than the association between sleep apnea risk with obesity. Healthcare providers should be aware that solely focusing on BMI may lead to an underestimation of the consequence of sleep apnea risk among older Chinese and Korean Americans. Second, our study suggests a possible mechanism for the increased incidence of cardiovascular disease in Chinese and Korean Americans ages 50 to 75 years with sleep apnea [28]. Recent evidence indicates that the increased prevalence of obesity and cardiovascular diseases in the US adult population has been catalyzed and compounded by the increased occurrence of sleep apnea, but previous studies did not include large enough samples of Asian Americans to determine whether this pattern is true for this population [54, 55]. With a prospective study design, future research on this topic should use objective measurements to examine the associations between sleep apnea risk, WHR, obesity, and subsequent cardiovascular disease among Asian subgroups across various ages to provide richer information and greater generalizability.

Physicians, nurses, and mid-level providers should understand that sleep apnea can contribute to abdominal obesity, which may be a better indicator of poor health than obesity measured using BMI for Chinese and Korean American patients. Medical professionals may provide their Asian American patients with education about the causes, symptoms, and consequences of sleep apnea as well as abdominal obesity prevention. Future public health and policy interventions should address how Asian Americans have been underdiagnosed and undertreated for sleep apnea [56]. These interventions may take into consideration these findings to monitor abdominal obesity when identifying and treating East Asian patients for sleep apnea, including when physicians and other healthcare providers prescribe effective treatments such as nasal continuous positive airway pressure (CPAP) [56].

Appendix

Table 4

Table 4 Poisson regression analysis: association between sleep apnea and obesity using Asian BMI ($n = 394$)

	Model 1 PR (95% CI)	Model 2 PR (95% CI)	Model 3 PR (95% CI)
High risk of sleep apnea (ref: low risk)	1.37 (0.84–2.23)	1.26 (0.78–2.03)	1.27 (0.80–2.04)
Age		1.00 (0.97–1.03)	1.00 (0.96–1.04)
Sex (ref: male)			
Female		0.60* (0.40–0.89)	0.58** (0.38–0.87)
Asian subgroup (ref: Korean)			
Chinese		0.83 (0.56–1.23)	0.82 (0.53–1.28)
Marital status (ref: married/cohabit)			
Not currently married		0.57 (0.28–1.16)	0.56 (0.28–1.14)
Education (ref: Graduate/Professional)			
< HS			1.08 (0.54–2.18)
HS graduate/GED			1.50 (0.86–2.61)
Some college/vocational school			1.14 (0.61–2.16)
College grad			0.99 (0.56–1.76)
Household income (ref: > $60 K)			
< $20			0.78 (0.40–1.54)
$20 K-39,999			1.11 (0.65–1.89)
$40 K-59,999			0.81 (0.49–1.36)
Employment status (ref: full-time)			
Part-time			0.90 (0.51–1.58)
Not employed			1.05 (0.60–1.83)
Constant	0.21** (0.17–0.26)	0.29 (0.04–1.92)	0.28 (0.03–2.79)

$^{\dagger}p < 0.10$; $*p < 0.05$; $**p < 0.01$

Model 1: sleep apnea

Model 2: model 1 + age, sex, Asian subgroup, marital status

Model 3: model 2 + education, household income, employment status

PR, prevalence ratio; *CI*, confidence interval

Non-obese: BMI < 27; obese: BMI ≥ 27

Author Contribution Sunmin Lee contributed to the study's conception and design. Material preparation, data collection, and analysis were performed by Soomin Ryu and Sunmin Lee. The first draft of the manuscript was written by Soomin Ryu, Grace Lee, and Sunmin Lee. Susan Redline and Brittany Morey provided extensive comments on data interpretation and revision of drafts. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Funding This research was supported by the National Institute on Minority Health and Health Disparities of the National Institutes of Health under award number R01MD012778. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Declarations

Ethics Approval This study was approved by the Institutional Review Boards of the University of Maryland, College Park, and the University of California, Irvine.

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

Conflict of Interest Dr. Redline has received consulting fees from Eli Lilly Inc., ApniMed, and Jazz Pharma, all unrelated to this work. All other authors have no other conflicts of interest to disclose.

