



# Sex-difference in chewing difficulty and the risk of obstructive sleep apnea among middle-aged and older adults

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## Abstract

**Purpose** Chewing difficulty may reflect orofacial factors linked to obstructive sleep apnea (OSA) risk, yet evidence remains limited, especially regarding sex differences. This study examined the association between perceived chewing difficulty and OSA risk according to sex.

**Methods** The study used five-year (2019–2023) data from the Korean National Health and Nutrition Examination Survey, including 16,105 participants aged  $\geq 40$  years (6,965 males and 9,140 females). Chewing difficulty was assessed on a five-level scale, and OSA risk was determined using the STOP-Bang questionnaire. A significant interaction between sex and chewing difficulty ( $p=0.0387$ ) in the model prompted sex-stratified analyses. Multivariable and multinomial logistic regression models were used to estimate adjusted odds ratios (ORs) and 95% confidence intervals (CIs).

**Results** Among participants, 62.7% of males and 18.5% of females were classified as having middle-to-high risk of OSA. In adjusted models, chewing difficulty was significantly associated with higher OSA risk (OR: 1.28, 95% CI: 1.11–1.48) in females but not in males, with stronger associations observed at higher OSA risk levels (middle-risk, OR: 1.26, 95% CI: 1.09–1.46; high-risk, OR: 1.86, 95% CI: 1.09–3.18). This association persisted when chewing difficulty was analyzed as a graded variable, showing a trend of increasing association with greater severity ( $p<0.0001$  for trend).

**Conclusions** In females, higher levels of chewing difficulty were associated with increased OSA risk. These findings suggest that chewing difficulty could be explored as a potential factor in identifying individuals at higher risk of OSA.

**Keywords** Obstructive sleep apnea · Chewing difficulty · Sex-difference · Oral health · STOP-Bang · Sleep health

## Introduction

Obstructive sleep apnea (OSA) is the most common sleep-related breathing disorder and characterized by repetitive episodes of partial or complete collapse of the upper airway during sleep, resulting in reduced or absent airflow [1]. Previous epidemiological studies conducted between 1993 and

2013 reported mean OSA prevalence rates of 22% in males and 17% in females worldwide [2]. However, a meta-analysis in 2023 estimated the prevalence at 54% [3], which may reflect differences in study design, diagnostic criteria, or population characteristics, as well as the global rise in obesity [2, 4]. More concerning than the high global prevalence of OSA is the fact that a substantial portion of OSA patients remain undiagnosed and inadequately managed [5, 6].

As a potential therapy for OSA, oral appliances and surgical procedures that reposition the mandible and maxilla to expand the upper airway may be considered [1, 7]. These interventions aim to improve the anatomical structures surrounding the oral cavity, suggesting a possible correlation between orofacial tissue abnormalities and the development of OSA [8]. Chewing is one of the vital functions of orofacial tissues, and any disruptions in this function may lead to various problems, not only within the oral cavity but also in overall health [9].

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Oral health has increasingly been recognized as an important factor in sleep-related breathing disorders. Conditions such as periodontitis, tooth loss, and other oral diseases may contribute to chewing difficulties [9–13]. Although a meta-analysis suggested an association between periodontal disease and OSA [13], the limited number of studies and regional differences in OSA characteristics highlight the need for further research [14, 15]. Furthermore, considering the sex-related variation in OSA prevalence and emerging evidence of potential sex-specific associations, it is important that future investigations account for these patterns [9, 12, 16].

