Sex-specific prevalence and correlates of possible undiagnosed obstructive sleep apnea in rural Canada

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Abstract

Background Obstructive Sleep Apnea (OSA) has been under-investigated in rural communities, particularly through a sex/gender lens. The purpose of this study was to examine the prevalence and correlates of OSA risk among rural-dwelling women and men in Saskatchewan, Canada.

Methods Participants for this cross-sectional study were 2340 women and 2030 men living in rural Saskatchewan, Canada and were without a prior diagnosis of OSA. The dependent variable, OSA risk, was estimated from self-reported symptoms of OSA and percentage body fat. Independent variables included socio-demographic characteristics, health behaviors, comorbidities, and quality of life indicators. Multivariable logistic regression was the primary statistical technique employed, conducted separately for women and men.

Results A greater proportion of men (30.1%) than women (19.4%) were at high risk of OSA. While many of the correlates of OSA risk were similar for women and men, sex differences emerged for marital status, educational attainment, financial strain, depression, asthma, and perceptions of community support.

Conclusion A sizable minority of rural women and men may have possible undiagnosed OSA, which in turn, is associated with substantial comorbidity and reduced quality of life. Additional research with enhanced measurement and a longitudinal design is required to test the veracity of these findings and further clarify the role of sex/gender in relation to OSA risk in rural adults.

Keywords Epidemiology, Gender, Obstructive sleep apnea, Rural adults, Sex differences

Background

Obstructive Sleep Apnea (OSA) is characterized by loud snoring, excessive daytime sleepiness, and episodes of breathing cessation during sleep, causing the individuals to wake up choking and gasping (Laratta et al. 2017; Javaheri et al. 2017). Associated with numerous adverse physical, psychosocial, and economic consequences, OSA is a serious public health concern (Borsoi et al. 2022). While prevalence estimates of OSA vary considerably, depending on the population sampled and how OSA is defined and measured (Senaratna et al. 2017), several fairly consistent patterns have emerged, in that OSA: 1) may be increasing over time (Peppard et al. 2013), including in Canada (Pendharkar et al. 2023; Statistics Canada: Health Fact Sheet 2018); 2) is associated with older age (Senaratna et al. 2017) and obesity (Senaratna et al. 2017); and 3) at all ages, is identified more often in men than women (Bonsignore et al. 2019). Many people may have

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OSA but are undiagnosed (Fuhrman et al. 2012; Heinzer et al. 2015) and untreated OSA may increase risk of morbidity and mortality (Knauert et al. 2015; Fu et al. 2017). Two population subgroups that may be more prone to OSA under-recognition are women (Lindberg et al. 2017; Orbea et al. 2020) and rural dwellers (Spagnuolo et al. 2019).

The interaction of factors related to both sex (e.g., anatomical and physiological features of the upper airways) and gender (e.g., misattribution of OSA symptoms in women as depression) have been proposed to explain differences in the prevalence of OSA in women and men (Bonsignore et al. 2019; Bublitz et al. 2022). Common screening instruments may also be less sensitive for detecting OSA in women (Lindberg et al. 2017; Mou et al. 2019). In addition, OSA-related risk factors, comorbidities, and quality of life may differ for women and men (Thompson et al. 2022; Huang et al. 2018); however, sex-specific findings are rarely reported in the literature.

Rural dwellers are another segment of the population in which OSA may be more likely to go unrecognized, due, in part, to more limited access to primary and specialist health care (Spagnuolo et al. 2019). Rural adults may also be at greater risk of developing OSA than their urban counterparts, given older age and higher rates of obesity (Shields and Tjepkema 2006). To our knowledge, research investigating OSA risk and associated factors through a sex/gender lens has not been conducted in rural residents.

The objectives of this cross-sectional study of rural dwelling women and men in Saskatchewan, Canada were to determine: 1) the prevalence of high risk for OSA; and 2) the association of high risk OSA status with sociodemographic characteristics, health behaviors, comorbidities, and quality of life.

Methods

Design and sample

This research was set in Saskatchewan, a western Canadian province with a population of approximately 1 million people. The present study involved secondary analysis of cross-sectional data from the Saskatchewan Rural Health Study (SRHS) (Pahwa et al. 2012; Pahwa et al. 2017). The purpose of the SRHS was to enhance understanding of rural dwellers' respiratory health and determinants. The rural population for the SRHS was defined as 'those living in towns and municipalities outside the commuting zone of larger urban centers with a population of 10,000 or more' (Plessis et al. 2004).

The SRHS was conducted in several phases, with detailed methods of phase 1 (2010) (Pahwa et al. 2012) and phase 2 (2014) (Pahwa et al. 2017) published previously. The study base consisted of tax-paying households located in rural municipalities (RMs) and small towns situated in one of four geographical quadrants (south-east, south-west, north-east and north-west) in the southern half of Saskatchewan. The local councils for the vast majority of these communities (32/36 RMs and 15/16 towns) provided mailing addresses. Dillman's mail data collection methodology was followed to recruit adult study participants (Dillman 2000). A key informant in each household was asked to provide household-level information and individual information for each adult living in the household. Of the 11,004 eligible addresses in the phase 1 survey, responses were obtained from 4624 households, representing 8261 individuals. Various knowledge translations activities were employed to maintain engagement with participants for the next study phase.

