The impact of insomnia symptoms on obesity among Mexicans aged 50 and older

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Abstract

Objective. To examine the association between insomnia and obesity in Mexican adults aged 50 and older. **Materials and methods.** We used data from the Mexican Health and Aging Study (2015-2018). Self-reported insomnia was measured using the modified insomnia severity index with scores ranging from zero to six. Obesity was categorized using body mass index (BMI ≥ 30 kg/m^2). We used generalized estimating equations to assess the association between insomnia and obesity over three years. **Results.** Insomnia was associated with obesity (odds ratio [OR]: 1.06, 95% confidence interval [CI]: 1.01,1.11), among those with no obesity at baseline. Among those with obesity, insomnia was not associated with changes in BMI. Lastly, obesity was not associated with changes in insomnia symptoms. **Conclusion.** This work highlights the association between insomnia and obesity among older Mexican adults and demonstrates the importance of further studies on the effects of insomnia within this population.

Keywords: insomnia; obesity; gender; sex; Mexico

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Resumen

Objetivo. Examinar la asociación entre insomnio y obesidad en adultos mexicanos de 50 años o más. **Material y métodos.** Se utlizaron datos del Estudio Nacional de Salud y Envejecimiento (2015-2018). El insomnio se midió utilizando el índice de gravedad del insomnio modificado con puntuaciones que oscilaban entre cero y seis. La obesidad se clasificó utilizando el índice de masa corporal (IMC ≥ 30 kg/m^2). Se utilizaron ecuaciones de estimación generalizadas para evaluar la asociación entre el insomnio y la obesidad durante tres años. **Resultados.** El insomnio se asoció con la obesidad (razón de momios [OR]:1.06, intervalo de confianza [IC] al 95%: 1.01,1.11), entre aquéllos sin obesidad en la ronda basal. Entre aquéllos con obesidad el insomnio no se asoció con cambios en el IMC. La obesidad no se asoció con cambios en los síntomas del insomnio. **Conclusión.** Este trabajo demuestra la asociación entre insomnio y obesidad entre adultos mayores mexicanos y la importancia de realizar más estudios sobre los efectos del insomnio en esta población.

Palabras clave: insomnio; obesidad; género; sexo; México

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Despite the large portion of the lifespan that is spent sleeping, sleep problems are largely ignored as a controllable risk factor for chronic conditions by physicians and patients.[1,2] For all age groups, insufficient sleep affects immunological function, cognition, memory, learning, chronic health conditions, and overall quality of life.[2] Such effects of sleep deprivation more profoundly affect older adults and particularly women.[3] Here, we contribute to past research by analyzing the association between self-reported insomnia and obesity among older adults in Mexico while examining gender differences. A matter of concern has been the proliferation of obesity rates in Mexico, leading it to be named a leading public health concern.[4-6] Thus, understanding the biopsychosocial determinants, including sleep, of obesity is paramount to improving the well-being of the Mexican population.

The changes older adults experience in their sleep circadian rhythms include advanced sleep phase disorder (shifting sleep patterns to sleeping and arising progressively earlier), increased patterns of insomnia (trouble falling asleep), increased sleep latency, decreased slow wave and rapid eye movement sleep, and decreased sleep maintenance.[7-9] These shifts in rhythms, particularly symptoms of insomnia and decreased sleep maintenance, have been associated with a decrease in health-related quality of life among older adults. Among older adults, women tend to be at an even greater risk of sleep difficulties, with an international meta-analysis of 31 cohort studies on insomnia showing a female predisposition for insomnia across all ages that is more pronounced among older adults, but is not found in men.[10] Additionally, among Mexicans aged 75 years and older, women more often report a worse quality of sleep than men.[11] It is postulated that the decreased sleep quality among older adult women is caused by hormonal changes, particularly due to the decreased levels of estrogen and progesterone, associated with menopause, which cause increased sleep arousals and decreased time in deep sleep.[7]

The association between sleep and obesity in older adults overall, is especially important to understand due to obesity's association with reduced life expectancy and increased morbidity due to increased risk of hypertension, dyslipidemia, glucose intolerance, and overall cardiovascular disease, as well as the high worldwide rates of obesity, which are particularly pronounced in Mexico.[12,13] Population studies conducted in adults aged 60 years and older in Spain showed that subjects that slept less than five hours per day had a greater frequency of obesity and severe obesity than individuals that received more than five hours of sleep.[14] Previous work in other high-income countries, such as Australia and Sweden, have also found an association between sleep, including sleep duration and insomnia symptoms, and obesity; however, research in low- and middle-income countries remains limited,[15,16] and it is not well understood whether insomnia symptoms are associated with obesity among older Mexican adults, which is important, given the disproportionately high levels of obesity in Mexico.[4,5] Similarly, we are unaware of any past research that examines body mass index (BMI) changes that may result from insomnia patterns among those who are obese or whether obesity is associated with insomnia symptoms among older Mexicans. However, literature shows that obstructive sleep apnea (OSA), defined as episodes of breathing cessation during sleep, has a higher prevalence among individuals with obesity and is genetically linked to both obesity and insomnia symptoms.[17-19] Thus, having pronounced insomnia symptoms or being obese, can both increase one's risk of OSA, thereby creating an ongoing undesirable cycle.[20]

