Turkish Journal of Audiology and Hearing Research
Türk Odyoloji ve İşitme Araştırmaları Dergisi
E-ISSN: 2667-6877

REVIEW / DERLEME

TJAHR 2024;7(3):32–36
https://doi.org/10.34034/tjahr.1523632

Audiological Findings in Obstructive Sleep Apnea Syndrome

Ayşegül EŞDOĞAN[1], Ayşenur AYKUL YAĞCIOĞLU[1], Füsun SUNAR[2]

[1]KTO Karatay Üniversitesi Sağlık Bilimleri Fakültesi Odyoloji Bölümü, Konya, Türkiye
[2]Karamanoğlu Mehmetbey Üniversitesi, Tıp Fakültesi, Karaman, Türkiye

ABSTRACT

Obstructive sleep apnea syndrome (OSAS) is a common breathing disorder that is characterized by snoring, apnea and hypopnea attacks as a result of airway obstruction during sleep, and can lead to hearing loss. Obstructive sleep apnea syndrome can cause complications in many organ systems associated with ischemia and intermittent hypoxia that develop with recurrent apnea attacks. Because the cochlea is highly dependent on the amount of oxygen, repeated apnea attacks can cause damage to cochlear cells. One study found that obstructive sleep apnea increases the likelihood of hearing loss by 21%. This study aims to determine the effect of OSAS on hearing and raise awareness on this issue by compiling studies in the literature examining the relationship between obstructive sleep apnea syndrome and hearing loss. In studies conducted with pure tone audiometry evaluation in individuals with OSAS, it has been reported that hearing thresholds are higher, especially at high frequencies. In studies where OSAS patients were evaluated with otoacoustic emission (OAE) measurement, the results varied, but lower repeatability, signal-to-noise ratio and amplitude were obtained, especially at high frequencies. In studies examining auditory brainstem responses (ABR) in OSAS patients, absolute latencies and interpeak latencies were often found to be prolonged compared to the control group. In the audiological evaluation of patients with OSAS symptoms and suspected hearing loss who apply to the audiology clinic, high-frequency pure tone audiometry, OAE and ABR measurements, as well as pure tone audiometry measurements, are thought to be important for early diagnosis and treatment.

Keywords: obstructive sleep apnea syndrome; hearing; hearing loss

ÖZ

Obstrüktif Uyku Apne Sendromunda Odyolojik Bulgular

Obstrüktif uyku apne sendromu (OUAS), uyku sırasında hava yolunun tıkanması sonucu horlama, apne ve hipopne atakları ile karakterize, işitme kaybına yol açabilen yaygın bir solunum bozukluğudur. OUAS, tekrarlayan apne ataklarıyla gelişen iskemi ve aralıklı hipoksi ile ilişkili olarak birçok organ sisteminde komplikasyonlara neden olabilir. Koklea, oksijen miktarına oldukça bağımlı olduğundan dolayı tekrarlayan apne atakları koklear hücrelerde hasara neden olabilir. Yapılan bir çalışmada obstrüktif uyku apnesinin %21 oranında işitme kaybı olasılığını artırdığı bulunmuştur. Bu çalışma, obstrüktif uyku apne sendromu ile işitme kaybı arasındaki ilişkiyi inceleyen literatürdeki araştırmaları derleyerek OUAS'ın işitme üzerindeki etkisini belirlemek ve bu konuda farkındalık yaratmayı amaçlamaktadır. OUAS'lı bireylerde saf ses odyometri değerlendirmesi ile yapılan çalışmalarda özellikle yüksek frekanslarda işitme eşiklerinin daha yüksek olduğu rapor edilmiştir. Obstrüktif uyku apne sendromu hastalarının otoakustik emisyon (OAE) ölçümü ile değerlendirildiği çalışmalarda sonuçlar farklılık göstermekle birlikte özellikle yüksek frekanslarda daha düşük tekrarlanabilirlik, sinyal-gürültü oranı ve amplitüd elde edilmiştir. Obstrüktif uyku apne sendromu hastalarında işitsel beyin sapı yanıtlarını (ABR) inceleyen çalışmalarda sıklıkla mutlak latans ve interpeak latansların kontrol grubuyla karşılaştırıldığında uzamış olduğu bulunmuştur. Odyoloji kliniğine başvuran OUAS semptomları ve işitme kaybı şüphesi olan hastaların odyolojik değerlendirmesinde, saf ses odyometri ölçümlerinin yanı sıra yüksek frekanslı saf ses odyometri, OAE ve ABR ölçümlerinin de erken tanı ve tedavi açısından önemli olduğu düşünülmektedir.