Phase 2 of the SRHS provides the data for the present study, as additional screening questions for OSA were introduced into the survey. Questionnaires were mailed to all individuals who participated in the 2010 baseline survey. Initial mailing was done for 4454 households due to 170 households being lost to follow-up after baseline knowledge translation mailings were returned to sender. Questionnaires were returned from 2797 households, consisting of 4866 individuals. Participants were excluded ($n=415$; 70% male) if they answered yes to the question "has a doctor ever said you had sleep apnea", resulting in a sample size of 2340 women and 2030 men.

Measures

Dependent variable

OSA risk was estimated using a combination of self-reported symptoms of OSA and percentage body fat (%BF) (Thompson et al. 2022). The STOP questionnaire (Chung et al. 2008) was used to measure OSA symptoms and consisted of four questions measuring: (S) snoring ("Do you snore loudly? By 'loudly' I mean louder than talking or loud enough to be heard through closed doors"), (T) tiredness ("Do you often feel tired, fatigued, or sleepy during daytime?"), (O) observed apnea ("Has anyone ever observed you stop breathing in your sleep?"), and (P) high blood pressure ("Has a doctor ever told you that you have high blood pressure or hypertension?"). A score of one was applied each time participants answered "yes" to a question; scores for the STOP questionnaire ranged from 0–4 (Chung et al. 2008). Evidence of the predictive ability of the STOP tool has been reported with both clinical and general population samples (Chung et al. 2008; Patel et al. 2022).

The STOP questionnaire can be combined with information on BMI (B), age (A), neck circumference (N), and sex/gender (G) to obtain a STOP-BANG score (Chung et al. 2008). The BANG component was not

calculated for this study for several reasons. First, there was a large amount of missing data for neck circumference, especially among women, an issue that has been noted in prior research (Orbea et al. 2020). Second, BMI is dependent on age and sex (Gallagher et al. 1996); that is, even though women have more body fat than men (especially during certain life stages, such as menopause), as do older people compared to younger, the same BMI classification is applied. This awareness, combined with knowledge of our study population's older age demographic (Pahwa et al. 2012; Pahwa et al. 2017) and the methodological approach adopted in a recent Canadian study of OSA prevalence and correlates (Thompson et al. 2022), resulted in our decision to use %BF to measure obesity. We estimated %BF using a validated prediction equation (Gallagher et al. 2000; Marin-Jimenez et al. 2022) which takes into account sex (coded: 0 female; 1 male) and age: $64.5 - 848 \times (1/BMI) + 0.079 \times age - 16.4 \times sex + 0.05 \times sex \times age + 39.0 \times sex \times (1/BMI)$. Following recommended sex-specific guidelines for classification of obesity (WHO 1995), women with a %BF higher than 35 and men higher than 25 were considered obese and given a score of one.

STOP questionnaire and %BF scores were summed to obtain a STOP-Obesity score, with values ranging from 0 to 5; following the methods of a recent Canada-wide population based study of OSA risk using the STOP-Obesity tool (Thompson et al. 2022), participants with a score of three or greater were considered as being at high risk of OSA, and less than three, at low risk.

Independent variables

The independent variables were socio-demographic characteristics, health behaviors, comorbidities, and quality of life indicators. Socio-demographics included age (< 50yrs, 50–59, 60–69, 70–79, and 80+), marital status (married, common law, widowed, separated/divorced, single/never married), home location (farm/town), and educational attainment (high school or less, post-secondary). In addition, income adequacy was a derived variable combining information on household income and number of residents with responses categorised into one of four groups: low income, medium income, high income, and missing. Current employment status was a categorical variable with four options for women (employed, retired, homemaker, and 'other') and three options for men (employed, retired, and 'other'). The fewer number of categories for men were due to the small number indicating homemaker status ($n = 2$); this choice, therefore, was subsumed for men under 'other'. Financial strain was a categorical variable assessed on the basis of participants' response to the question 'At the end of the month, do you have some money left over: a) some money, b) just enough money,

or c) not enough money'; responses were kept in their original form but with a 'missing' option incorporated.

For health behaviors, exercise was assessed with the question "Do you exercise?" (yes/no) and binge drinking was assessed with the question "How often in the past 12 months have you had five or more alcoholic drinks on one occasion?" (never, less than once/month, once/month, 2–3 times/month, once/week, more than once/week). Based on recommended operationalization of binge drinking (Bulloch et al. 2016), participants were categorized as having engaged in binge drinking if they indicated consuming five or more alcoholic drinks at least once a month. For women, it is recommended that the threshold be reduced to four drinks (Bulloch et al. 2016); therefore, it is likely that the prevalence of binge drinking in women was underestimated in this study. Three smoking statuses were also measured: current smoker (smoking in the past year), ex-smoker (no current smoking and a lifetime history of smoking at least 20 packs), or nonsmoker (all other categories).

Comorbidities were based on participants' response to the question of whether they had ever been diagnosed (yes/no) with each of the following diseases: diabetes, high cholesterol, chronic obstructive pulmonary disease (COPD), asthma, and depression. In addition, injury was assessed by the question "During the past 12 months, were you seen by a doctor or other primary care giver for an injury?" (yes/no).