Mexico, a low- and middle-income country (LMIC), has some of the highest documented rates of obesity worldwide and is facing a rapidly aging population,[5,21] with 49.4% of Mexican adults aged 50 years and older being overweight and 28.7% being obese.[22] Additionally, insomnia prevalence in Mexico City, was measured to be as high as 39.7%.[6] Despite these high levels of both insomnia and obesity in Mexico, the link between insomnia and obesity among older Mexican adults has not been well studied. Additionally, studies of Hispanic populations in the U.S. with origins in Mexico, Cuba, the Dominican Republic, Central America, Puerto Rico, and South America, have shown that Hispanic populations are 59% more likely to report poor quality of sleep in the U.S. and face greater increases in insomnia severity over an eight-year period compared to non-Hispanic white individuals.[23-25] Despite this high prevalence of sleep problems among Hispanics, research has shown that 43% Hispanic adults aged 75 and older believed sleep problems were a normal part of aging, with little possibility for intervention.[26] Thus, understanding the implications of insomnia on obesity is paramount to developing tailored interventions that can stem from the high levels of obesity observed in the Mexican older adult population.

Although the prevalence of sleep problems in older adults and their implications for chronic health conditions have been well documented among high-income countries in Europe, America, and even some parts of Asia,[14,15,27] the prevalence and implications of sleep problems has not been widely studied among older adults in LMICs such as Mexico. Mexico is an especially important setting of investigation due to their lower quality diets that may contribute to exacerbating their insomnia symptoms,[28] their high rates of obesity,[5] as well as their limited knowledge of sleep hygiene and its protective effects.[25,27,29] Our objective is to examine the

longitudinal association between insomnia and obesity, among a population-based sample of Mexican adults aged 50 and older. We consider three questions. First, are insomnia symptoms associated with the development of obesity over 3-years among those with normal weight or overweight? Second, among those who have obesity, do insomnia symptoms influence BMI? Lastly, does obesity status influence changes in insomnia symptoms? We also examine sex/gender differences. We hypothesize that insomnia will be positively associated with obesity, particularly among women because the age-related hormonal changes they experience increase their susceptibility to insomnia.[10] We also hypothesize that insomnia symptoms will be associated with changes in BMI among those with obesity and obesity status will be associated with insomnia due to health variables such as OSA that would predispose insomnia and obesity to a bidirectional relationship.[18-20]

Materials and methods

Data source

We used data from the 2015 and 2018 waves of the Mexican Health and Aging Study (MHAS), a longitudinal, and nationally representative study on adults aged 50 and older in Mexico.[30] The MHAS started in 2001, with individuals born before 1951. Refresher samples of adults born in 1952-1962 were included in 2012, and of adults born in 1963-1968 were incorporated in 2018. The MHAS has a high response and follow-up rate and has been used by previous researchers analyzing obesity.[30,31] Informed consent was obtained from all participants and the MHAS was approved by the Institutional Review Board or Ethics Committee of the University of Texas Medical Branch (IRB#11-061), *Instituto Nacional de Estadística y Geografía* (INEGI) in Mexico, and the *Instituto Nacional de Salud Pública* in Mexico.

For the purposes of our study, we used the 2015 and 2018 waves for our analysis, as 2015 was the first year in which the MHAS assessed participants' insomnia symptoms. Figure 1 displays our analytical sample selection. We included participants aged 50 and older in 2015, with a direct interview and complete information at both waves. It should be noted that we excluded those who were underweight, due to their small numbers (n= 184).