References

1. Slowik JM, Collen JF. Obstructive sleep apnea. StatPearls: Treasure Island; 2021.
2. Dudley KA, Patel SR. Disparities and genetic risk factors in obstructive sleep apnea. Sleep Med. 2016;18:96–102. https://doi.org/10.1016/j.sleep.2015.01.015.
3. Chen X, Wang R, Zee P, et al. Racial/ethnic differences in sleep disturbances: the multi-ethnic study of atherosclerosis (MESA). Sleep. 2015;38(6):877–88. https://doi.org/10.5665/sleep.4732.
4. Reutrakul S, Mokhlesi B. Obstructive sleep apnea and diabetes: a state of the art review. Chest. 2017;152(5):1070–86. https://doi.org/10.1016/j.chest.2017.05.009.
5. Mehra R, Redline S. Sleep apnea: a proinflammatory disorder that coaggregates with obesity. J Allergy Clin Immunol. 2008;121(5):1096–102. https://doi.org/10.1016/j.jaci.2008.04.002.
6. Barreto PR, Diniz DLO, Lopes JP, et al. Obstructive sleep apnea and wake-up stroke - a 12 months prospective longitudinal study. J Stroke Cerebrovasc Dis. 2020;29(5): 104564. https://doi.org/10.1016/j.jstrokecerebrovasdis.2019.104564.
7. Blackwell JN, Walker M, Stafford P, Estrada S, Adabag S, Kwon Y. Sleep apnea and sudden cardiac death. Circ Rep. 2019;1(12):568–74. https://doi.org/10.1253/circrep.cr-19-0085.
8. Punjabi NM, Caffo BS, Goodwin JL, et al. Sleep-disordered breathing and mortality: a prospective cohort study. PLoS Med. 2009;6(8): e1000132. https://doi.org/10.1371/journal.pmed.1000132.
9. Eun YG, Kim MG, Kwon KH, Shin SY, Cho JS, Kim SW. Short-term effect of multilevel surgery on adipokines and pro-inflammatory cytokines in patients with obstructive sleep apnea. Acta Otolaryngol. 2010;130(12):1394–8. https://doi.org/10.3109/00016489.2010.495134.
10. Pandey A, Demede M, Zizi F, et al. Sleep apnea and diabetes: insights into the emerging epidemic. Curr Diab Rep. 2011;11(1):35–40. https://doi.org/10.1007/s11892-010-0164-9.
11. Beccuti G, Pannain S. Sleep and obesity. Curr Opin Clin Nutr Metab Care. 2011;14(4):402–12. https://doi.org/10.1097/MCO.0b013e3283479109.
12. Quan SF, O'Connor GT, Quan JS, et al. Association of physical activity with sleep-disordered breathing. Sleep Breath. 2007;11(3):149–57. https://doi.org/10.1007/s11325-006-0095-5.
13. Jehan S, Zizi F, Pandi-Perumal SR, et al. Obstructive sleep apnea and obesity: implications for public health. Sleep Med Disord. 2017;1(4).
14. Wen CP, Cheng TYD, Tsai SP, et al. Are Asians at greater mortality risks for being overweight than Caucasians? Redefining obesity for Asians. Public Health Nutr. 2009;12(4):497–506. https://doi.org/10.1017/S1368980008002802.
15. Centers for Disease Control Prevention (CDC). Adult obesity facts. 2016. https://www.cdc.gov/obesity/data/adult.html. Accessed May 11 2017.
16. Fang J, Zhang ZF, Ayala C, Thompson-Paul AM, Loustalot F. Cardiovascular health among non-hispanic Asian Americans: NHANES, 2011–2016. J Am Heart Assoc. 2019;8(13):1. https://doi.org/10.1161/JAHA.118.011324.
17. Palaniappan LP, Wong EC, Shin JJ, Fortmann SP, Lauderdale DS. Asian Americans have greater prevalence of metabolic syndrome despite lower body mass index. Int J Obes (Lond). 2011;35(3):393–400. https://doi.org/10.1038/ijo.2010.152.
18. Deurenberg P, Deurenberg-Yap M, Guricci S. Asians are different from Caucasians and from each other in their body mass index/body fat per cent relationship. Obes Rev. 2002;3(3):141–6. https://doi.org/10.1046/j.1467-789x.2002.00065.x.
19. Park YW, Allison DB, Heymsfield SB, Gallagher D. Larger amounts of visceral adipose tissue in Asian Americans. Obes Res. 2001;9(7):381–7. https://doi.org/10.1038/oby.2001.49.
20. Lim U, Monroe KR, Buchthal S, et al. Propensity for intra-abdominal and hepatic adiposity varies among ethnic groups. Gastroenterology. 2019;156(4):966-75.e10. https://doi.org/10.1053/j.gastro.2018.11.021.
21. Xu L, Keenan BT, Wiemken AS, et al. Differences in three-dimensional upper airway anatomy between Asian and European patients with obstructive sleep apnea. Sleep. 2020;43(5). https://doi.org/10.1093/sleep/zsz273.
22. Wang SH, Keenan BT, Wiemken A, et al. Effect of weight loss on upper airway anatomy and the apnea-hypopnea index. The Importance of Tongue Fat. Am J Respir Crit Care Med. 2020;201(6):718–27. https://doi.org/10.1164/rccm.201903-0692OC.
23. Schwab RJ, Pasirstein M, Pierson R, et al. Identification of upper airway anatomic risk factors for obstructive sleep apnea with volumetric magnetic resonance imaging. Am J Respir Crit Care Med. 2003;168(5):522–30. https://doi.org/10.1164/rccm.200208-866OC.
24. Bjorntorp P. Fat cell distribution and metabolism. Ann N Y Acad Sci. 1987;499:66–72. https://doi.org/10.1111/j.1749-6632.1987.tb36198.x.
25. Lam BC, Koh GC, Chen C, Wong MT, Fallows SJ. Comparison of body mass index (BMI), body adiposity index (BAI), waist circumference (WC), waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) as predictors of cardiovascular disease risk factors in an adult population in Singapore. PLoS One. 2015;10(4): e0122985. https://doi.org/10.1371/journal.pone.0122985.
26. Pham NM, Eggleston K. Prevalence and determinants of diabetes and prediabetes among Vietnamese adults. Diabetes Res Clin Pract. 2016;113:116–24. https://doi.org/10.1016/j.diabres.2015.12.009.
27. Van Bui N, Vo Hoang L, Van Bui T, et al. Prevalence and risk factors of hypertension in the Vietnamese elderly. High Blood Press Cardiovasc Prev. 2019;26(3):239–46. https://doi.org/10.1007/s40292-019-00314-8.