Quality of life was assessed with five indicators: self-rated physical health, self-rated mental health, change in health, life stress, and community support. Self-rated physical (mental) health was assessed with the question(s): "In general, would you say your physical (mental) health is excellent, very good, good, fair, poor"; responses were collapsed into two categories (excellent/very good/good and fair/poor). Change in health was assessed by the question "Compared to one year ago, how would you say your health is now" and grouped into three responses: much/somewhat better, about the same, much/somewhat worse. Life stress was measured by the question "Thinking about the amount of stress in your life, would you say most days are: a) not at all stressful, b) not very stressful, c) a bit stressful, d) quite stressful, or e) very stressful?", with responses grouped into three options (not at all/not very stressful, a bit stressful, quite/very stressful. Community social support was measured by the question "How well do you feel like you are generally supported (socially, emotionally, medically, etc.) by your community?" (Janzen et al. 2020). Participants were asked to mark their response along a 50 mm line, anchored between 'no support' and 'extremely supported'. Participants' markings were measured, converted into numerical values (out of 50), and then categorized

into tertiles: 'low support', 'medium support', and 'high support'.

Analyses

Initially, two sets of chi-square analyses were conducted to examine: 1) whether the distribution of study variables differed for women and men; and 2) the association of sleep apnea risk with each study variable, separately for women and men. Spearman rank correlations were conducted among all independent variables to assess multicollinearity. Following descriptive analyses, sex-specific multiple logistic regression analyses were conducted using a manual backward selection approach; only statistically significant variables were retained in the final models. Generalized estimating equations (GEE) were utilized to account for household clustering. The quasi-likelihood under the independence model criterion (QIC) goodness of fit statistic was used to identify the best fitting GEE model (Pan 2001). Statistical analyses were conducted using the Statistical Package for the Social Sciences v21 (IBM; http://www.spss.com).

Results

Based on STOP-Obesity scores, 19.4% of women and 30.1% of men were classified as high risk of OSA. Table 1 shows the distribution of all other study variables by sex. No age difference was present, but a greater proportion of men than women were married, employed, living on a farm, had a high school education or less, and were in the highest income adequacy grouping. Women and men did not differ in financial strain. A higher percentage of women reported exercising and being a non-smoker, whereas men were more likely to binge drink. A greater proportion of men than women reported the presence of diabetes, heart disease, and high cholesterol, with depression showing the opposite pattern. While no sex difference emerged in the prevalence of asthma, COPD, self-rated mental health, or life stress, a higher proportion of women than men indicated positive self-rated physical health, better health compared to the previous year, and high social support.

Table 2 shows the relationship between OSA risk and each study variable, separately for women and men. With the exception of binge drinking and injury, all variables were significantly associated with OSA risk, and for most variables, the nature of association was similar for women and men. That is, high OSA risk was associated with older age, town rather than farm residence, lower income, lower education, being a current or ex-smoker, not exercising, and the presence of a chronic condition (ie., heart disease, diabetes, high cholesterol, COPD, and depression). Elevated OSA risk was also associated with lower quality of life, in the form of fair/poor self-rated

Table 1 Distribution of study variables, by sex

Variables	Women n(%)	Men n(%)	p
Socio-demographics			
Age (years)			
< 50	504 (21.5)	376 (18.5)	
50–59	623 (26.6)	540 (26.6)	
60–69	590 (25.2)	531 (26.2)	
70–79	399 (17.1)	375 (18.5)	
80 +	224 (9.6)	208 (10.2)	0.13
Marital status			
Married	1839 (78.6)	1721 (84.8)	
Common-law	71 (3.0)	62 (3.1)	
Widowed	293 (12.6)	53 (2.6)	
Separated/divorced	69 (2.9)	65 (3.2)	
Single/never married	62 (2.6)	124 (6.1)	< .001
Missing	6 (0.3)	5 (0.2)	
Employment status			
Employed	1126 (48.1)	1423 (70.1)	
Retired	707 (30.2)	546 (26.9)	
Homemaker	429 (18.3)	n/a	
Other	74 (3.2)	52 (2.6)	n/a
Missing	4 (0.2)	9 (0.4)	
Home location			
Farm	952 (40.7)	938 (46.2)	
Town	1378 (58.9)	1083 (53.3)	< .001
Missing	10 (0.4)	9 (0.4)	
Education			
Post-secondary	1208 (52.2)	678 (33.4)	
High school or less	1105 (47.8)	1321 (65.1)	< .001
Missing	27 (1.2)	31 (1.5)	
Income adequacy			
Low	356 (15.2)	229 (11.3)	
Middle	626 (26.8)	560 (27.6)	
High	997 (42.6)	937 (46.2)	
Missing	361 (15.4)	304 (15.0)	.001
Financial strain (money left over at end of the month)			
Some money	1411 (60.3)	1275 (62.8)	
Just enough money	434 (18.5)	348 (17.1)	
Not enough money	256 (10.9)	203 (10.0)	
Missing	239 (10.2)	204 (10.0)	.354
Health behaviors			
Smoking status			
Current smoker	219 (9.4)	181 (8.9)	
Ex-smoker	776 (33.2)	855 (42.1)	
Never smoker	1337 (57.1)	987 (48.6)	< .001
Missing	8 (0.3)	7 (0.3)	
Binge drinking			
Yes	242 (10.3)	471 (23.2)	
No	2065 (88.2)	1541 (75.9)	< .001
Missing	33 (1.4)	18 (0.9)	

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Table 1 (continued)