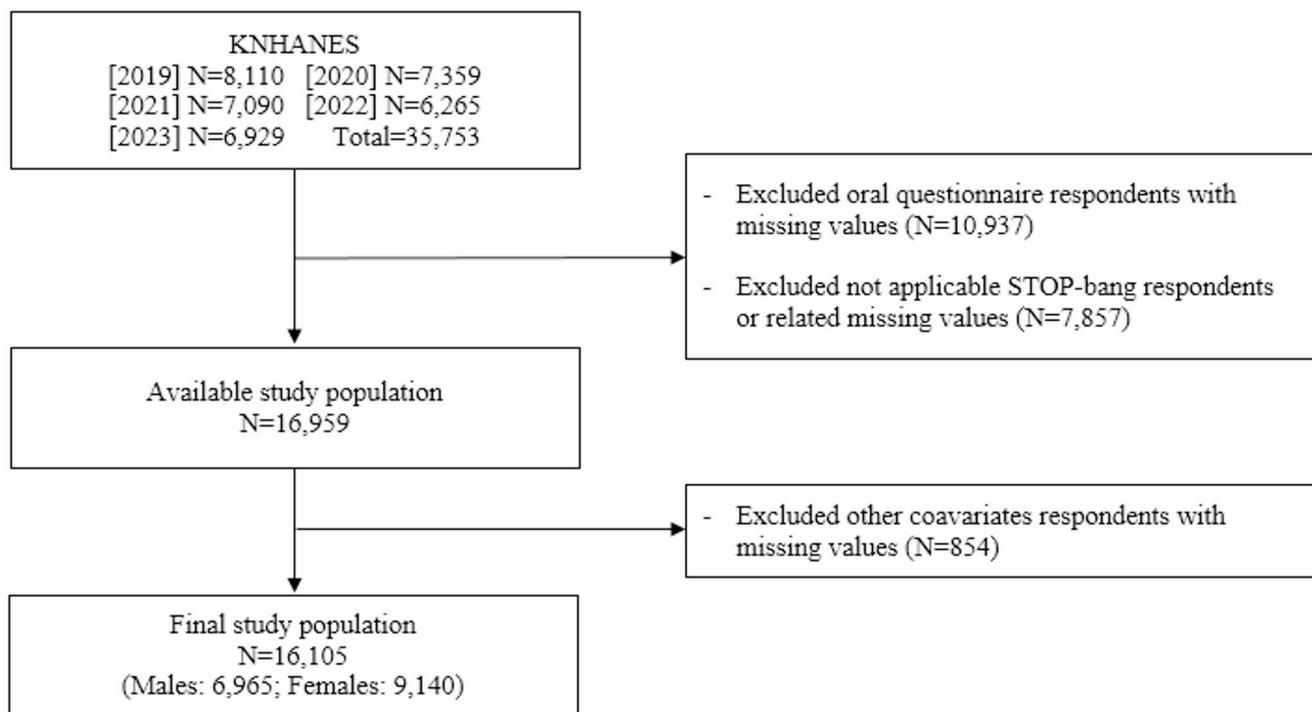
Chewing difficulties may arise from factors like tooth loss or oral pathologies, although they can also occur independently of these conditions. In existing research, masticatory function is often assessed using objective indicators of oral disease, which may underestimate its true extent compared to subjective assessments that consider multidimensional factors [17]. Given that subjective evaluations are commonly used in clinical practice, they can provide valuable insights alongside objective assessments [18]. Additionally, since the multiple adverse health outcomes associated with OSA, such as decreased quality of life and increased mortality [19, 20], recognizing and addressing its risk factors remains an important public health issue [21, 22]. Therefore, the objective of this study was to explore the association between perceived chewing difficulty and the risk of OSA, stratified by sex, in the South Korean population.

## Methods

### Data and study participants

This study used data from the Korean National Health and Nutrition Examination Survey (KNHANES) conducted by the Korean Disease Control and Prevention Agency (KDCA). Using a multilevel clustered probability design, the KNHANES sampled the South Korean population. Considering its nationwide population-based sampling design, the KNHANES is perceived as representative of the whole population [23].

This cross-sectional study used 5-year (2019–2023) data from the KNHANES. The flow of participant inclusion and exclusion is presented in Fig. 1. Initially, a total of 35,753 individuals were included in the dataset spanning over 5 years. 10,937 individuals were excluded due to non-participation in the oral questionnaire, and an additional 7,857 individuals were excluded due to ineligibility (primarily age-related) or missing data from the STOP-Bang questionnaire, leaving a total of 16,959 participants. Subsequently, 854 missing values corresponding to covariates were further removed from the dataset, resulting in a final sample size of 16,105 participants (males: 6,965; females: 9,140) included in the study. All participants were aged  $\geq 40$  years since the KNHANES examined OSA measurement only for this age group and the oral survey respondents were given a distinct weighting value in the KNHANES. As using the raw data



**Fig. 1** Flowchart of the study participants displaying the inclusion and exclusion

of KNHANES is publicly available, ethics approval was exempt.

