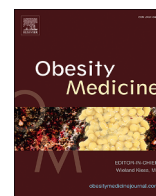




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The role of obesity, nutrition, and physical activity on tinnitus: A narrative review

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ABSTRACT

Tinnitus is defined as the sound perceived in the head or ear without any external stimulus. Although there are many hypotheses about the etiology of tinnitus there is no generally accepted theory due to its complex physiology. Obesity and physical inactivity, which have increased as a result of radical changes in diet and lifestyle in the last century, are significantly associated with tinnitus. Therefore, low glycemic index/low carbohydrate diets and active lifestyle are becoming increasingly common among the recommendations given to individuals with tinnitus. As a result of the spread of Western-style diet, a decrease in the consumption of antioxidant-rich foods and decreased blood antioxidant status can also affect tinnitus. In this review, it was aimed to discuss the role of obesity, nutrition and physical activity on tinnitus in the light of recent research results.

1. Introduction

Tinnitus is defined as the sound perceived in the head or ear without any external stimulus. Tinnitus symptoms are often associated with depression, anxiety, and sleep disorders and are quite challenging to treat (Esmaili and Renton 2018). In population-based national studies conducted in America and Europe, the prevalence of tinnitus in adults was found to be between 9.6% and 16.9% (Bhatt et al., 2016; Martines et al., 2015). Although there are many hypotheses about the etiopathogenesis of tinnitus, which is one of the most common reasons for admission to audiology clinics, there is no generally accepted theory because of its complex physiology. The most common accepted risk factors are exposure to loud noise, hearing loss, advanced age, head trauma, some ototoxic drugs, metabolic diseases and psychological disorders (Makar 2021). In addition to these, some studies have found that obesity and physical activity are significantly associated with tinnitus, especially due to the changing diet and lifestyle factors in the last century (Carpenter-Thompson et al., 2015a, Gallus et al., 2015; Özbey-Yücel et al., 2022; Sogebi 2013). This is an expected result because of possible effects of the Western lifestyle, which has become widespread all over the world, on the inflammatory response (Haider et al., 2020). The aim of this review is to highlight the relationship between nutrition, obesity, and physical activity on tinnitus.

2. Obesity and tinnitus

Obesity is defined as the accumulation of excess adipose tissue in the body, which can adversely affect health status. It results from the fact that energy intake through food is greater than the energy expenditure and reflects the impaired energy homeostasis (Purnell 2018). Although the prevalence of obesity differs between countries and genders, it has reached epidemic level in many developed

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countries such as the United States (USA) (Lynch et al., 2021). According to World Health Organization (WHO) data, it is estimated that approximately 1.9 billion adults over the age of 18 are overweight and more than 600 million of them are obese (Hakkak and Bell 2016).

In recent years, increase in the incidence of tinnitus and rising obesity trends strengthens the hypothesis that both diseases are related to each other because the fact that tinnitus severity is higher in obese individuals than in normal-weight individuals (Gallus et al., 2015; Sogebi 2013). The association of obesity with tinnitus is mostly explained by obesity-induced inflammatory response, vascular damage, hearing loss, and social factors (Fig. 1). All these factors, triggered by obesity, can directly lead to the emergence of tinnitus or increase its severity (Torun et al., 2016).

In a study examining the factors affecting tinnitus, the prevalence of obesity in individuals with tinnitus (21.5%) was found to be higher than in individuals without tinnitus (6.3%) ($p < 0.05$) (Sogebi 2013). In another study conducted on 14,178 individuals using the National Health and Nutrition Examination Survey (NHANES) database in the USA, it was found that gradual increase in BMI increased the prevalence of tinnitus (Shargorodsky et al., 2010). In another study conducted with 1724 individuals with tinnitus, the incidence of tinnitus in obese individuals was found to be 2.14 times higher than in those with normal body weight (Odds Ratio (OR): 2.14 (Confidence Interval (CI): 1.25–3.67)) ($p < 0.01$) (Gallus et al., 2015). According to the results of the Korean National Health and Nutrition Examination Surveys (KHANES) conducted by Lee and Kim (2018) with 4628 premenopausal women, the risk of tinni-