Variables	Women n(%)	Men n(%)	p
Exercise			
Yes	1411 (60.3)	945 (46.6)	
No	888 (37.9)	1037 (51.1)	< .001
Missing	41 (1.8)	48 (2.4)	
Comorbidities			
Heart disease			
No	2162 (92.4)	1805 (88.9)	
Yes	178 (7.6)	225 (11.1)	< .001
Diabetes			
No	2134 (91.2)	1790 (88.2)	
Yes	206 (9.8)	240 (11.8)	< .001
High cholesterol			
No	1749 (74.7)	1434 (70.6)	
Yes	591 (25.3)	596 (29.4)	.002
COPD			
No	2067 (88.3)	1778 (87.6)	
Yes	102 (4.4)	113 (5.6)	.071
Missing	171 (7.3)	139 (6.8)	
Asthma			
No	2081 (88.9)	1832 (90.2)	
Yes	259 (11.1)	198 (9.8)	.157
Depression			
No	2055 (87.8)	1925 (94.8)	
Yes	285 (12.2)	105 (5.2)	< .001
Injury (Last 12 months)			
No	2026 (86.6)	1724 (84.9)	
Yes	233 (10.0)	234 (11.5)	.091
Missing	81 (3.5)	72 (3.5)	
Quality of life			
Self-rated physical health			
Good/very good/excellent	2054 (87.8)	1722 (84.8)	
Fair/poor	281 (12.0)	300 (14.8)	.007
Missing	5 (0.2)	8 (0.4)	
Self-rated mental health			
Good/very good/excellent	2170 (92.7)	1897 (93.4)	
Fair/poor	163 (7.0)	124 (6.1)	.271
Missing	7 (0.3)	9 (0.4)	
Health compared to last year			
Better	440 (18.8)	288 (14.2)	
Same	1617 (69.1)	1519 (74.8)	
Worse	276 (11.8)	213 (10.5)	< .001
Missing	7 (0.3)	10 (0.5)	
Perception of stress			
Not/barely stressful	951 (40.6)	883 (43.5)	
Somewhat stressful	1047 (44.7)	865 (42.6)	
Very stressful	335 (14.3)	268 (13.2)	.122
Missing	7 (0.3)	14 (0.7)	
Community support			
High	857 (36.6)	655 (32.3)	

Table 1 (continued)

Variables	Women n(%)	Men n(%)	p
Medium	619 (26.5)	600 (29.6)	
Low	701 (30.0)	614 (30.2)	.008
Missing	163 (7.0)	161 (7.9)	

physical and mental health, worse health compared to the previous year, and high life stress. Regarding sex differences, OSA risk was highest for married men and divorced women, and asthma was associated with high OSA risk in women but not in men. Among the employment categories, retired women and "other" status men had the highest prevalence of high OSA risk. For financial strain, high OSA risk in women was associated with not having enough money at the end of the month, whereas in men, high OSA risk was most common among those with missing data. Finally, low community support was related to high OSA risk in men but unrelated in women.

Table 3 displays the final adjusted models predicting high OSA risk for women and men. For both women and men, high risk of OSA was associated with older age, town residence (compared to farm), not exercising, heart disease, diabetes, high cholesterol, fair/poor self-rated physical health, and greater life stress. For women only, the presence of asthma, depression, and financial strain were also related to an elevated odds of OSA risk. Conversely, for men only, high risk of OSA was associated with being married/partnered, lower educational attainment, and lower community support.

Discussion

In this sample of rural adults, based on their STOP-Obesity score, 19.4% of women and 30.1% of men were at risk of OSA. Many of the correlates of OSA risk were similar for women and men, with high OSA risk associated with older age, town residence, not exercising, the presence of chronic conditions such as heart disease, diabetes, and high cholesterol, fair/poor self-rated physical health, and life stress. Sex differences were observed in the relationship between OSA risk and marital status, education, financial strain, asthma, depression, and community support.

Prevalence

A greater proportion of men (30%) than women (19%) were considered at high risk of OSA, findings consistent with a vast amount of previous research (Senaratna et al. 2017; Bonsignore et al. 2019; Fuhrman et al. 2012; Heinzer et al. 2015; Thompson et al. 2022; Huang et al. 2018). The reasons underlying this pattern are no doubt complex and likely related to the interaction of exposures

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Table 2 Crude associations between independent variables and OSA risk, by sex