## Variables

### Chewing difficulty

The variable of interest was used to measure subjective chewing inconvenience: Do you have difficulty chewing food because of struggles with your teeth, dentures, or gums? (If you have dentures, please describe how you feel when wearing them). The question used had five response options to select from, and participants were divided into two groups based on their answer: those who answered, “very difficult” and “difficult” were allocated to the “yes” group, while those who answered “regular,” “not difficult,” and “not at all” were allocated to the “no” group. For additional analyses, chewing difficulty was recategorized into three, four, or five levels, with the definition of no difficulty group (reference category) varying by scheme: same as the main analysis for three levels, “not at all” and “not difficult” for four, and “not at all” only for five.

### The risk of obstructive sleep apnea (OSA)

The dependent variable was measured using the STOP–Bang OSA screening questionnaire [24], which comprises questions (yes/no) that assess S (snoring), T (tiredness), O (observed apnea), P (high blood pressure), B (body mass index [BMI]), A (age), N (neck circumference), and G (gender), with a score of 1 or 0 for a positive or negative answer, respectively [25]. Those with a score of 0–2 were assigned to the low-risk group; 3–4, middle-risk group; 5–8, high-risk group. The last group also comprised those with a combination of STOP part score  $\geq 2$  with male sex, with BMI  $>35$  kg/m<sup>2</sup>, or with neck circumference  $\geq 43$  cm (17 inches) in males or  $\geq 41$  cm (16 inches) in females [24]. In accordance with this risk classification, OSA “yes” was categorized into the middle-risk and high-risk groups, while “no” was into the low-risk group. Additionally, participants were stratified into risk groups based on their STOP-Bang scores to further explore associations.

### Covariates

The covariates related to chewing difficulty and OSA were sociodemographic factors and health behavior factors or others [2–4]. Sociodemographic factors included age (10-year interval from 40 years of age: 40s, 50s, 60s, and over 70s), area of residence, household income quintiles, education level, and marital status. Health behavior factors or others included mean sleeping time in a day, smoking status,

drinking frequency, physical activity (calculating incorporated moderate and vigorous regular aerobic exercise more than 150 min per week: yes or no), waist circumference ( $\geq 90$  cm in males or  $\geq 85$  cm in females: normal or abdominal obesity), diabetes (diabetes: fasting plasma glucose [FPG]  $\geq 126$  mg/dL, glycated hemoglobin [HbA1c]  $\geq 6.5\%$ , current use of antidiabetic medication or insulin, or a physician diagnosis of diabetes, pre-diabetes: FPG = 100–125 mg/dL or HbA1c = 5.7–6.4%, normal: FPG  $< 100$  mg/dL and HbA1c  $\leq 5.6\%$ ), number of natural teeth, and each survey year.

## Statistical analyses

Due to the significant interaction between chewing difficulty and sex ( $p=0.0387$ ) in this dataset, and the established role of sex as a risk factor for OSA, all analyses were stratified by sex. Descriptive analyses were presented as number and percentage with a chi-square test to identify the participants’ distribution of general characteristics. Multivariable logistic regression was conducted to examine the association between chewing difficulty and OSA, accounting for the stratification and clustering variables as well as year-specific sampling weights. To further investigate the association between OSA risk division and chewing difficulty levels, additional analyses were performed. Multinomial logistic regression was used with OSA risk categories as the dependent variable. In the analysis of chewing difficulty levels, p-value for trend was presented to determine whether the effect size varied according to the degree of chewing difficulty. To explore potential effect modification, subgroup analyses were performed by stratifying the analyses based on covariates included in the model. Statistical tests were two-tailed with a significance level set at a p-value  $< 0.05$ , and adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were used to assess the associations among the variables. SAS version 9.4M7 (SAS Institute, Cary, NC, USA) was used for all statistical analyses.

## Results

### Descriptive analyses

Supplementary Table 1 shows the distribution of the general characteristics of the study population according to sex. Based on the STOP-Bang questionnaire, the “yes” group—classified as having middle or high OSA risk—comprised 4,368 of the 6,965 male participants (62.7%) and 1,692 of the 9,140 female participants (18.5%), indicating a substantially higher OSA risk level among males compared to females. The proportion of individuals who have

chewing difficulty were 1,696 (24.4%) in male and 2,025 (22.2%) in female participants. The results of the chi-square test between chewing difficulty and OSA were significant ( $p < 0.0001$ ) in both males and females. An age-related increase in OSA risk was observed in both sexes, reflecting the role of age as a major risk factor.