Measures

Insomnia symptoms

Insomnia symptoms were assessed in 2015 and 2018 using three questions from the nighttime sleep difficulties category of the Insomnia Severity Index (ISI). The modified Spanish version of the ISI was designed to measure the participants' perceptions of their sleep habits.[32] Importantly the ISI has been validated for use in Spanish.[32] The first question measured sleep-onset related insomnia by asking, "How often do you have trouble falling asleep?" The next question measured sleep maintenance and asked, "How often do you have trouble with waking up during the night after you have fallen asleep?" The last question evaluated undesired early awakenings by asking "How often do you have trouble with waking up too early and not being able to fall asleep again?" Participants' responses to these questions could vary between rarely or never, sometimes, or most of the time, for which they would receive a score of zero, one, or two, respectively. Insomnia symptoms were measured as a continuous variable with the participants' numerical score for each question totaled, ranging between zero, no symptoms of insomnia, and six, severe symptoms of insomnia. Previous studies examining insomnia also measured insomnia symptoms as a continuous variable.[33,34] We also conducted a sensitivity analysis where we assessed insomnia as a binary variable, in which individuals were considered to have insomnia if they responded with "most of the time" to any of the three questions in our modified ISI, and we found similar results.[16]

Obesity and body mass index

Obesity was categorized using BMI based on self-reported height and weight. We used imputed height and weight provided by the MHAS, for participants who were missing height or weight data, as previous research has shown that using imputed height and weight with MHAS data results in more robust data.[35] We categorized the participants as having normal weight (BMI ≤25 kg/m^2), overweight (BMI<30), or obesity (BMI ≥30 kg/m^2).

Covariates

Covariates included sex/gender (men, women), age, years of education, marital status, locality size (rural, urban), consumer durables (0-3, 4-6, or 7+), exercise status (yes, no), smoking status, elevated depressive symptoms (yes, no), pain (yes, no), and hypertension (yes, no). Marital status was categorized as single, married, or widowed. Localities with a population larger than 100 000 were classified as urban. Consumer durables were assessed by asking participants if they had the following household assets: radio, television, refrigerator, washing machine, telephone, water heater, internet, or computer. Consumer durables were used as a marker for socioeconomic well-being because they

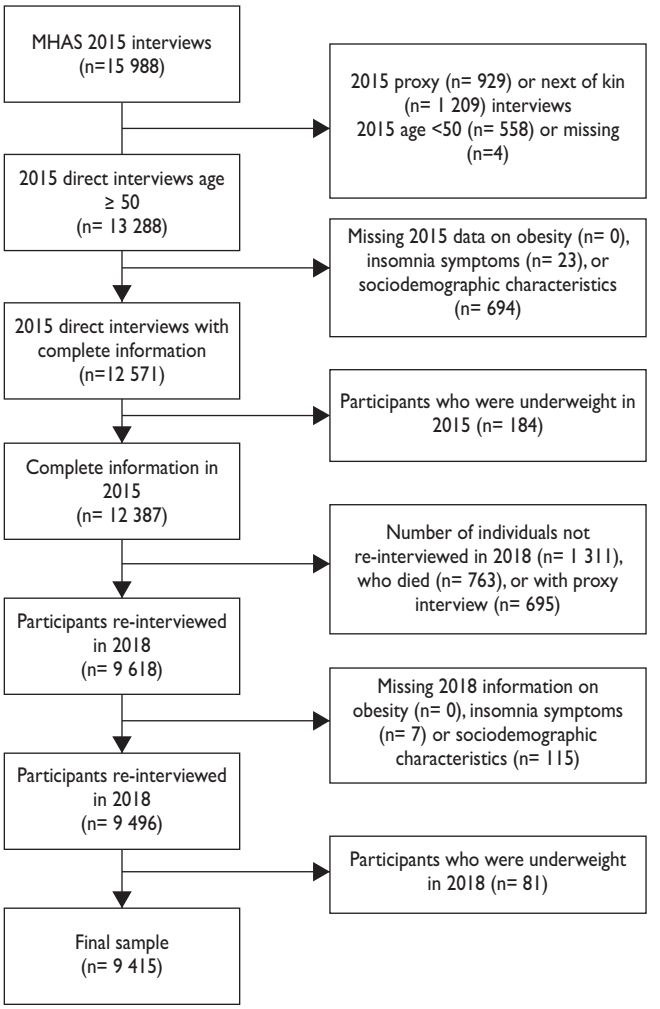

Figure 1. Selection of Mexican Health and Aging Study (MHAS) participants aged 50 and older from Mexico in 2015, included in this analysis

may reflect older adults' true economic well-being better than income, which can be low in older age. Smoking status was categorized as abstainer, past smoker, or current smoker. Exercise was assessed by asking participants if "on average during the last two years, have you exercised or done hard physical work three or more times per week in a row?" (yes/no). Depressive symptoms were evaluated using a modified version of the Center for Epidemiological Studies-Depression (CES-D). A score of 5 or higher on a 0-9 scale on the modified CES-D was used as the cutoff for elevated depressive symptoms.[36] Pain was assessed by asking participants "Do you often suffer from pain?" Hypertension and diabetes were assessed by asking participants "Has a doctor or medical personnel ever diagnosed you with [health condition]?"

Statistical analysis

Descriptive statistics, including Chi-square tests of independence and t-tests, were used to assess characteristics of the sample by obesity status in 2015. We assessed the association of obesity with insomnia based on three approaches. For all models, we evaluated interactions and stratified by sex/gender. For all models we also calculated robust standard errors to adjust for potential clustering.