	Women			Men		
	High Risk n (%)	Low Risk n (%)	p	High Risk n (%)	Low Risk n (%)	p
Socio-demographics						
Age (years)						
< 50	46 (9.1)	458 (90.9)		68 (18.1)	308 (81.9)	
50–59	110 (17.7)	513 (82.3)		165 (30.6)	375 (69.4)	
60–69	140 (23.7)	450 (76.3)		176 (33.1)	355 (66.9)	
70–79	106 (26.6)	293 (73.4)		142 (37.9)	233 (62.1)	
80+	53 (23.7)	171 (76.3)	< .001	76 (36.5)	132 (63.5)	< .001
Home location						
Farm	154 (16.2)	798 (83.8)		262 (27.9)	676 (72.1)	
Non-farm	301 (21.8)	1077 (78.2)	< .001	363 (33.5)	720 (66.5)	.007
Partner status						
Married	334 (18.2)	1505 (81.8)		564 (32.8)	1157 (67.2)	
Common-law	15 (21.1)	56 (78.9)		18 (29.0)	44 (71.0)	
Widowed	71 (24.2)	222 (75.8)		16 (30.2)	37 (69.8)	
Separated/divorced	22 (31.9)	47 (68.1)		13 (20.0)	52 (80.0)	
Single/never married	12 (19.4)	50 (80.6)	0.01	16 (12.9)	108 (87.1)	< .001
Employment Status						
Employed	189 (16.8)	937 (83.2)		398 (28.0)	1025 (72.0)	
Retired	165 (23.3)	542 (76.7)		201 (36.8)	345 (63.2)	
Homemaker	84 (19.6)	345 (80.4)		n/a	n/a	
Other	16 (21.6)	58 (78.4)	.007	25 (48.1)	27 (51.9)	< .001
Education						
Post-secondary	198 (16.4)	1010 (83.6)		165 (24.3)	513 (75.7)	
High school or less	246 (22.3)	859 (77.7)	< .001	456 (34.5)	865 (65.5)	< .001
Income adequacy						
Highest	148(14.8)	849 (85.2)		268 (28.6)	669 (71.4)	
Middle	144 (23.0)	482 (77.0)		171 (30.5)	389 (69.5)	
Lowest	97 (27.2)	259 (72.8)		74 (32.3)	155 (67.7)	
Missing	66 (18.3)	295 (81.7)	< .001	114 (37.5)	190 (62.5)	.032
Financial strain (money left over at end of the month)						
Some money	247 (17.5)	1164 (82.5)		360 (28.2)	915 (71.8)	
Just enough money	88 (20.3)	346 (79.7)		112 (32.2)	236 (67.8)	
Not enough money	84 (32.8)	172 (67.2)		77 (37.9)	126 (62.1)	
Missing	36 (15.1)	203(84.9)	< .001	78 (38.2)	126 (61.8)	.002
Health behaviors						
Smoking status						
Current smoker	43 (19.6)	176 (80.4)		54 (29.8)	127 (70.2)	
Ex-smoker	183 (23.6)	593 (76.4)		325 (38.0)	530 (62.0)	
Never smoker	228 (17.1)	1109 (82.9)	.001	245 (24.8)	742 (75.2)	< .001
Binge drinking						
Yes	41 (16.9)	201 (83.1)		143 (30.4)	328 (69.6)	
No	409 (19.8)	1656 (80.2)	.287	477 (31.0)	1064 (69.0)	.807
Exercise						
Yes	216 (15.3)	1195 (84.7)		244 (25.8)	701 (74.2)	
No	227 (25.6	661 (74.7)	< .001	367 (35.4)	670 (64.6)	< .001

Table 2 (continued)

	Women			Men		
	High Risk n (%)	Low Risk n (%)	p	High Risk n (%)	Low Risk n (%)	p
Comorbidities						
Heart disease						
Yes	70 (39.3)	108 (60.7)		118 (52.4)	107 (47.6)	
No	385 (17.8)	1777 (82.2)	<.001	509 (28.2)	1296 (71.8)	<.001
Diabetes						
Yes	95 (46.1)	111(53.9)		132 (55.0)	108 (45.0)	
No	360 (16.9)	1774 (83.1)	<.001	495 (27.7)	1295 (72.3)	<.001
High cholesterol						
Yes	193 (32.7)	398 (67.3)		273 (45.8)	323 (54.2)	
No	262 (15.0)	1487 (85.0)	<.001	354 (24.7)	1080 (75.3)	<.001
COPD						
Yes	37 (30.6)	84 (69.4)		78 (52.7)	70 (47.3)	
No	447 (20.5)	1737 (79.5)	.008	717 (35.2)	1322 (64.8)	<.001
Asthma						
Yes	70 (30.6)	159 (69.4)		63 (37.3)	106 (62.7)	
No	385 (18.2)	1726 (81.8)	<.001	564 (30.3)	1297 (69.7)	.060
Depression						
Yes	88 (30.9)	197 (69.1)		44 (41.9)	69 (58.1)	
No	367 (17.9)	1688 (82.1)	<.001	583 (30.3)	1342 (69.7)	.012
Injury (Last 12 months)						
Yes	54 (23.2)	179 (76.8)		72 (30.8)	162 (69.2)	
No	374 (18.5)	1652 (81.5)	.08	525 (30.5)	1199 (69.5)	.92
Quality of life						
Self-rated physical health						
Good/very good/excellent	351 (17.1)	1703 (82.9)		465 (27.0)	1257 (73.0)	
Fair/poor	103 (36.7)	178 (63.3)	<.001	157 (52.3)	143 (47.7)	<.001
Self-rated mental health						
Good/very good/excellent	391 (18.0)	1779 (82.0)		567 (29.9)	1330 (70.1)	
Fair/poor	61 (37.4)	102 (62.6)	<.001	58 (46.8)	66 (53.2)	<.001
Change in health						
Better	89 (20.2)	351 (79.8)		94 (32.6)	194 (67.4)	
Same	274 (16.9)	1343 (83.1)		422 (27.8)	1097 (72.2)	
Worse	90 (32.6)	186 (67.4)	<.001	107 (50.2)	106 (49.8)	<.001
Perception of stress						
Not/barely stressful	163 (17.1)	788 (82.9)		248 (28.1)	635 (71.9)	
Somewhat stressful	207 (19.8)	840 (80.2)		270 (31.2)	595 (68.8)	
Very stressful	82 (24.5)	253 (75.5)	<.001	105 (39.2)	163 (60.8)	.003
Community support						
High	151 (17.6)	706 (82.4)		180 (27.5)	475 (72.5)	
Medium	121 (19.5)	498 (80.5)		170 (28.3)	430 (71.7)	
Low	154 (22.0)	547 (78.0)	.100	217 (35.3)	397 (64.7)	.004

linked to both sex and gender (Bonsignore et al. 2019; Bublitz et al. 2022). The prevalence of OSA risk observed here is not inconsistent with the 9%-38% range reported in a recent systematic review of objectively measured OSA in community samples (Senaratna et al. 2017). Our estimates are higher, however, than those reported in a recent Canada-wide study also applying STOP-Obesity scores, whereby 13.1% of women and 21.9% of men were