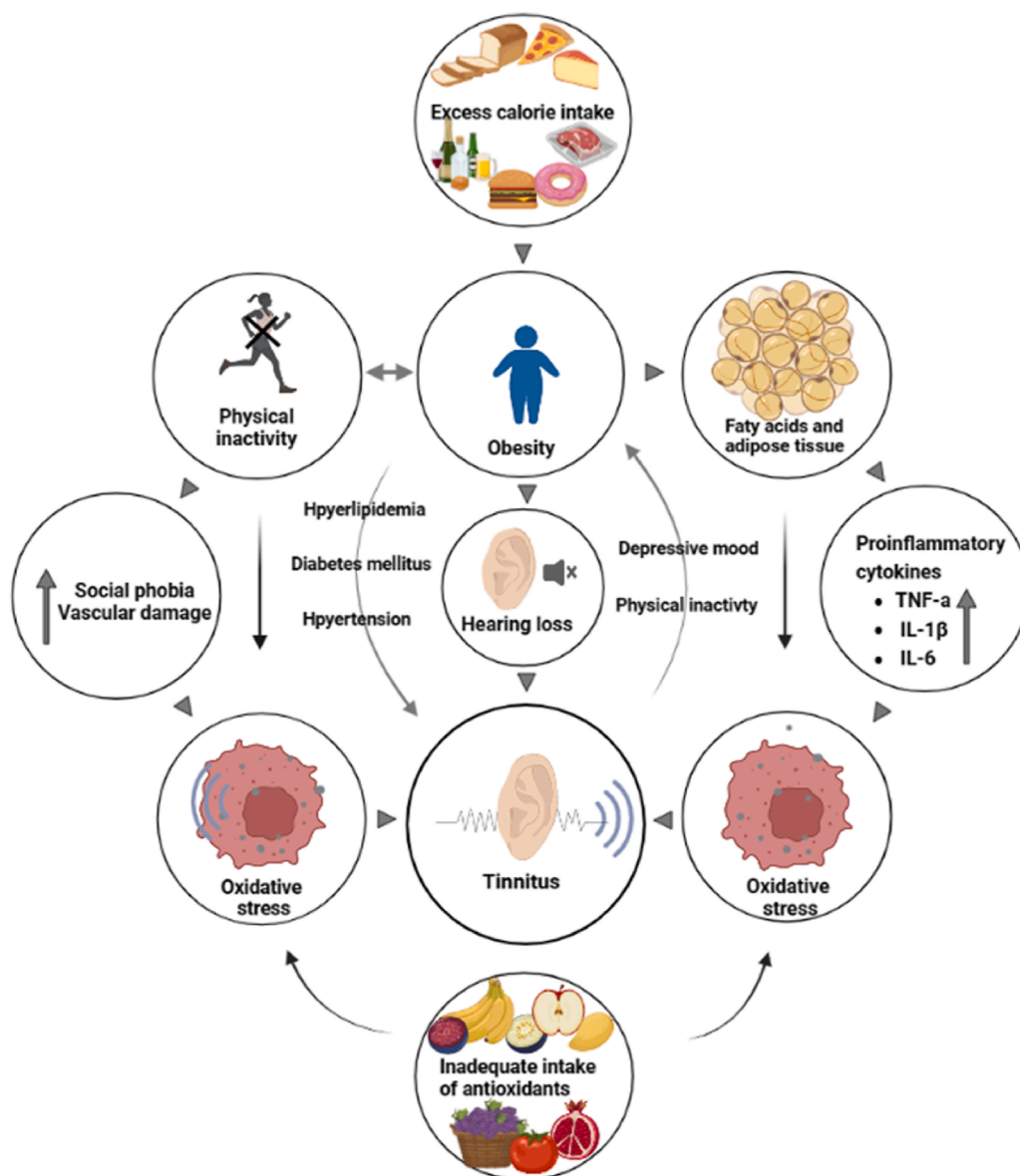


Fig. 1. Possible effects of obesity, nutrition and physical activity on tinnitus (created via biorender.com).

tus in obese people was higher than in non-obese women (OR: 1.33 (CI: 0.89–1.99)) (Lee and Kim 2018). In another cohort study conducted in Italy, BMI \geq 30.0 was found to be an important risk factor for tinnitus (Martines et al., 2015).