First, we used general estimation equation models to assess the association of obesity (dependent variable) in 2018 as a function of insomnia symptoms (independent variable) over the course of two waves, among those without obesity in 2015 (both those with normal weight and overweight). We used a logit link binomial distribution

with an exchangeable correlation structure to account for the repeated measures among most participants. Secondly, we used general estimation equation models to assess the changes in BMI (dependent variable) as a function of insomnia symptoms (independent variable) among those with obesity in 2015. Lastly, we examined the changes in insomnia symptoms (dependent variable) as a function of obesity status (independent variable). For these last two approaches, we used an identity link with normal distribution with an exchangeable correlation structure.

All models controlled for sex/gender, age, years of education, marital status, locality, consumer durables, smoking status, exercise, elevated depressive symptoms, pain, hypertension, and diabetes. Sex/gender, age, and years of education were measured as time-stable at baseline, while time-varying characteristics with the potential to change over the two waves included marital status, locality, consumer durables, exercise status, smoking status, depressive symptoms, pain, hypertension, and diabetes.

For all models, we conducted a sensitivity analysis where we refit these three models with insomnia as a binary categorical variable. We also conducted a sensitivity analysis where we examined insomnia symptoms as a function of continuous BMI. Stata 17.0 was used for all analyses (StataCorp LLC, College Station, TX).

Results

Baseline characteristics

Table I displays baseline characteristics of the 2015 sample, by obesity status assessed that year. In 2015, 26.0% of our sample was classified as having obesity, and 44.7% was classified as being overweight. The number of insomnia symptoms did not differ by obesity status in 2015, but those with obesity were more often classified as having insomnia symptoms and defined as reporting "most of the time" to any of the three symptoms ($p<0.05$). Those in the sample who were overweight and with obesity also more often reported problems falling asleep and with sleep maintenance, but not with early morning awakenings compared to those with normal weight ($p<0.05$).

Generalized estimating equation models

In the fully adjusted total model that assessed the development of obesity as a function of insomnia symptoms, for every unit increase in insomnia symptoms reported, the odds of obesity increased by 6% (OR: 1.06 [95%CI: 1.01,1.11]) (table II). The interaction between insomnia symptoms and sex/gender was not significant ($p=0.32$). In the stratified analysis, among men, for every unit increase in insomnia symptoms, the odds of obesity increased by 9% (OR: 1.09 [95%CI: 1.01,1.17]) (table II). The relationship between insomnia symptoms and obesity was not significant for women (OR: 1.05 [95%CI: 0.99,1.12]). The results of our sensitivity analysis, where insomnia was categorized dichotomously, were consistent.

Further analyses that evaluated changes in BMI as a function of insomnia symptoms showed that, among those with obesity at baseline, insomnia was not associated with changes in BMI (β: 0.00 [95%CI: -0.07,0.07]) (table III). Similarly, the interaction between insomnia symptoms and sex/gender when including those with obesity at baseline was also not significant ($p=0.29$), and insomnia was not associated with changes in BMI when analyzed by gender. We had similar results in our sensitivity analysis where insomnia was dichotomously categorized.

When analyzing for changes in insomnia symptoms as a function of obesity status, the results indicated that obesity was not associated with insomnia symptoms over time when obesity was categorized using three levels: normal weight, overweight, or obesity (table IV). The results were consistent when the BMI was specified as a continuous variable (results not shown). The interaction between obesity as a three-level variable and sex/gender was not significant ($p=0.31$); however, when stratified by gender, obesity was associated with increases in insomnia symptoms in women (β: 0.09 [95%CI: 0.003,0.18]), but not in men (results). In our sensitivity analysis, where we dichotomized insomnia symptoms, obesity was also not associated with insomnia symptoms over time. When we examined continuous insomnia symptoms as a function of BMI, we did not observe an association.

Discussion

This study analyzed longitudinal data from a nationally representative sample of Mexicans aged 50 and older to investigate the association between self-reported insomnia symptoms and self-reported obesity. Overall, we found that insomnia symptoms were associated with the development of obesity over three years among those without obesity at baseline. These results suggest that sleeping patterns could be an important determinant of one of Mexico's leading public health concerns; the dramatic recent increases in obesity.[4] However, the results also indicated that, among those with obesity at baseline, insomnia symptoms were not associated with changes in the BMI. Lastly, obesity, analyzed both as a discrete and continuous BMI variable, was not associated with insomnia symptoms over time.