Anahtar kelimeler: obstrüktif uyku apne sendromu; işitme; işitme kaybı

Cite this article as: Eşdoğan, A., Aykul Yağcıoğlu, A., Sunar, F. (2024). Audiological Findings in Obstructive Sleep Apnea Syndrome. Turk J Audiol Hearing Res 2024;7(3):32–36

INTRODUCTION

Obstructive sleep apnea syndrome (OSAS) is a common respiratory disorder characterized by snoring, apnea and hypopnea attacks that occur as a result of obstruction of the airways during sleep (Kalathingal, Vijendra Shenoy, Kamath, Sriperumbudur, Parvathareddy, Mohan Kumar, & Acharya, 2023).[1] Although the prevalence of OSAS is stated to vary between 2–4% in the general population, its prevalence exceeds 50% in some countries (Benjafield et al., 2009; İriz, Düzlü, Köktürk, Kemaloğlu, Eravcı, Küükünal, & Karamert, 2018). Additionally, advancing age, male gender and higher body mass index increase the prevalence of OSAS (Senaratna[1] et al., 2017). Obstructive sleep apnea syndrome can cause complications in

Correspondence Address/Yazışma Adresi: Ayşegül EŞDOĞAN, KTO Karatay Üniversitesi Sağlık Bilimleri Fakültesi Odyoloji Bölümü, Konya, Türkiye
E-mail: aysglesdogan@gmail.com

Received/Geliş Tarihi: 22 Eylül 2024, **Accepted/Kabul Tarihi:** 18 Aralık 2024, **Available Online Date/Çevrimiçi Yayın Tarihi:** 31 Aralık 2024

many organ systems, associated with ischemia and intermittent hypoxia that develop with recurrent apnea attacks (Gozeler & Sengoz, 2020). There is also evidence that OSAS is a risk factor for hypertension, stroke and cardiovascular diseases (McArdle, Hillman, Beilin, & Watts, 2007).

The cochlea is highly dependent on the amount of oxygen because it receives its blood needs from a single terminal arterial source and has insufficient collateral circulation. Therefore, repeated apnea attacks can cause damage to cochlear cells. It has also been reported that reactive oxygen species or free radicals may form in OSAS, which can damage the cochlea (Kalathingal et al., 2023). Therefore, it has been reported that cochlear functions are affected in OSAS patients due to intermittent hypoxemia and decreased blood oxygen saturations (İriz et al., 2018; Chopra et al., 2016; Kayabasi, Hizli, &Yildirim, 2019).

In patients with obstructive sleep apnea syndrome, recurrent apnea attacks may lead to a decrease in oxygen content in the cerebrovascular circulation and the arteries feeding the cochlea, resulting in a severe hypoxemic condition (Kalathingal et al., 2023; Martines, Ballacchino, Sireci, Mucia, La Mattina, Rizzo, & Salvago, 2016; Deniz, Çiftçi, Ersözlü, Gültekin, & Alp, 2016). This condition may disrupt the conduction of auditory nerve impulses or cause abnormalities in the central auditory pathways, resulting in temporary or permanent loss of hearing (Lim et al., 2023; Kuhn, Heman-Ackah, Shaikh, & Roehm, 2011; Wang et al., 2022). It is also assumed that increased blood viscosity in these patients may affect the auditory system by causing changes in microcirculation (Kuhn et al., 2011). A prospective study conducted in France by Lisan et al. (2020) found that obstructive sleep apnea increased the likelihood of hearing loss by 21%. It has also been stated that another possible cause of hearing loss in patients with severe OSAS may be acoustic trauma resulting from loud snoring (Kayabasi et al., 2019).