### Regression analyses

Table 1 shows the results of multivariable logistic regression analysis between chewing difficulty and OSA, after adjusted all covariates. Female participants with chewing difficulty had higher likelihoods of OSA (OR: 1.28, 95% CI: 1.11–1.48), compared with those without chewing difficulty. Among female participants, even when OSA risk groups were further stratified, those with chewing difficulty showed higher odds of being in middle- and higher-risk group compared to the low-risk group: OR 1.26 (95% CI: 1.09–1.46) for the middle-risk group and OR 1.86 (95% CI: 1.09–3.18) for the high-risk group.

A rising trend in the strength of association across risk groups is visually presented in Fig. 2.

In contrast to the significant association observed in the chi-square test between chewing difficulty and OSA in Supplementary Table 1, the association was not significant in the regression analysis adjusted for covariates among male participants (OR: 1.05, 95% CI: 0.90–1.23), as shown in Supplementary Table 2.

### Additional analyses

Table 2 shows the results of the subgroup analysis stratified by independent variables in female participants. The association was more prominent in individuals aged 50–69 years (50–59, OR: 1.45, 95% CI: 1.08–1.96; 60–69, OR: 1.36, 95% CI: 1.09–1.69) and those with lower socioeconomic status (middle-low household income, OR: 1.36, 95% CI: 1.09–1.69; low household income, OR: 1.36, 95% CI: 1.09–1.69; education level of middle school, OR: 1.39, 95% CI: 1.02–1.91). Additionally, a slightly stronger association was observed among participants who were unmarried, separated, widowed, or divorced (OR: 1.38, 95% CI: 1.08–1.78).

Figure 3 shows the results of the analysis stratified by chewing difficulty level in female participants. The likelihood of OSA increased with higher levels of chewing difficulty, and this trend was consistent across all categorization schemes (all  $p$ -values for trend  $< 0.0001$ ). Notably, the ‘very difficult’ category consistently showed the highest OR across all levels of classification (3 levels, OR: 1.93, 95% CI: 1.47–2.52; 4 levels, OR: 2.01, 95% CI: 1.53–2.63; 5 levels, OR: 2.06, 95% CI: 1.56–2.72).

## Discussion

This study used nationally representative data from South Korea to explore the association between perceived chewing difficulty and OSA. A significant interaction between sex and chewing difficulty in relation to OSA risk was observed in the sample. Sex-stratified analyses revealed that chewing difficulty was significantly associated with the risk of OSA in females, whereas no such association was found in males. Moreover, among females, the association was more pronounced in individuals with both higher risk for OSA and higher levels of chewing difficulty.

Prior investigations conducted in the United States and Brazil have documented a connection between tooth loss and OSA [10, 11]. Tooth loss has been linked to subjective discomfort while chewing [18], which aligns with the findings of the current study. Studies conducted in Japan have also demonstrated that chewing problems can affect sleep quality and duration, with a stronger association observed in females [9]. Two previous studies also utilized data from the KNHANES [26, 27], one of which reported no significant association after adjustment and the other identifying a significant relationship, although the latter compared low- and high-risk groups based on the STOP-Bang score—an approach that differs from that of the present study. Additionally, differences in the study periods, adjustment variables included in the models, and other methodological aspects exist between the previous studies and ours. Notably, most previous studies, including those based on KNHANES, did not account for sex-differences, which represents a key distinction.

Another major difference from previous South Korean studies lies in the interpretation of the directionality. Although, like the present study, they were based on cross-sectional data—limiting the ability to infer causality—the current findings suggest a possible direction, as evidenced by a trend of increasing association strength with higher chewing difficulty and OSA risk levels [28]. A recent review of studies on this topic has also highlighted the possibility of complex bidirectional influences [13, 29]. In line with this, although the causal pathway remains unclear, the association between chewing difficulty and OSA may be tentatively explained through three major factors: dental status (the number of natural antagonist teeth), salivation status (the quantity and/or quality of saliva), and motor control of mastication (i.e., impairment of the motor apparatus) [30]. Specifically, tooth loss may constrict the occlusal vertical dimension may lead to forward position of the mandible. This mandibular displacement can cause tongue root retraction, which might collapse the upper airway’s patency [10, 11]. Even in the absence of tooth loss, reduced tongue mobility and impaired masticatory muscle function can