Our findings are consistent with other studies on sleep and obesity.[15,16] Cai and colleagues found that

Table I

BASELINE (2015) CHARACTERISTICS OF THE MEXICAN HEALTH AND AGING STUDY PARTICIPANTS AGED 50 AND OLDER IN MEXICO, BY OBESITY STATUS IN 2015 (N= 9 415)

2015 characteristic	*Normal weight (n= 2 757; 29.3%)*	*Overweight (n= 4 211; 44.7%)*	*Obesity (n= 2 447; 26.0%)*
Sex/gender*			
Men	1 275 (46.2)	1 836 (43.6)	736 (30.1)
Women	1 482 (53.8)	2 375 (56.4)	1 711 (69.9)
Age (SD)*	67.9 (9.1)	65.8 (8.7)	63.7 (8.0)
Years of education (SD)*	5.4 (4.7)	5.8 (4.6)	6.0 (4.4)
Marital status*			
Single	433 (15.7)	559 (13.3)	326 (13.3)
Married	1 784 (64.7)	2 928 (69.5)	1 730 (70.7)
Widowed	540 (19.6)	724 (17.2)	391 (16.0)
Locality*			
Rural	1 305 (47.3)	1 841 (43.7)	956 (39.1)
Urban	1 452 (52.7)	2 370 (56.3)	1 491 (60.9)
Consumer durables*			
0-3	655 (23.8)	704 (16.7)	317 (13.0)
4-6	1 343 (48.7)	2 093 (49.7)	1 278 (52.2)
7+	759 (27.5)	1 414 (33.6)	852 (34.8)
Exercise*			
Yes	1 151 (41.8)	1 716 (40.8)	826 (33.8)
No	1 606 (58.3)	2 495 (59.2)	1 621 (66.2)
Smoking status*			
Abstainer	1 621 (58.8)	2 520 (59.8)	1 553 (63.5)
Past smoker	754 (27.3)	1 232 (29.3)	675 (27.6)
Current smoker	382 (13.9)	459 (10.9)	219 (8.9)
Elevated depressive symptoms*			
Yes	818 (29.7)	1 174 (27.9)	813 (33.2)
No	1 939 (70.3)	3 037 (72.1)	1 634 (66.8)
Pain*			
Yes	929 (33.7)	1 543 (36.6)	1 150 (47.0)
No	1 828 (66.3)	2 668 (63.4)	1 297 (53.0)
Hypertension*			
Yes	1 033 (37.5)	2 004 (47.6)	1 522 (62.2)
No	1 724 (62.5)	2 207 (52.4)	925 (37.8)
Diabetes*			
Yes	585 (21.2)	1 047 (24.9)	715 (29.2)
No	2 172 (78.8)	3 164 (75.1)	1 732 (70.8)
Insomnia symptoms (SD)	2.0 (1.7)	2.1 (1.7)	2.2 (1.8)
Insomnia symptoms*			
Yes	746 (27.1)	1 234 (29.3)	831 (34.0)
No	2 011 (72.9)	2 977 (70.7)	1 619 (66.0)
Problems falling asleep*			
Never	1 621 (59.2)	2 436 (57.9)	1 367 (55.9)
Sometimes	838 (30.4)	1 250 (29.7)	723 (29.6)
Most of the time	288 (10.5)	525 (12.5)	357 (14.6)
Problems with sleep maintenance*			
Never	1 017 (36.9)	1 443 (34.3)	775 (31.7)
Sometimes	1 307 (47.4)	2 049 (48.7)	1 166 (47.7)
Most of the time	433 (15.7)	719 (17.1)	506 (20.7)
Problems with early morning awakening			
Never	1 390 (50.4)	2 099 (49.9)	1 197 (48.9)
Sometimes	901 (32.7)	1 353 (32.1)	763 (31.2)
Most of the time	466 (16.9)	759 (18.0)	487 (19.9)

* $p<0.05$

Table II

General estimation equation for the development of obesity as a function of insomnia symptoms in 2015 and 2018, among adults aged 50 and older without obesity at baseline, in Mexico (n= 6 968)