In this study, studies in the literature investigating the relationship between OSAS and hearing loss were examined and it was aimed to determine the effect of OSAS on hearing and to raise awareness on this issue. In this review study, 35 studies published in PubMed, Web of Science and Scopus electronic databases between 2010 and 2024 that examined the relationship between obstructive sleep apnoea syndrome and hearing loss were examined. Within the scope of this review, since audiological evaluations differ in studies conducted on OSAS patients, the findings are given under subheadings according to test batteries.

Pure Tone Audiometry and Speech Audiometry

The studies showed that evaluate the auditory system in patients with obstructive sleep apnea, it has been observed that both low and high frequencies are affected (Gozeler & Sengoz, 2020; Chopra et al., 2016; Kasemsuk et al., 2023). Lee & Lee (2023) emphasizing that in their studies, moderate and high risk groups in terms of OSAS showed significantly worse hearing levels than the low risk group. In this study, they stated that the presence of OSAS affected the hearing level. However, Hwang, Chen, Hsu, & Liu (2011), have reported that the presence of OSAS does not affect the hearing thresholds of patients. Similarly, Casale, Vesperini, Potena, Pappacena, Bressi, Baptista, & Salvinelli (2012) reported that hearing thresholds in patients with OSAS were within normal limits, but were significantly higher than those in the control group.

Varying degrees of sensorineural type hearing loss have been observed in individuals with moderate and severe OSAS in the literature (Deniz et al., 2016; Kasemsuk et al., 2023). In many studies conducted in patients with OSAS, it has been found that hearing thresholds are significantly higher, especially at high frequencies, compared to the control group (Kalathingal et al., 2023; Martines et al., 2016; Wang et al., 2022; Ekin, Turan, Arısoy, Gunbatar, Sunnetcioglu, Asker, & Yıldız, 2016; Li, Chen, Zhang, Liang, Guo, Lu, & Ye, 2020; Matsumura, Matas, Magliaro, Pedreño, Lorenzi-Filho, Sanches, & Carvallo, 2016; Chauhan, Guleria, Sharma, Minhas, Dadwal, & Mohindroo, 2022). In a study conducted in severe OSAS patients, it was reported that high-frequency hearing thresholds worsened, and this loss was reported to be correlated with the severity of OSAS (Vorlová, Dlouhá, Kemlink, & Šonka, 2016). In a study conducted in patients with moderate and severe OSAS, a higher rate of hearing loss (41.66%) was reported, especially at frequencies of 6–16 kHz (Martines et al., 2016).

In a study conducted on 794 men between the ages of 40–65, it was found that the risk of hearing loss in men in the medium and high-risk OSAS group was significantly increased compared to the low-risk group, especially at high frequencies such as 4 kHz (Li, Wang, Cui, Ren, Xin, & Chen, 2022). This can be explained by the hypothesis that the outer hair cells in the basal region of the cochlea, responsible for high-frequency hearing, are much more sensitive to hypoxia than the apical region (Lim et al., 2023).

Chen, Shen, Lee, Sun, Chen, Chuang, & Li (2021) in their study, idiopathic sudden sensorineural hearing loss was subsequently observed in 28 (0.33%) of 8500 patients with OSAS. In the study, less improvement was found in hearing thresholds after treatment in patients with OSAS compared to the control group, especially at higher frequencies (4000 and 8000 Hz). Also Sheu, Wu, & Lin (2012) found in their study that male patients with sudden sensorineural hearing loss were more likely to have had OSAS before than controls. This suggested that OSAS may be associated with sudden sensorineural hearing loss (Chen et al., 2021).