28. Kim NH, Lee SK, Eun CR, et al. Short sleep duration combined with obstructive sleep apnea is associated with visceral obesity in Korean adults. Sleep. 2013;36(5):723–9. https://doi.org/10.5665/sleep.2636.
29. Li K, Powell N, Kushida C, Riley R, Adornato B, Guilleminault C. A comparison of Asian and white patients with obstructive sleep apnea syndrome. Laryngoscope. 1999;109(12):1937–40. https://doi.org/10.1097/00005537-199912000-00007.
30. Phillips BG, Hisel TM, Kato M, et al. Recent weight gain in patients with newly diagnosed obstructive sleep apnea. J Hypertens. 1999;17(9):1297–300. https://doi.org/10.1097/00004872-199917090-00009.
31. Tseng PH, Lee PL, Hsu WC, et al. A higher proportion of metabolic syndrome in Chinese subjects with sleep-disordered breathing: a case-control study based on electrocardiogram-derived sleep analysis. PLoS ONE. 2017;12(1): e0169394. https://doi.org/10.1371/journal.pone.0169394.
32. Hu G, Jousilahti P, Antikainen R, Katzmarzyk PT, Tuomilehto J. Joint effects of physical activity, body mass index, waist circumference, and waist-to-hip ratio on the risk of heart failure. Circulation. 2010;121(2):237–44. https://doi.org/10.1161/CIRCULATIONAHA.109.887893.
33. Edelstein ZR, Farrow DC, Bronner MP, Rosen SN, Vaughan TL. Central adiposity and risk of Barrett's esophagus. Gastroenterology. 2007;133(2):403–11. https://doi.org/10.1053/j.gastro.2007.05.026.
34. Leahy LG. Medication-assisted weight loss in the age of obesity. J Psychosoc Nurs Ment Health Serv. 2017;55(8):21–6. https://doi.org/10.3928/02793695-20170718-02.
35. Prevention CfDC. Defining adult overweight & obesity. Centers for Disease Control and Prevention. 2021. https://www.cdc.gov/obesity/adult/defining.html. Accessed 09/21/2021 2021.
36. Initiative JAAD. BMI for Asian and Asian American Adults. Joslin Diabetes Center. 2015. Accessed 09/21/2021 2021.
37. Netzer NC, Stoohs RA, Netzer CM, Clark K, Strohl KP. Using the Berlin questionnaire to identify patients at risk for the sleep apnea syndrome. Ann Intern Med. 1999;131(7):485–91. https://doi.org/10.7326/0003-4819-131-7-199910050-00002.
38. Senaratna CV, Perret JL, Matheson MC, et al. Validity of the Berlin questionnaire in detecting obstructive sleep apnea: a systematic review and meta-analysis. Sleep Med Rev. 2017;36:116–24. https://doi.org/10.1016/j.smrv.2017.04.001.
39. Saengsuwan J, Ungtrakul N, Saengsuwan J, Sawanyawisuth K. Preliminary validity and reliability of a Thai Berlin questionnaire in stroke patients. BMC Res Notes. 2014;7(1):348. https://doi.org/10.1186/1756-0500-7-348.
40. Best MW, Fitzpatrick M, Milev R, Bowie CR, Jokic R. Utility of the Berlin questionnaire for predicting obstructive sleep apnea in individuals with treatment-resistant depression. Sleep Breath. 2013;17(4):1221–7. https://doi.org/10.1007/s11325-013-0827-2.
41. Peker Y, Celik Y, Arbatli S, et al. Effect of high-risk obstructive sleep apnea on clinical outcomes in adults with coronavirus disease 2019: a multicenter, prospective, observational cohort study. Ann Am Thorac Soc. 2021; (2325–6621 (Electronic)). https://doi.org/10.1513/AnnalsATS.202011-1409OC.