Predictor variables	*Total* *OR (95%CI)*	*Men* *OR (95%CI)*	*Women* *OR (95%CI)*
Insomnia symptoms	**1.06 (1.01,1.11)**	**1.09 (1.01,1.17)**	1.05 (0.99,1.12)
Sex			
Men	ref.	-	-
Women	1.15 (0.95,1.39)	-	-
Age	**0.96 (0.95,0.97)**	**0.96 (0.95,0.98)**	**0.96 (0.95,0.98)**
Years of education	**0.97 (0.95,0.99)**	0.99 (0.96,1.03)	0.95 (0.93,0.98)
Marital status			
Single	ref.	ref.	ref.
Married	1.16 (0.91,1.49)	0.81 (0.54,1.20)	**1.40 (1.03,1.89)**
Widowed	**1.38 (1.04,1.83)**	0.78 (0.44,1.38)	**1.69 (1.20,2.37)**
Locality			
Rural	ref.	ref.	ref.
Urban	1.01 (0.86,1.20)	0.80 (0.60,1.06)	1.13 (0.92,1.41)
Consumer durables			
0-3	ref.	ref.	ref.
4-6	**1.38 (1.10,1.72)**	0.98 (0.69,1.40)	**1.73 (1.29,2.33)**
7+	1.29 (0.98,1.69)	0.98 (0.64,1.50)	**1.57 (1.10,2.24)**
Smoking status			
Abstainer	ref.	ref.	ref.
Past smoker	1.07 (0.89,1.30)	0.98 (0.75,1.30)	1.16 (0.89,1.51)
Current smoker	0.80 (0.61,1.06)	0.73 (0.49,1.06)	0.89 (0.59,1.34)
Exercise			
No	ref.	ref.	ref.
Yes	**0.66 (0.56,0.79)**	**0.52 (0.40,0.69)**	**0.77 (0.62,0.96)**
Elevated depressive symptoms			
No	ref.	ref.	ref.
Yes	0.89 (0.74,1.08)	0.98 (0.71,1.36)	0.85 (0.68,1.07)
Pain			
No	ref.	ref.	ref.
Yes	**1.24 (1.05,1.46)**	1.30 (0.98,1.73)	1.19 (0.97,1.45)
Hypertension			
No	ref.	ref.	ref.
Yes	**1.23 (1.05,1.44)**	**1.38 (1.06,1.78)**	1.15 (0.94,1.40)
Diabetes			
No	ref.	ref.	ref.
Yes	1.04 (0.88,1.24)	0.93 (0.69,1.25)	1.09 (0.88,1.35)

OR: odds ratio
95%CI: 95% confidence intervals
Bolded values indicate $p<0.05$

insomnia symptoms were associated with significantly higher odds of developing obesity in a population of Swedish individuals between the ages of 45 and 78 years.[16] Additionally, Cai and colleagues, measured insomnia consistently with the present study. Other studies have found that individuals who had less than seven hours of sleep per night had higher BMIs, were more likely to develop obesity, and had higher odds of weight gain.[17,18] In certain regions of Mexico, the average adult aged 18 to 64 reported fewer than seven hours of sleep on average, predisposing this population to the aforementioned odds risk of obesity development that we observed in this study.[37] We extended these findings, by analyzing measures of insomnia (rather than dura-

Table III

General estimation equation for changes in body mass index (BMI) as a function of insomnia symptoms in 2015 and 2018, among adults aged 50 and older with obesity at baseline, in Mexico (n= 2 447)

Predictor variables	*Total* ß *(95%CI)*	*Men* ß *(95%CI)*	*Women* ß *(95%CI)*
Insomnia symptoms	0.00 (0-0.07,0.07)	-0.04 (-0.16,0.07)	0.02 (-0.06,0.10)
Sex			
Men	ref.	-	-
Women	**1.15 (0.83,1.46)**	-	-
Age	**-0.06 (-0.08,-0.04)**	**-0.04 (-0.07,-0.01)**	**-0.07 (-0.09,0.05)**
Years of education	0.01 (0-0.02,0.05)	0.03 (-0.02,0.07)	0.01 (-0.04,0.05)
Marital status			
Single	ref.	ref.	ref.
Married	0.13 (-0.27,0.53)	-0.05 (-0.85,0.75)	0.16 (-0.30,0.63)
Widowed	-0.43 (-0.89,0.03)	-0.93 (-2.10,0.24)	-0.31 (-0.82,0.19)
Locality			
Rural	ref.	ref.	ref.
Urban	0.17 (-0.11,0.46)	-0.14 (-0.58,0.31)	0.28 (-0.09,0.65)
Consumer durables			
0-3	ref.	ref.	ref.
4-6	0.30 (-0.03,0.63)	0.29 (-0.21,0.79)	0.31 (-0.12,0.73)
7+	**0.48 (0.10,0.85)**	0.41 (-0.19,1.01)	**0.55 (0.07,1.02)**
Smoking status			
Abstainer	ref.	ref.	ref.
Past smoker	0.29 (0.00,0.58)	0.20 (-0.22,0.62)	0.35 (-0.05,0.74)
Current smoker	0.32 (-0.13,0.76)	-0.05 (-0.58,0.47)	0.55 (-0.16,1.25)
Exercise			
No	ref.	ref.	ref.
Yes	0.03 (-0.19,0.25)	-0.11 (-0.47,0.25)	0.05 (-0.23,0.32)
Elevated depressive symptoms			
No	ref.	ref.	ref.
Yes	-0.19 (-0.44,0.06)	0.06 (-0.50,0.61)	-0.24 (-0.52,0.04)
Pain			
No	ref.	ref.	ref.
Yes	**0.45 (0.23,0.68)**	0.19 (-0.20,0.57)	**0.53 (0.25,0.80)**
Hypertension			
No	ref.	ref.	ref.
Yes	**0.68 (0.42,0.93)**	0.33 (-0.04,0.70)	**0.86 (0.52,1.20)**
Diabetes			
No	ref.	ref.	ref.
Yes	-0.05 (-0.32,0.23)	0.08 (-0.36,0.53)	-0.10 (-0.43,0.24)