It has been assumed in the literature that intermittent hypoxemia due to OSAS may have negative effects on both speech discrimination and hearing function. It has been reported in the literature that average pure tone thresholds and speech reception thresholds are higher in the OSAS group, and speech discrimination scores are significantly lower in the severe OSAS

group (Solmaz, Ekim, & Simsek, 2023). Kayabasi et al. (2019) in their study, they stated that while high-frequency hearing thresholds and speech discrimination scores were affected in individuals with moderate sleep apnea, all hearing functions were significantly affected in those with severe sleep apnea. However, there is also a study in which a significant decrease was observed in speech discrimination scores compared to the control group, although the hearing thresholds of individuals with OSAS were within normal limits. These findings suggest that recurrent hypoxic episodes in OSAS may cause impairments in the central auditory pathways, even if the hearing threshold is within normal limits (İriz et al., 2018).

Tinnitus

There are also studies in the literature reporting that the risk of tinnitus is high in OSAS patients (Martines et al., 2016; Koo & Hwang, 2017). It has been reported that high-frequency snoring sound energy, in particular, can cause tinnitus by affecting the cochlea (Lu, Lee, Lee, & Li, 2022). In a study, a tinnitus rate of 31.03% was reported in the mild OSAS group, while a tinnitus rate of 57.14% was found in the moderate and severe OSAS group (Martines et al., 2016). In another study examining 115 patients diagnosed with OSAS, the tinnitus prevalence was found to be 38.26% (Liu, Wang, Hong, & Zhongshan, 2018). In addition, Hildebrandt, Koehler, Conradt, Hildebrandt, Cassel, Degerli, & Viniol (2024) reported that the duration of tinnitus was correlated with the severity of OSAS. A recent meta-analysis found that the association between sleep apnoea and tinnitus was not significant for patients with mild or moderate sleep apnoea, but was significant for patients with severe sleep apnoea (Gao, Tan, Liu, Chen, & Liu, 2024).

Otoacoustic Emission (OAE) Measurements

In individuals with OSAS, hypoxia may affect outer hair cell function and cause a decrease in otoacoustic emission responses. In a study comparing OSAS severity, they reported that in the OAE test, all patients in the control and mild OSAS groups passed the test, but 9 of 40 patients in the moderate OSAS group and 16 of 40 patients in the severe OSAS group failed the test (Deniz et al., 2016). In another study examining transient evoked otoacoustic emissions (TEOAE) responses in OSAS patients, low repeatability and signal-to-noise ratio (SNR) values were obtained (Casale et al., 2012). In another study examining the effect of OSAS on TEOAE responses, no statistically significant difference could be obtained between the patient and control groups in terms of SNR or amplitude values, while the repeatability rate was found to be significantly lower in the study group (Gozeler & Sengoz, 2020). Martines et al. (2016) evaluated TEOAE responses in severe OSAS patients and found significantly lower SNR values only at 3 kHz and 4 kHz frequencies.

In the study conducted by Baki (2018), no statistically significant difference was found between the OSAS group and the control group in the distortion product otoacoustic emissions (DPOAE) values of 1.0 kHz, 1.4 kHz, 2.0 kHz, 2.8 kHz and 4.0 kHz in the right and left ears. In contrast to this study, other studies in the literature showed that DPOAE amplitudes were affected in OSAS patients (Casale et al., 2012; Li et al., 2020). It has been stated that DPOAE amplitudes are lower at all frequencies in both ears in individuals with severe OSAS (Matsumura et al., 2018). Kalathingal et al. (2023) consistent with other studies in the literature, found that there was no DPOAE response at high frequencies (4 kHz, 6 kHz, 8 kHz) in 62.5% and 95% of the moderate and severe OSAS groups, respectively. It is thought that the significantly lower OAE levels in individuals with OSAS is due to its relationship with the sensitivity of cochlear hair cells to blood oxygen levels (Sheu et al., 2012).