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Table 3 Estimates of odds ratios (OR) and 95% confidence intervals (95% CI) based on multivariable logistic regression for high risk of OSA, by sex[a]

Variables	Women OR (95% CI)	Men OR (95% CI)
Socio-demographics		
Age (years)		
<50	1.00	1.00
50–59	**2.19(1.49–3.25)**	**1.75(1.23–2.49)**
60–69	**2.82(1.89–4.18)**	**1.74(1.20–2.52)**
70–79	**2.72(1.77–4.20)**	**2.13(1.41–3.22)**
80+	**2.01(1.20–3.39)**	**1.85(1.08–3.19)**
Marital status		
Single/never married		1.00
Separated/divorced		1.11(0.57–2.18)
Widowed		1.86(0.80–3.54)
Common-law		**2.88(1.25–6.62)**
Married		**3.13(1.67–5.86)**
Home location		
Farm	1.00	1.00
Town	**1.28(1.01–1.62)**	**1.26(1.01–1.57)**
Education		
Post-secondary		1.00
High school or less		**1.33(1.04–1.69)**
Financial strain (money left over at end of the month)		
Some money	1.00	
Just enough money	1.08(0.80–1.46)	
Not enough money	**1.80(1.29–2.49)**	
Missing	0.76(0.51–1.14)	
Exercise		
Yes	1.00	1.00
No	**1.61(1.29–2.03)**	**1.41(1.13–1.76)**
Comorbidities		
Heart disease		
No	1.00	1.00
Yes	**2.03(1.39–3.00)**	**1.58(1.10–2.27)**
Diabetes		
No	1.00	1.00
Yes	**2.53(1.81–3.54)**	**2.28(1.65–3.16)**
High cholesterol		
No	1.00	1.00
Yes	**1.86(1.45–2.38)**	**1.86(1.49–2.35)**
Asthma		
No	1.00	
Yes	**1.86(1.33–2.60)**	
Depression		
No	1.00	
Yes	**1.75(1.26–2.42)**	
Quality of life		
Self-rated physical health		
Good/very good/excellent	1.00	1.00
Fair/poor	**1.62(1.17–2.25)**	**1.91(1.41–2.58)**

Table 3 (continued)

Variables	Women OR (95% CI)	Men OR (95% CI)
Perception of stress		
Not/barely stressful	1.00	1.00
Somewhat stressful	1.23(0.95–1.58)	**1.70(1.23–2.64)**
Very stressful	**1.57(1.10–2.23)**	**2.00(1.41–2.84)**
Community support		
High		1.00
Medium		**1.32(1.02–1.73)**
Low		**1.38(1.05–1.81)**

[a] values in bold are statistically significant

classified as being at high risk of OSA (Thompson et al. 2022). Our higher estimates could have been due, in part, to a greater prevalence of obesity in our sample; that is, people living in rural areas of Canada tend to have an elevated risk of obesity when compared to the national average (Shields and Tjepkema 2006), and this elevation may be even more pronounced in several provinces, including Saskatchewan (Chen et al. 2009). Also, while Thompson objectively measured %BF (Thompson et al. 2022), our estimate was based on a prediction equation, which may have resulted in an overestimation, thus inflating OSA risk prevalence (Gallagher et al. 2000). It is important to note, however, that Thompson et al. acknowledge that their estimates were considerably lower than those obtained in prior research with similar sample demographics (Thompson et al. 2022). Generally speaking, meaningful comparisons of OSA prevalence between studies are extremely challenging, given the wide variability in population characteristics and study methodologies (Senaratna et al. 2017).

Socio-demographics
Previous research suggests that OSA risk increases with age (Senaratna et al. 2017), and is consistent with the findings of the present study. The areas of the hypothalamus undergo reductions in volume with age, contributing to fragmentation in critical stages of sleep and homeostatic dysregulation, disrupting the dopaminergic system and increasing the risk of sleep disorders (Sosso and Matos 2021). For women, OSA risk increases after menopause due to lower progesterone levels, reducing the responsiveness of hypoxia chemoreceptors to oxygen reduction or depletion (Bonsignore et al. 2019; Sosso and Matos 2021; Mallampalli and Carter 2014; Jeler and Mihaltan 2016), often leading to smaller sex differences in prevalence during this life stage. Although menopausal status was not assessed in this study, the ratio of male to female OSA risk was largest among those less than

60 years of age and smallest in those between 60 and 69 years, the latter of which corresponds to an age range in which the majority of women would likely be post-menopausal (Costanian et al. 2018). The highest prevalence of OSA in this study was observed in 70–79 year old women (26.6%) and men (37.9%), which is not inconsistent with the results of a recent systematic review of OSA in the general population in which observed rates among older adults were described by authors as "strikingly high" (Senaratna et al. 2017).