95%CI: 95% Confidence intervals
Bolded values indicate $p<0.05$

Table IV

General estimation equation for changes in insomnia symptoms as a function of obesity status in 2015 and 2018, among adults aged 50 and older in Mexico (n= 9 415)

Predictor variables	*Total* ß *(95%CI)*	*Men* ß *(95%CI)*	*Women* ß *(95%CI)*
Obesity status			
Normal weight	ref.	ref.	ref.
Overweight	0.01 (-0.05,0.07)	-0.03 (-0.11,0.05)	0.04 (-0.04,0.11)
Obesity	0.06 (-0.01,0.13)	0.01 (-0.10,0.12)	**0.09 (0.003,0.18)**
Sex			
Men	ref.	-	-
Women	**0.14 (0.08,0.20)**	-	-
Age	**0.01 (0.01,0.01)**	**0.01 (0.01,0.02)**	**0.01 (0.00,0.01)**
Years of education	0.00 (-0.01,0.00)	0.00 (-0.01,0.01)	-0.01 (-0.02,0.00)
Marital status			
Single	ref.	ref.	ref.
Married	0.08 (0.00,0.15)	0.04 (-0.10,0.17)	0.08 (-0.01,0.18)
Widowed	0.01 (-0.08,0.10)	0.05 (-0.12,0.23)	0.00 (-0.10,0.11)
Locality			
Rural	ref.	ref.	ref.
Urban	-0.02 (-0.08,0.04)	-0.02 (-0.11,0.06)	-0.01 (-0.09,0.06)
Consumer durables			
0-3	ref.	ref.	ref.
4-6	**0.12 (0.05,0.18)**	**0.11 (0.01,0.21)**	**0.12 (0.03,0.21)**
7+	0.06 (-0.02,0.14)	0.07 (-0.06,0.19)	0.06 (-0.05,0.16)
Smoking status			
Abstainer	ref.	ref.	ref.
Past smoker	**0.17 (0.11,0.23)**	**0.21 (0.13,0.29)**	**0.12 (0.03,0.22)**
Current smoker	0.05 (-0.03,0.14)	**0.13 (0.02,0.24)**	-0.03 (-0.18,0.11)
Exercise			
No	ref.	ref.	ref.
Yes	0.00 (-0.04,0.05)	-0.05 (-0.12,0.03)	0.05 (-0.02,0.12)
Elevated depressive symptoms			
No	ref.	ref.	ref.
Yes	**0.97 (0.91,1.03)**	**0.89 (0.79,0.99)**	**1.01 (0.93,1.08)**
Pain			
No	ref.	ref.	ref.
Yes	**0.53 (0.48,0.58)**	**0.49 (0.41,0.57)**	**0.56 (0.50,0.63)**
Hypertension			
No	ref.	ref.	ref.
Yes	**0.23 (0.18,0.28)**	**0.27 (0.19,0.35)**	**0.20 (0.13,0.27)**
Diabetes			
No	ref.	ref.	ref.
Yes	**0.15 (0.09,0.21)**	**0.22 (0.13,0.32)**	**0.11 (0.03,0.18)**

95%CI: 95% Confidence intervals
Bolded values indicate $p<0.05$

tion), utilized a longitudinal design, and we focused on adults aged 50+.

The mechanism underlying the relationship between sleep and obesity can be conceptualized biologically. Appetite, wakefulness, and energy expenditure are all regulated by the same neuropeptide system involving orexin and exert activity on the hypothalamus.[38] This activity is regulated by ghrelin and leptin, hormones that modulate hunger and satiety, respectively.[39] Sleep deprivation has been shown to be associated with an increased amount of ghrelin and salt retention, and a decreased amount of leptin and insulin sensitivity.[40-42] These effects, particularly decreased leptin and insulin sensitivity are already more pronounced in older individuals, making this population especially prone to developing obesity and, therefore, rendering it even more important to study and find ways to mitigate this increased risk.[43] Thus, we contribute to this research by studying the relationship between insomnia symptoms and obesity in these older adults in a region like Mexico, which has high prevalence of both obesity[12,13] and insomnia.[37]