Auditory Evoked Brainstem Responses (ABR)

Casale et al. (2012) examined auditory evoked brainstem responses in OSAS patients in addition to pure tone audiometry and otoacoustic emission measurement. In this study, they reported that the mean latencies of waves I, III, and V in OSAS patients were prolonged compared to the control group, especially for wave V. When Interpeak Latency (IPL) was examined, they reported that I–III, I–V and III–V IPLs were significantly higher in OSAS patients compared to the control group. Similarly, another study reported significant changes in wave V latency in individuals with OSAS (Matsumura et al., 2016).

In a study evaluating ABR at 11/s and 51/s stimulation rates, it was observed that wave I and wave V latencies in the OSAS group were longer than the control group in both measurements (Li et al., 2020). Wang, Su, Kong, Pang, & Kang (2016), they found longer latencies in waves I and V in OSAS patients compared to the control group. Additionally, in this study, both wave III and wave V latencies and I–III and I–V interpeak latencies were found to be longer in male patients with severe OSAS than in female patients. Simsek, & Aslan (2024) found a statistically significant difference in I. wave latency in the right and left ear between control, moderate OSAS and severe OSAS groups.

Contrary to these studies, Vorlová et al. (2016) did not detect significant differences in auditory brainstem responses among patients in their study in which they grouped their participants according to OSAS severity. Similar to this study, in a study conducted in 2019, there was no significant difference in Click-ABR results between the OSAS group and the control group in terms of absolute latency (I–III–V) and IPL (I–III, III–V). However, in this study, it was observed that OSAS patients had longer latency values in speech-ABR than the control group (Fu, Wang, Liang, Lin, Zhao, Wan, & Fan, 2019).

In the study conducted by KouzoS., Talaat, BahgatY., Zamel, & Eldeeb (2020), it was reported that both the mean absolute latencies of waves I, III and V, and the latencies between waves I-III, I-V and III-V were significantly prolonged in OSAS

patients compared to the control group. Similarly, Gallina, Dispenza, Kulamarva, Riggio, & Speciale (2010) observed an increased I-V wave interval in auditory brainstem responses in 36.5% of OSAS cases.

The significant prolongation of ABR wave latencies and interpeak latencies observed in OSAS patients is thought to be a result of chronic intermittent hypoxia causing oxidative stress and systemic inflammation in the higher auditory pathways (Lim et al., 2023).

CONCLUSION

The research showed that obstructive sleep apnea appears to cause changes in the auditory system and often affects hearing at high frequencies. It is thought that high frequency pure tone audiometry, OAE and ABR measurements, in addition to pure tone audiometry measurements, are important for early diagnosis and treatment in the audiological evaluation of patients with OSAS symptoms and suspicion of hearing loss who apply to the audiology clinic.

Author Contributions: Concept – A. E., A. A. Y., F. S.; Design – A. E.; Supervision –F. S.; Resources– A. E., A. A. Y.; Data Collection and/or Processing – A. E., A. A. Y., F. S.; Analysis and/or Interpretation – A. E., A. A. Y., F. S.; Literature Search – A. E., A. A. Y.; Writing Manuscript – A. E., A. A. Y.

Yazar Katkıları: Fikir – A. E., A. A. Y., F. S.; Tasarım: A. E.; Denetleme – F. S.; Kaynaklar – A. E., A. A. Y.; Veri Toplanması ve/veya İşlemesi – A. E., A. A. Y., F. S.; Analiz ve/veya Yorum – A. E., A. A. Y., F. S.; Literatür Taraması – A. E., A. A. Y.; Yazıyı Yazan – A. E., A. A. Y.