In this rural sample, we found town residents, both women and men, were more likely to be at high risk of OSA than farm residents. This finding is difficult to explain given that factors which may be associated with town residence and a greater risk of OSA, such as older age and the presence of chronic conditions, were adjusted for in the multivariable analysis. Additional research is needed to identify those determinants of OSA risk that may be more common in town than farm dwellers that were unmeasured in this study.

Sex differences in relation to OSA risk emerged for several demographic factors in this study. Regarding marital status, being partnered was associated with a high risk of OSA for men but was unrelated for women. Some previous research has similarly reported a higher prevalence of OSA in those married or cohabiting (Fuhrman et al. 2012; Charokopos et al. 2007); being partnered increases the likelihood of another person sleeping nearby and possibly alerting a partner to their OSA symptoms and encouraging health professional contact. Although the focus of the present study was not on diagnosis, several questions on our screening tool involved snoring and observed sleep apnea, both of which might become more apparent in the presence of a partner. But why was a similar relationship not observed for partnered women in this study? Some research suggests that men may be less likely than women to notice sleep-related abnormalities in their partners (Breugelmans et al. 2004), possibly emanating from traditional gender role expectations whereby girls and women are raised to be attentive to the needs of others, and men, more individualistic and self-focused. It is important to note, however, we did not have information on the sex/gender of partners in this study. Also, some research has failed to find any association between marital status and OSA diagnosis or symptomology (Krüger et al. 2023; Spuy et al. 2018). Additional research is clearly needed to clarify this relationship between gender, OSA, and marital status.

Regarding socioeconomic status (SES), lower education and greater financial strain were associated with high risk of OSA for men only and women only, respectively, whereas household income was unrelated to OSA for both sexes. The broader literature to a certain extent mirrors the findings of the present study, with mixed results reported, often dependent on the particular SES indicator, sex/gender, and the measure of OSA (Spuy et al. 2018; Cunningham et al. 2021; Tufik et al. 2010; Li et al. 2008; Adams et al. 2012). Although results have been variable, including some studies which suggest no association between SES and OSA (Spuy et al. 2018), research to date leans towards the presence of an increased prevalence of OSA among those lower in the social hierarchy (Park et al. 2022), which is generally consistent with the findings of this study. Compared to other chronic conditions, research examining the relationship between SES and OSA is somewhat in the beginning stages, and it is currently unclear as to whether the increased occurrence observed among those less advantaged is linked to OSA risk, severity, access to medical care, and/or reverse causality (Park et al. 2022).

Health behaviors

Exercise in the present study was associated with reduced odds of OSA risk for both women and men, which is consistent with previous research (Huang et al. 2018; Spuy et al. 2018; Sunwoo et al. 2018; Hall et al. 2020), including the results of a recent longitudinal study (Liu et al. 2022). Various mechanisms have been proposed to explain how physical inactivity or a sedentary lifestyle may increase OSA risk such as systemic inflammation, insulin resistance, and lower extremity oedema (Dempsey et al. 2010; Huang et al. 2021; Yumino et al. 2010; Duan et al. 2022). Conversely, it is also possible that OSA-related difficulties may deter individuals from engaging in physical activities due to time constraints or diminished physical capabilities (Hiestand et al. 2006).

Binge drinking in the present study was unrelated to OSA risk, a finding in contrast with the results of several meta-analyses reporting alcohol use to be associated with an increased likelihood of OSA (Simou et al. 2018; Taveira et al. 2018). Alcohol may increase OSA risk by reducing the body's sensitivity to blood-oxygen reduction during sleep and binge drinking can increase this stress (Simou et al. 2018; Urbanik et al. 2020). Alcohol may also aggravate OSA severity by increasing levels of *apnea*, episodes of breathing cessation (Scanlan et al. 2000). However, varied measurement and a lack of longitudinal research precludes any definitive statements about the precise nature of the relationship between alcohol and OSA (Qian et al. 2023). In this cross-sectional study, we used a threshold measure of 5 or more drinks on a single occasion at least once a month to determine binge drinking and failed to find any association for women or men; this measure, although standard (Bulloch et al. 2016), combines individuals who binge drink once a month with those binging more than once a week. In supplementary

exploratory analysis (data not shown) we recoded the binge drinking variable from dichotomous to ordinal, with results suggesting an association between binge drinking and increased OSA risk, but only among men in the most extreme binge drinking category (i.e., more than once a week). Clearly, additional research is needed to clarify the relationship between alcohol use (e.g., quantity and pattern) and OSA risk and whether associations vary by sex/gender.