The results indicated that insomnia symptoms were associated with the development of obesity in men but not in women. However, the overlapping confidence intervals between men and women and the lack of a significant interaction term highlight the need for future work to explore potential sex/gender differences in this relationship. Although few studies have examined insomnia symptoms and obesity among men, a study conducted in Austria showed that twice as many men as women were referred for a polysomnography study by primary care providers due to more prominent sleep problems such as early and sudden awakening, and sleep-related breathing disorders.[44] When women were referred, it was for more subtle sleep problems such as subjective quality of sleep, showing that women may have a lower awareness of sleep disorders and thus may underreport their symptoms.[44] Thus, while the results don't align with our original hypothesis of insomnia symptoms leading to the development of obesity in older women, a lack of awareness regarding sleep problems within this population may serve as an explanation. Indeed, a survey study on Mexicans, Puerto Ricans, and Cubans living in the U.S. showed poor sleep hygiene knowledge, and practice, and less acceptance of medical and non-medical assistance for sleep problems compared to white Americans.[45] These findings point to the need for future research on sex/gender discrepancies on how sleep problems are perceived among older Mexican adults.

We also found that among those with obesity at baseline, insomnia symptoms were not associated with changes in the BMI. These findings suggests that insomnia symptoms may be a risk factor for obesity, but do not increase BMI among those with obesity. BMI variations would be limited among a sample of older adults that are already more prone to obesity.[5,46]

Lastly, our study found that obesity, analyzed as both a discrete or a continuous BMI variable, was associated with insomnia symptoms over time only among women. The unidirectional relationship observed in our total sample supports the importance of interventions focused on improving sleep in order to prevent obesity among older Mexican adults. While OSA may cause insomnia among those with obesity, the unidirectional relationship seen in this analysis might point to OSA not prominently affecting this sample, suggesting an important area of future investigation.[46] Although studies have shown that one in four Mexicans have a pronounced risk of OSA, studies have not shown how many Mexicans have a formal diagnosis or have distinguished the risk or prevalence by sex/gender.[47] Thus, future research should study OSA within this population, especially since we see that, in our total population, insomnia is associated with the development of obesity, but obesity does not worsen insomnia symptoms. Prior research has suggested the relationship between insomnia and obesity is bidirectional, although our evidence points to a unidirectional relationship with nuanced gender differences.[32]

Limitations

There are several limitations of these analyses. First, the use of self-report data to measure sleep quality and height and weight, utilized to calculate the BMI may have been affected by recall bias. However, a study conducted on Mexican adults showed that self-reported height and weight are valid measures for assessing the BMI and the overall nutritional status.[48] Also, while self-reported insomnia may not perfectly correlate with objective measures of sleep, sleep is increasingly conceptualized as a multidimensional construct that relies on self-reports.[49] Secondly, the three-year period of analysis may be too short for evaluating the development of obesity and to determine the temporality of the insomnia and obesity relationship. As future waves of the MHAS are released, we can trace this association over a longer follow-up period and examine the development of obesity, rather than the association between obesity and insomnia symptoms. Third, there are important variables that can serve as potential mediators in explaining the relationships seen in this study, such as OSA, which is not included in the MHAS questionnaire and, thus, could not be accounted for. Addition of extra variables such as OSA may help contribute to a more robust analysis by supporting the directionality seen in this study. Lastly, we were unable to include more detailed measures of sleep, such as sleep duration, bedtime, wake time, daytime somnolence, and

sleep latency, as the MHAS questionnaire assessed sleep through three variables only (insomnia, sleep maintenance, and wakefulness). However, a study conducted on the validity and reliability of the Insomnia Severity Index showed that it is a valid instrument to assess subjective insomnia, including in Spanish-speaking populations.[32] The study also found that an abbreviated version of the Insomnia Severity Index which comprised the three items addressing sleep onset, sleep maintenance, and early morning awakenings as included in the MHAS, was as robust and valid an instrument as the full Insomnia Severity Index.[32]

Despite these limitations, our study has several notable strengths. The MHAS is a large, representative study of older adults in Mexico. An additional strength is the use of repeated measurements, which allowed us to incorporate time-varying covariates, as well as our examination of sex/gender differences.

Conclusions

Among Mexican adults aged 50 and older, we found that insomnia symptoms were associated with the development of obesity over three years among those without obesity at baseline. We did not observe the BMI worsening insomnia symptoms among those who had obesity at the baseline. Lastly, we did not see an association between obesity and changes in insomnia status. Future research should examine the nuanced sex/gender differences in this relationship, as well as how the influence of insomnia on obesity may also vary by health conditions such as OSA. Our results show that sleep is an important point of intervention in preventing obesity and related outcomes within a region of the world where obesity rates are documented to be among the highest.

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