REFERENCES

Baki, A. (2018). Evaluation of auditory function in patients with obstructive sleep apnea syndrome. *Age, 30*, 30–39. *Haydarpasa Numune Med J, 58*(2): 74–78. [CrossRef]

Benjafield, A. V., Ayas, N. T., Eastwood, P. R., Heinzer, R., Ip, M. S. M., Morrell, M. J., …, & Malhotra, A. (2019). Estimation of the global prevalence and burden of obstructive sleep apnoea: a literature-based analysis. *Lancet Respir Med, 7*(8), 687–698. [CrossRef]

Casale, M., Vesperini, E., Potena, M., Pappacena, M., Bressi, F., Baptista, P. J., & Salvinelli, F. (2012). Is obstructive sleep apnea syndrome a risk factor for auditory pathway?. *Sleep Breath, 16*(2), 413–417. [CrossRef]

Chauhan, P., Guleria, T. C., Sharma, S., Minhas, R. S., Dadwal, M., & Mohindroo, N. K. (2022). Obstructive sleep apnea and hearing loss: is there any correlation?. *Int Arch Otorhinolaryngol, 27*(3), e435–e439. [CrossRef]

Chen, C. K., Shen, S. C., Lee, L. A., Sun, M. H., Chen, N. H., Chuang, L. P., & Li, H. Y. (2021). Idiopathic sudden sensorineural hearing loss in patients with obstructive sleep apnea. *Nat Sci Sleep, 13*, 1877–1885. [CrossRef]

Chopra, A., Jung, M., Kaplan, R. C., Appel, D. W., Dinces, E. A., Dhar, S., …, & Shah, N. A. (2016). Sleep apnea is associated with hearing impairment: the hispanic community health study/study of latinos. *J Clin Sleep Med, 12*(5), 719–726. [CrossRef]

Deniz, M., Çiftçi, Z., Ersözlü, T., Gültekin, E., & Alp, R. (2016). The evaluation of auditory system in obstructive sleep apnea syndrome (OSAS) patients. *Am J Otolaryngol, 37*(4), 299–303. [CrossRef]

Ekin, S., Turan, M., Arısoy, A., Gunbatar, H., Sunnetcioglu, A., Asker, S., & Yıldız, H. (2016). Is there a relationship between obstructive sleep apnea (OSA) and hearing loss?. *Med Sci Monit, 22*, 3124–3128. [CrossRef]

Fu, Q., Wang, T., Liang, Y., Lin, Y., Zhao, X., Wan, J., & Fan, S. (2019). Auditory deficits in patients with mild and moderate obstructive sleep apnea syndrome: a speech syllable evoked auditory brainstem response study. *Clin Exp Otorhinolaryngol, 12*(1), 58–65. [CrossRef]

Gallina, S., Dispenza, F., Kulamarva, G., Riggio, F., & Speciale, R. (2010). Obstructive sleep apnoea syndrome (OSAS): effects on the vestibular system. *Acta Otorhinolaryngol Ital, 30*(6), 281–284.

Gao, J., Tan, P., Liu, Y., Chen, S., & Liu, J. (2024). Association between sleep apnea and tinnitus: a meta-analysis. *Ear Nose Throat J*, 1455613241226853. Advance online publication. [CrossRef]

Gozeler, M. S., & Sengoz, F. (2020). Auditory function of patients with obstructive sleep apnea syndrome: a study. *Eurasian J Med, 52*(2), 176–179. [CrossRef]

Hildebrandt, J., Koehler, U., Conradt, R., Hildebrandt, O., Cassel, W., Degerli, M. A., & Viniol, C. (2024). Schlafstörungen bei Patienten mit chronischem Tinnitus [Sleep disorders in patients with chronic tinnitus]. *Laryngorhinootologie, 103*(1), 47–52. [CrossRef]

Hwang, J. H., Chen, J. C., Hsu, C. J., & Liu, T. C. (2011). Association of obstructive sleep apnea and auditory dysfunctions in older subjects. *OTO Open, 144*(1), 114–119. [CrossRef]