**Table 1** Results of factors associated between chewing difficulty and obstructive sleep apnea in female participants

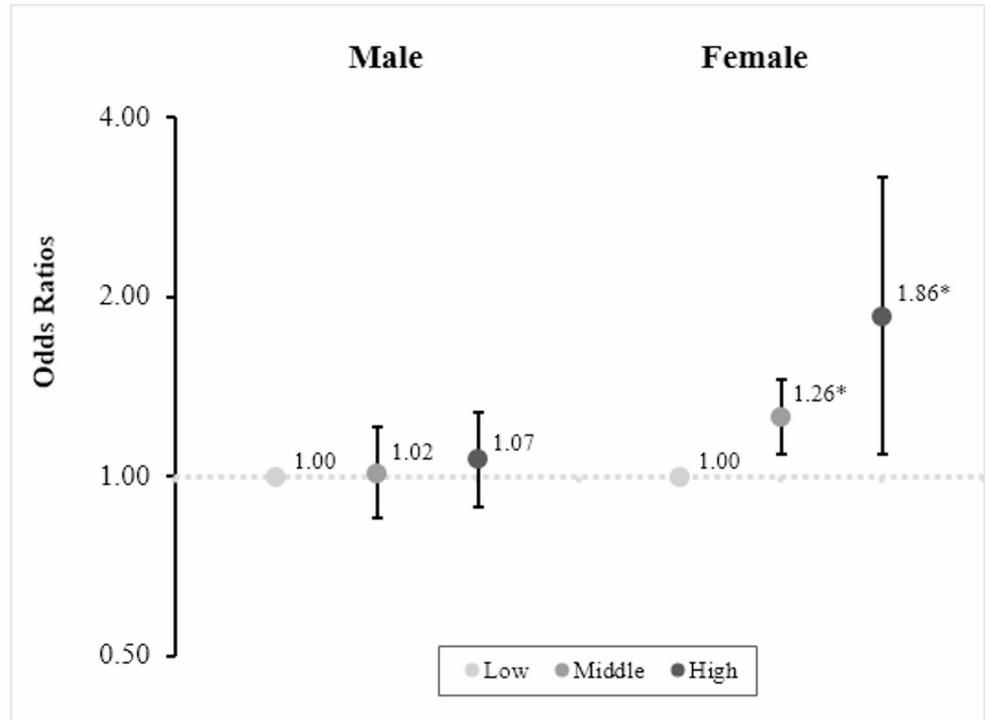
Variables	Obstructive sleep apnea					
	Yes (Middle and High)			High <sup>a</sup>		
	OR	95% CI	Middle <sup>a</sup>	OR	95% CI	High <sup>a</sup>
<b>Chewing difficulty</b>						
No	1.00		1.00	1.00		1.00
Yes	1.28	(1.11 – 1.48)	1.26	1.86	(1.09 – 3.18)	1.86
<b>Age</b>						
40–49	1.00		1.00	1.00		1.00
50–59	7.90	(5.65 – 11.07)	9.01	2.56	(6.25 – 13.00)	2.56
60–69	8.53	(6.05 – 12.04)	9.97	1.72	(6.89 – 14.42)	1.72
70+	10.58	(7.24 – 15.44)	12.37	2.15	(8.28 – 18.48)	2.15
<b>Region</b>						
Metropolitan	1.00		1.00	1.00		1.00
Urban & Rural	1.31	(1.14 – 1.50)	1.31	1.30	(1.14 – 2.41)	1.30
<b>Household income</b>						
High	1.00		1.00	1.00		1.00
Middle-high	1.09	(0.87 – 1.36)	1.12	0.65	(0.89 – 1.41)	0.65
Middle	1.28	(1.02 – 1.61)	1.31	0.79	(1.03 – 1.66)	0.79
Middle-low	1.15	(0.92 – 1.44)	1.17	0.87	(0.92 – 1.48)	0.87
Low	1.48	(1.16 – 1.90)	1.47	1.79	(1.14 – 4.36)	1.79
<b>Education level</b>						
College or above	1.00		1.00	1.00		1.00
High school	0.86	(0.70 – 1.04)	0.83	1.64	(0.68 – 1.01)	1.64
Middle school	0.76	(0.63 – 0.93)	0.75	1.26	(0.61 – 0.91)	1.26
Elementary school or below	0.77	(0.61 – 0.98)	0.76	1.14	(0.60 – 0.98)	1.14
<b>Marital status</b>						
Married	1.00		1.00	1.00		1.00
Unmarried, separated, widowed, divorced	0.96	(0.83 – 1.12)	0.97	0.87	(0.83 – 1.13)	0.87
<b>Sleeping time</b>						
Less than 6 h	1.17	(0.99 – 1.39)	1.19	0.83	(1.00 – 1.42)	0.83
6–8 h	1.00		1.00	1.00		1.00
More than 8 h	0.93	(0.79 – 1.09)	0.93	0.87	(0.79 – 1.10)	0.87
<b>Smoking</b>						
Current	1.00		1.00	1.00		1.00
Former	0.64	(0.39 – 1.05)	0.70	0.24	(0.42 – 1.18)	0.24
None	0.57	(0.38 – 0.84)	0.62	0.23	(0.41 – 0.94)	0.23
<b>Drinking frequency</b>						
No	1.00		1.00	1.00		1.00
Less than 1 time in a month	1.13	(0.96 – 1.33)	1.15	0.76	(0.98 – 1.35)	0.76
1–4 time(s) in a month	1.08	(0.90 – 1.29)	1.11	0.61	(0.93 – 1.33)	0.61
Several times in a week	1.20	(0.93 – 1.55)	1.25	0.60	(0.96 – 1.61)	0.60