42. Coutinho LM, Scazufca M, Menezes PR. Methods for estimating prevalence ratios in cross-sectional studies. Rev Saude Publica. 2008;42(6):992–8.
43. Richardson DB, Kinlaw AC, MacLehose RF, Cole SR. Standardized binomial models for risk or prevalence ratios and differences. Int J Epidemiol. 2015;44(5):1660–72. https://doi.org/10.1093/ije/dyv137.
44. Lear SA, Humphries KH, Kohli S, Chockalingam A, Frohlich JJ, Birmingham CL. Visceral adipose tissue accumulation differs according to ethnic background: results of the multicultural community health assessment trial (M-CHAT). Am J Clin Nutr. 2007;86(2):353–9. https://doi.org/10.1093/ajcn/86.2.353.
45. Darbandi M, Pasdar Y, Moradi S, Mohamed HJJ, Hamzeh B, Salimi Y. Discriminatory capacity of anthropometric indices for cardiovascular disease in adults: a systematic review and meta-analysis. Prev Chronic Dis. 2020;17:E131. https://doi.org/10.5888/pcd17.200112.
46. Pillar G, Shehadeh N. Abdominal fat and sleep apnea: the chicken or the egg? Diabetes Care. 2008;31(Suppl 2):S303–9. https://doi.org/10.2337/dc08-s272.
47. Ozturk L, Unal M, Tamer L, Celikoglu F. The association of the severity of obstructive sleep apnea with plasma leptin levels. Arch Otolaryngol Head Neck Surg. 2003;129(5):538–40. https://doi.org/10.1001/archotol.129.5.538.
48. UlukavakCiftci T, Kokturk O, Bukan N, Bilgihan A. Leptin and ghrelin levels in patients with obstructive sleep apnea syndrome. Respiration. 2005;72(4):395–401. https://doi.org/10.1159/000086254.
49. Saarelainen S, Lahtela J, Kallonen E. Effect of nasal CPAP treatment on insulin sensitivity and plasma leptin. J Sleep Res. 1997;6(2):146–7. https://doi.org/10.1046/j.1365-2869.1997.00034.x.
50. Harsch IA, Konturek PC, Koebnick C, et al. Leptin and ghrelin levels in patients with obstructive sleep apnoea: effect of CPAP treatment. Eur Respir J. 2003;22(2):251. https://doi.org/10.1183/09031936.03.00010103.
51. Tschöp M, Smiley DL, Heiman ML. Ghrelin induces adiposity in rodents. Nature. 2000;407(6806):908–13. https://doi.org/10.1038/35038090.
52. Nakazato M, Murakami N, Date Y, et al. A role for ghrelin in the central regulation of feeding. Nature. 2001;409(6817):194–8. https://doi.org/10.1038/35051587.
53. Chasens ER, Sereika SM, Houze MP, Strollo PJ. Subjective and objective appraisal of activity in adults with obstructive sleep apnea. J Aging Res. 2011;2011: 751819. https://doi.org/10.4061/2011/751819.
54. Surani SR. Diabetes, sleep apnea, obesity and cardiovascular disease: why not address them together? World J Diabetes. 2014;5(3):381–4. https://doi.org/10.4239/wjd.v5.i3.381.
55. Wolk R, Somers VK. Obesity-related cardiovascular disease: implications of obstructive sleep apnea. Diabetes Obes Metab. 2006;8(3):250–60. https://doi.org/10.1111/j.1463-1326.2005.00508.x.
56. Lattimore JDL, Celermajer David S, Wilcox I. Obstructive sleep apnea and cardiovascular disease. J Am Coll Cardiol. 2003;41(9):1429–37. https://doi.org/10.1016/S0735-1097(03)00184-0.