İriz, A., Düzlü, M., Köktürk, O., Kemaloğlu, Y. K., Eravcı, F. C., Küükünal, I. S., & Karamert, R. (2018). The effect of obstructive sleep apnea syndrome on the central auditory system. *Turk J Med Sci, 48*(1), 5–9. [CrossRef]

Kalathingal, N., Vijendra Shenoy, S., Kamath, M. P., Sriperumbudur, S., Parvathareddy, N., Mohan Kumar, K., & Acharya, V. (2023). Obstructive sleep apnoea syndrome and association of AHI scores with sensorineural hearing loss: an early predictor. *Indian J Otolaryngol Head Neck Surg, 75*(Suppl 1), 614–619. [CrossRef]

Kasemsuk, N., Chayopasakul, V., Banhiran, W., Prakairungthong, S., Rungmanee, S., Suvarnsit, K., …, & Keskool, P. (2023). Obstructive sleep apnea and sensorineural hearing loss: a systematic review and meta-analysis. *OTO Open, 169*(2), 201–209. [CrossRef]

Kayabasi, S., Hizli, O., & Yildirim, G. (2019). The association between obstructive sleep apnea and hearing loss: a cross-sectional analysis. *Eur Arch Otorhinolaryngol, 276*(8), 2215–2221. [CrossRef]

Koo, M., & Hwang, J. H. (2017). Risk of tinnitus in patients with sleep apnea: a nationwide, population-based, case-control study. *Laryngoscope, 127*(9), 2171–2175. [CrossRef]

Kouzo, H.S., Talaat, M. A. M., Bahgat, A.Y., Zamel, H. A. M., & Eldeeb, M. K. (2020). Postoperative audiovestibular assessment of obstructive sleep apnea patients. *Egypt J Otolaryngol, 36*, 56. [CrossRef] https://doi.org/10.1186/s43163-020-00059-5

~~Wang, W., Su, J., Kong, D., Pang, J., & Kang, J. (2016). Gender, nocturnal hypoxia, and arousal influence brainstem auditory evoked potentials in patients with obstructive sleep apnea. *Sleep Breath, 20*(4), 1239–1244. https://doi.org/10.1007/s11325-016-1346-8~~

Kuhn, M., Heman-Ackah, S. E., Shaikh, J. A., & Roehm, P. C. (2011). Sudden sensorineural hearing loss: a review of diagnosis, treatment, and prognosis. *Trends Amplif, 15*(3), 91–105. [CrossRef]

Lee, J. M., & Lee, H. J. (2023). Is sleep apnea truly associated with hearing loss? A nationwide, population-based study with STOP-BANG questionnaire. *Front Public Health, 11*, 1170470. [CrossRef]

Li, X., Chen, W. J., Zhang, X. Y., Liang, S. C., Guo, Z. P., Lu, M. L., & Ye, J. Y. (2020). Inner ear function in patients with obstructive sleep apnea. *Sleep Breath, 24*(1), 65–69. [CrossRef]

Li, Y., Wang, X., Cui, J., Ren, J., Xin, Z., & Chen, D. (2022). Increasing obstructive sleep apnea risk is associated with hearing impairment in middle-aged Chinese men-A cross-sectional study. *PloS One, 17*(5), e0268412. [CrossRef]

Lim, C. C., Ahmad, T. E. B. T. N., Sawali, H. B., Afandi, A. N. B., Paniselvam, V., Bernard, M. W., …, & Bakar, M. Z. B. A. (2023). Evaluation of auditory system in obstructive sleep apnea patients. *Eur Arch Otorhinolaryngol, 280*(5), 2201–2207. [CrossRef]

Lisan, Q., van Sloten, T., Climie, R. E., Boutouyrie, P., Guibout, C., Thomas, F., Danchin, N., …, & Empana, J. P. (2020). Sleep apnoea is associated with hearing impairment: The Paris prospective study 3. *Clin Otolaryngol, 45*(5), 681–686. [CrossRef]