Comorbidities

Previous research has reported associations between OSA and an increased occurrence of heart disease (Thompson et al. 2022; Kim et al. 2021), diabetes (Heinzer et al. 2015; Thompson et al. 2022; Huang et al. 2018; Hall et al. 2020; Kim et al. 2021), and high cholesterol (Hall et al. 2020), which was similarly observed for both women and men in the present study. Systemic inflammation is caused by *visceral fats*, the excess fats surrounding abdominal organs, which secrete inflammatory substances and reduce lung volumes (Drager et al. 2013; McArdle et al. 2007). People with OSA have resistance to *leptin*, a substance that inhibits hunger (Kim et al. 2021), and resistance to insulin, implicated in narrowing the upper airway by causing inflammation and increasing muscle fatigue (McArdle et al. 2007; Edwards et al. 2020). These metabolic dysregulations with insulin resistance show why diabetes is a common comorbidity of OSA (Drager et al. 2013). The intermittent hypoxia from breathing cessation in sleep among people with OSA also influences higher cholesterol production, inflammation, and lower clearance of fats (McArdle et al. 2007), which accounts for the prevalence of high cholesterol among the participants at high OSA risk. While some research suggests a stronger association between OSA and some cardiometabolic outcomes in women than men, such as diabetes (Cunningham et al. 2021), others have failed to report such differences (Bonsignore et al. 2019). The relationship between OSA risk and cardiometabolic comorbidities are no doubt complex and likely operate in a bi-directional fashion which we are unable to clarify further in this cross-sectional analysis.

In the present study, high OSA risk related to increased odds of depression among women but not men. An association between OSA and greater depression has been reported in a large body of research (Edwards et al. 2020; Garbarino et al. 2020). The higher rates of depression, alongside OSA, can be explained by the increased SNS activity due to fragmented sleep and systemic inflammation (Gupta and Knapp 2014; Canessa et al. 2011). In a different sense, the use of serotonin to affect upper airway muscles contribute to further sleep fragmentations and neurotransmitter imbalances, serving as another

link to depression (Canessa et al. 2011). Consistent with our findings, considerable research has reported a relationship between OSA and depression only in women (Heinzer et al. 2018; Mokhlesi et al. 2016; Davies et al. 2019), whereas other studies have observed increased odds in men as well (Garbarino et al. 2020; Gupta and Knapp 2014). Interestingly, in our univariate results, men at high risk of OSA also had an elevated prevalence of depression compared to those at low OSA risk, but this association became nonsignificant in multivariable analysis.

Another sex-specific association in this study emerged regarding asthma, with elevated odds reported among high OSA risk women but not men. A recent systematic review (Davies et al. 2019) concluded that between 19 and 60% of people with asthma also have OSA, and that their co-occurrence predicts poorer health outcomes. Systemic inflammation is considered a key pathophysiologic mechanism linking OSA and asthma (Ragnoli et al. 2021). Consistent with our study, some previous research has reported a more pronounced association between OSA and asthma in women than men (Bonsignore et al. 2018 Dec; Krishnan et al. 2022; Chua et al. 2023), whereas some studies have indicated a similar, elevated occurrence of asthma for both (Thompson et al. 2022).

Quality of life

A growing body of research suggests that quality of life (QOL) may be severely compromised in individuals with OSA (Chua et al. 2023; Moyer et al. 2001; Appleton et al. 2018). We incorporated several indicators of QOF into the present study and found that women and men at high risk of OSA were significantly more likely than their low risk counterparts to report poor self-rated physical health and high stress levels, associations which have been similarly reported in prior research (Ward et al. 2022; Wong et al. 2021; Pauletto et al. 2021). The adverse impact of OSA symptoms on daily life can be considerable (Moyer et al. 2001) and may be more pronounced if left untreated or undertreated (Pauletto et al. 2021). In addition, high OSA risk men in this study, but not women, reported feeling less supported by their community. This result is somewhat challenging to interpret, given the broad nature of the question [*How well do you feel like you are generally supported (socially, emotionally, medically,* etc*.) by your community?*]. While we could not find any prior research using a similar variable, this association is broadly consistent with the lower QOL generally reported by those with OSA (Moyer et al. 2001; Appleton et al. 2018). It is possible that we have identified a group of vulnerable rural men at high risk of OSA who experience social isolation and who are medically underserved. Additional research is required to understand

this sex-specific association, and whether such a finding can be linked with traditionally masculine attributes of stoicism and a lower likelihood of help-seeking behavior.

Study strengths and limitations

In addition to our positioning of sex/gender as an important consideration when examining OSA risk in a rural setting, strengths of this study include a large sample size and the inclusion of a broad array of risk factors. There are also several limitations in the current study. The gold standard for assessment of OSA, polysomnography, was not available in this study. However, the fact that the prevalence of high risk for OSA in this study was comparable to that from previous studies in general population samples lends some support regarding the validity of our screening tool. It is important to note, however, that the psychometric properties of the OSA tool used in this study are less established than those of other standard screening measures, such as STOP-BANG; further research is required to provide evidence of the validity of the STOP-Obesity tool. Our independent variables were also self-reported which may have resulted in some misclassification, as might the binary nature of many of these variables. In addition, the design of our study was cross-sectional thus preventing us from inferring causal associations.

Conclusion

A sizable minority of rural women and men may have possible undiagnosed OSA, which in turn, is associated with substantial comorbidity and reduced quality of life. While many of the correlates of OSA risk were similar for women and men, several sex differences also emerged. Additional research with enhanced measurement and a longitudinal design is required to test the veracity of these findings and further clarify the role of sex/gender in relation to OSA risk in rural adults.

Abbreviations

OSA   Obstructive sleep apnea
SRHS   Saskatchewan Rural Health Study
SES   Socioeconomic status
COPD   Chronic obstructive pulmonary disease
BMI   Body mass index

Declarations

Ethics approval and consent to participate

The study was approved by the Biomedical Research Ethics Board of the University of Saskatchewan (PSY-REC: #2021–2022-HLST-005).

Consent for publication

Not applicable.

Competing interests

The authors declare no conflict of interest.

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