**Table 1** (continued)

Variables	Obstructive sleep apnea					
	Yes (Middle and High)		Middle <sup>a</sup>		High <sup>a</sup>	
	OR	95% CI	OR	95% CI	OR	95% CI
Physical activity						
No	1.00		1.00		1.00	
Yes	0.91	(0.79 – 1.06)	0.91	(0.78 – 1.05)	1.04	(0.60 – 1.79)
Diabetes						
Normal	1.00		1.00		1.00	
Pre-diabetes	1.38	(1.17 – 1.63)	1.38	(1.17 – 1.63)	1.24	(0.57 – 2.70)
Diabetes	1.85	(1.52 – 2.26)	1.84	(1.51 – 2.25)	1.95	(0.87 – 4.35)
Waist circumference						
Normal	1.00		1.00		1.00	
Abdominal obesity	1.97	(1.72 – 2.25)	1.84	(1.60 – 2.11)	7.46	(3.73 – 14.95)
Number of teeth						
0–9	1.00		1.00		1.00	
10–19	1.06	(0.81 – 1.39)	1.04	(0.80 – 1.36)	3.47	(0.71 – 16.91)
20–	1.33	(1.05 – 1.68)	1.26	(1.00 – 1.60)	10.42	(2.40 – 45.18)
Year						
2019	1.00		1.00		1.00	
2020	0.84	(0.68 – 1.03)	0.79	(0.64 – 0.98)	2.53	(1.13 – 5.64)
2021	1.05	(0.85 – 1.30)	1.03	(0.83 – 1.28)	1.71	(0.52 – 5.56)
2022	0.89	(0.73 – 1.10)	0.86	(0.69 – 1.07)	2.10	(0.88 – 5.04)
2023	0.84	(0.69 – 1.01)	0.82	(0.67 – 0.99)	1.65	(0.69 – 3.92)

<sup>a</sup> Multinomial logistic regression was performed using ‘No chewing difficulty’ and ‘Low obstructive sleep apnea risk’ as reference categories