Liu, X. L., Wang, J., Hong, Z. J., & Zhongshan, M. F. (2018). [A preliminary study on the correlation between obstructive sleep apnea hypopnea syndrome and chronic tinnitus]. *Lin Chuang Er Bi Yan Hou Tou Jing Wai Ke Za Zhi, 32*(8), 575–578. [CrossRef]

Lu, C. T., Lee, L. A., Lee, G. S., & Li, H. Y. (2022). Obstructive sleep apnea and auditory dysfunction-does snoring sound play a role?. *Diagnostics (Basel), 12*(10), 2374. [CrossRef]

Martines, F., Ballacchino, A., Sireci, F., Mucia, M., La Mattina, E., Rizzo, S., & Salvago, P. (2016). Audiologic profile of OSAS and simple snoring patients: the effect of chronic nocturnal intermittent hypoxia on auditory function. *Eur Arch Otorhinolaryngol, 273*(6), 1419–1424. [CrossRef]

Matsumura, E., Matas, C. G., Magliaro, F. C. L., Pedreño, R. M., Lorenzi-Filho, G., Sanches, S. G. G., & Carvallo, R. M. M. (2016). Evaluation of peripheral auditory pathways and brainstem in obstructive sleep apnea. *Braz J Otorhinolaryngol, 84*(1), 51–57. Advance online publication. [CrossRef]

Matsumura, E., Matas, C. G., Sanches, S. G. G., Magliaro, F. C. L., Pedreño, R. M., Genta, P. R., …, & Carvallo, R. M. M. (2018). Severe obstructive sleep apnea is associated with cochlear function impairment. *Sleep Breath, 22*(1), 71–77. [CrossRef]

McArdle, N., Hillman, D., Beilin, L., & Watts, G. (2007). Metabolic risk factors for vascular disease in obstructive sleep apnea: a matched controlled study. *Am J Respir Crit Care Med, 175*(2), 190–195. [CrossRef]

Senaratna, C. V., Perret, J. L., Lodge, C. J., Lowe, A. J., Campbell, B. E., Matheson, M. C., …, & Dharmage, S. C. (2017). Prevalence of obstructive sleep apnea in the general population: a systematic review. *Sleep Med Rev, 34*, 70–81. [CrossRef]

Sheu, J. J., Wu, C. S., & Lin, H. C. (2012). Association between obstructive sleep apnea and sudden sensorineural hearing loss: a population-based case-control study. *Arch Otolaryngol Head Neck Surg, 138*(1), 55–59. [CrossRef]

Simsek, A., & Aslan, M. (2024). Evaluation of the auditory findings of patients with obstructive sleep apnea syndrome. *Am J Otolaryngol, 45*(1), 104027. [CrossRef]

Solmaz, F., Ekim, B., & Simsek, A. (2023). Does obstructive sleep apnea syndrome have negative effects on hearing?. *Iran J Otorhinolaryngol, 35*(126), 13–20.

Vorlová, T., Dlouhá, O., Kemlink, D., & Šonka, K. (2016). Decreased perception of high frequency sound in severe obstructive sleep apnea. *Physiol Res, 65*(6), 959–967. [CrossRef]

Wang, W., Su, J., Kong, D., Pang, J., & Kang, J. (2016). Gender, nocturnal hypoxia, and arousal influence brainstem auditory evoked potentials in patients with obstructive sleep apnea. *Sleep Breath, 20*(4), 1239–1244. [CrossRef]

Wang, C., Xu, F., Chen, M., Chen, X., Li, C., Sun, X., …, & Wang, Y. (2022). Association of obstructive sleep apnea-hypopnea syndrome with hearing loss: a systematic review and meta-analysis. *Front Neurol, 13*, 1017982. [CrossRef]