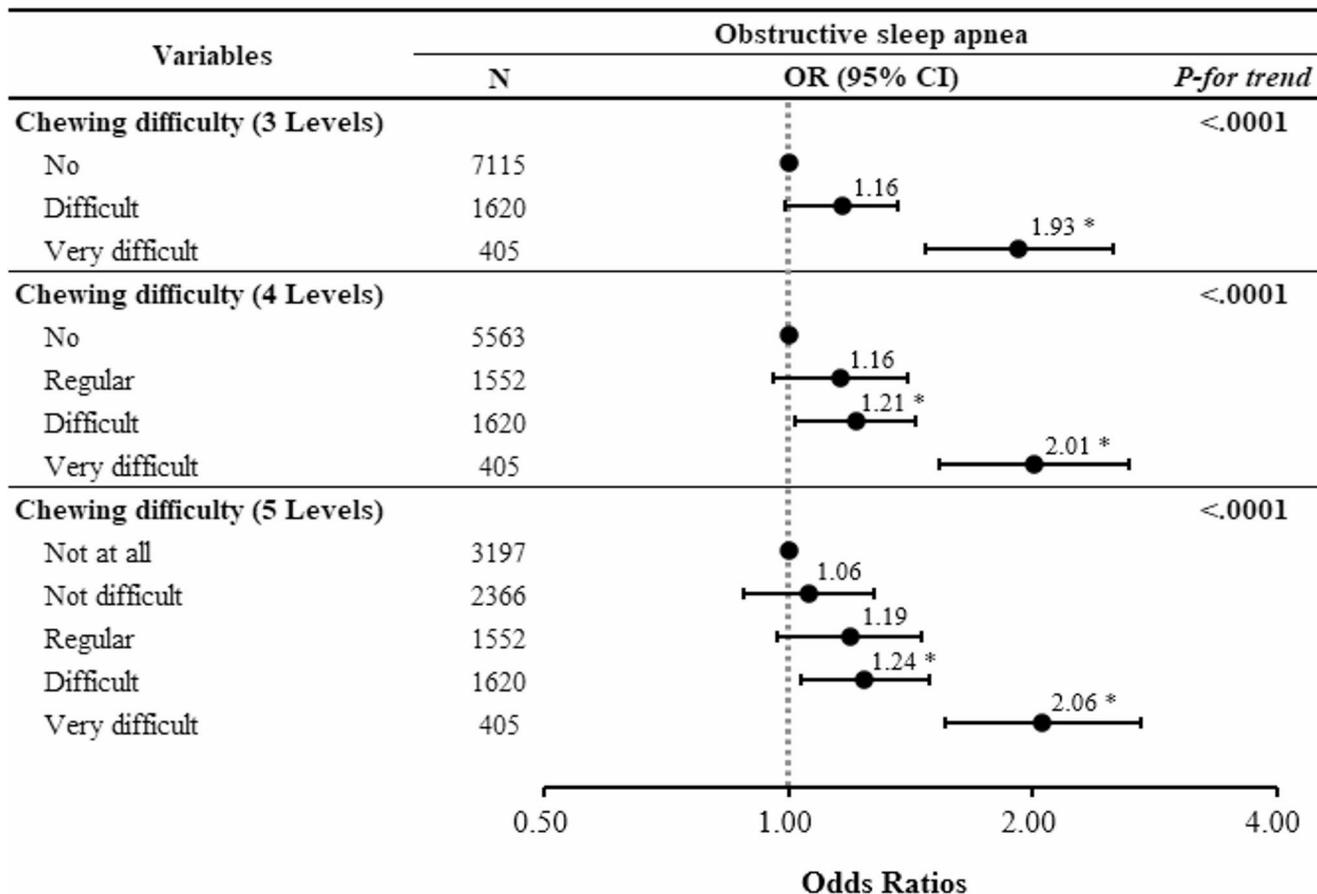
**Fig. 2** Results of analysis stratified by STOP-bang index risk group using multinomial logistic regression



**Table 2** Results of subgroup analysis stratified by independent variables in female participants

Variables	Obstructive sleep apnea				P-for interaction
	No		Yes		
	OR	OR	95% CI		
Age					0.5651
40–49	1.00	1.16	(0.44	–	3.06)
50–59	1.00	1.45	(1.08	–	1.96)
60–69	1.00	1.36	(1.09	–	1.69)
70-	1.00	1.20	(0.97	–	1.50)
Household income					0.9293
High	1.00	1.24	(0.75	–	2.06)
Middle-high	1.00	1.06	(0.70	–	1.60)
Middle	1.00	1.22	(0.85	–	1.74)
Middle-low	1.00	1.39	(1.03	–	1.88)
Low	1.00	1.46	(1.12	–	1.92)
Education level					0.8897
College or above	1.00	1.25	(1.02	–	1.54)
High school	1.00	1.19	(0.82	–	1.71)
Middle school	1.00	1.39	(1.02	–	1.91)
Elementary school or below	1.00	1.29	(0.82	–	2.04)
Marital status					0.8921
Married	1.00	1.24	(1.03	–	1.49)
Unmarried, separated, widowed, divorced	1.00	1.38	(1.08	–	1.78)
Sleeping time					0.0957
Less than 6 h	1.00	1.10	(0.82	–	1.46)
6–8 h	1.00	1.48	(1.19	–	1.85)
More than 8 h	1.00	1.08	(0.80	–	1.46)
Number of teeth					0.8095
0–9	1.00	1.47	(0.98	–	2.22)
10–19	1.00	1.12	(0.78	–	1.61)
20-	1.00	1.29	(1.08	–	1.55)

Adjusted all covariates except for each stratified variable



**Fig. 3** Results of subgroup analysis stratified by chewing difficulty level in female participants

impair masticatory efficiency. Such impairments may lead to unilateral chewing patterns, which in turn can induce palatal morphological changes that potentially exacerbate OSA symptoms [31].

A significant difference between chewing difficulty and OSA was observed in both sexes in unadjusted analyses, but remained significant only in females after adjustment for covariates, suggesting potential sex-specific pathological mechanisms. It is hypothesized that sex hormones may play a role in the substantial increase in OSA prevalence among females following menopause in their 50s [2, 16]. Chewing difficulty is also more prevalent in elderly females compared with males, possibly influenced by these sex hormones. This difficulty could negatively impact dental health in females due to bone and connective tissue deterioration resulting from estrogen deficiency post-menopause [32, 33].

In stratified analyses by other covariates, insufficient management of dental issues due to low household income can negatively affect oral health [34]. When accompanied by the association observed at lower educational levels in our findings, this circumstance may be linked to a high level of unmet healthcare needs among elderly females [35]. The observed association may also be influenced by marital

status, as females living without a spouse are more likely to experience greater unmet healthcare needs [35]. Therefore, inadequate management of oral problems due to financial constraints, persisting in an untreated state, could potentially be closely linked to OSA through this mechanism.

This study has the advantage of using the STOP-Bang tool to screen OSA, along with generalizability through a nationwide representative dataset. Furthermore, by highlighting a potential sex-difference that has been underexplored, this study suggests that future investigations should aim to clarify the causal direction, while also examining the sex-specific contributions to the underlying pathophysiological mechanisms. However, it is crucial to acknowledge the limitations of this study, which should be considered before interpreting the results. First, due to its cross-sectional design, causal inference cannot be established, and the possibility of reverse causality remains. Second, some variables were based on self-reported data from KNHANES, which may be subject to recall bias or intentional misreporting. Third, the presence of residual confounding factors not accounted for in the analysis cannot be ruled out. Fourth, the data lacked detailed questions addressing the specific causes of chewing difficulty, limiting the ability to identify

underlying mechanisms. Further research is needed to clarify the specific etiologies of chewing difficulty and to better understand their relationship with OSA. Fifth, differences in measurement methods for both chewing difficulty and OSA may influence the observed associations. Although subjective reports of oral symptoms are generally reliable and closely related to objective oral health status [36, 37], incorporating objective assessments alongside subjective reports may enhance measurement validity. Moreover, the STOP-Bang questionnaire, while widely used, has relatively low specificity, which may have led to an overestimation of OSA prevalence. Lastly, the generalizability of the findings to populations under 40 or to regions outside of South Korea may be limited due to differences in the epidemiological characteristics of the variables.

## Conclusions

This study found that chewing difficulty was significantly associated with an increased risk of OSA among middle-aged and older females, but no such association was observed in males. Participants with chewing difficulty were more likely to have additional OSA risk factors, and the severity of chewing difficulty was positively correlated with OSA risk. Therefore, it is imperative to concentrate on the meaningful correlation between chewing difficulty and OSA risk factors in the female population, and future research is required to elucidate this association in detail along with the underlying causes of masticatory discomfort.

## Abbreviations

OSA	obstructive sleep apnea
OR	odds ratio
CI	confidence interval
KNHANES	Korean National Health and Nutrition Examination Survey
KDCA	Korean Disease Control and Prevention Agency
BMI	body mass index

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1007/s11325-025-03549-z>.

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**Author contributions** Conceptualization: JHL, YSJ, and ECP; Data curation: JHL and DBK; Formal analysis: JHL, YSJ, and DBK; Investigation: JHL and DBK; Methodology: YSJ and ECP; Project administration: JS; Supervision: JS; Validation: JS; Visualization: JHL and YSJ; Writing - original draft preparation: JHL and DBK; Writing - review and editing: JHL, YSJ, and JS. All authors read and approved the final manuscript.

**Data availability** The datasets of this study are openly available in the Korea National Health and Nutrition Examination Survey (KNHANES) website at <https://knhanes.kdca.go.kr/knhanes/main.do>.

## Declarations

**Ethics approval** was exempt since the raw data of KNHANES are publicly available and all participants in KNHANES are investigated anonymously by the Korea Disease Control and Prevention Agency (KDCA).

**Conflict of interest** All authors declare no conflicts of interest.

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