Considering the possible effects of obesity on tinnitus and results of the studies given above, weight loss is expected to reduce tinnitus symptoms in obese individuals, but studies evaluating the effect of weight loss are very limited (Özbey-Yücel et al. 2021, 2021z, Özbey-Yücel et al., 2022). In a study examining the effect of weight loss through diet and physical activity in obese individuals with tinnitus, it was found that tinnitus symptoms decreased after a decrease in BMI. The reductions in tinnitus frequency and tinnitus severity scores of individuals with a weight loss of \geq 5.0% were found to be higher than those of individuals with a weight loss of <5.0% ($p < 0.05$) (Özbey-Yücel et al., 2022). In another study examining the effect of weight loss on tinnitus symptoms, it was found that the THI score decreased after the decrease in body weight ($p < 0.05$) (Özbey-Yücel et al., 2021) (Table 1). However, the results of some studies evaluating the obesity-tinnitus relationship were not consistent with these results (Marchiori et al., 2022; Nondahl et al., 2010; Park et al., 2014).

Although BMI is frequently used in the monitoring of obesity due to its ease and validity of measurement, it does not reflect body fat distribution (Özbey-Yücel et al., 2022). It is known that high body fat ratio and abdominal obesity are associated with hearing loss, and it has also been associated with tinnitus in recent studies (House et al., 2018; McCormack et al., 2014). In a study consisting of 68,421 individuals carried out by Curhan et al., the participants with increased waist circumference and abdominal obesity were associated with hearing loss, which is one of the main causes of tinnitus. According to the results of the study, waist circumference of 88 cm and above increased the risk of hearing loss 1.27 times (RR: 1.27 (CI: 1.17–1.38) (Curhan et al., 2013). In another study, individuals with a high waist circumference were found to have 1.5 times more hearing loss than those with a normal waist circumference (OR: 1.5 (CI: 1.09–2.07) (Tan et al., 2018).

In the study of House et al. (2018), which included 1314 individuals, it was found that waist circumference and tinnitus handicap inventory (THI) score were highly positively correlated (House et al., 2018). In another study conducted with 171,722 individuals using UK biobank data and examining the relationship between body fat ratio and tinnitus, it was found that increased body fat ratio was positively associated with the presence of tinnitus ($p < 0.01$) (McCormack et al., 2014). In other studies with a large population in which the factors leading to tinnitus were studied, similarly, an increased body fat ratio and waist-hip ratio were associated with the occurrence and severity of tinnitus (Cresswell et al., 2022; Schubert et al., 2021). Yücel et al. (2022) found that, in line with the

Table 1
Effects of nutrition and physical activity related factors on tinnitus.

	Related factors	The effects on tinnitus	Ref.
Obesity	High body weight and BMI	Increased risk of tinnitus, prevalence of tinnitus, and severity of tinnitus	(Shargorodsky et al., 2010; Sogebi 2013, Gallus et al., 2015; Martines et al., 2015; Lee and Kim 2018)
	High WC, WHR, and body fat ratio	Increased risk of bothersome/persistent tinnitus and THI score	(McCormack et al., 2014; House et al., 2018; Schubert et al., 2021, Cresswell et al., 2022)
	Weight loss intervention	Alleviated tinnitus severity, tinnitus frequency, THI score, and VAS score	(Özbey-Yücel et al., 2021; Özbey-Yücel et al., 2022)
Nutrition	High carbohydrate consumption	Increased risk of constant tinnitus	(Tomanic et al., 2020)
	Low carbohydrate/glycemic index diet	Protective effects against severe tinnitus symptoms	(Basut et al., 2003; Lavinsky et al., 2004; Almeida et al., 2009; Özbey-Yücel et al., 2021; Özbey-Yücel et al., 2022)
	High fat and processed food consumption	Increased risk of tinnitus and severity of tinnitus	(Spankovich et al., 2017; Dawes et al., 2020; Tomanic et al., 2020)
	Low-fat diet	Protective effects against tinnitus symptoms	(Sutbas et al., 2007; Özbey-Yücel et al., 2021; Özbey-Yücel et al., 2022)
		Reduced severity of tinnitus	
	Inadequate protein consumption	Increased risk of tinnitus, severity of tinnitus, and tinnitus discomfort	(Kim et al., 2015; Lee and Kim 2018, Kim et al., 2019; Dawes et al., 2020)
	Insufficient level of antioxidants	Worsened/bothered tinnitus symptoms	(Celik and Koyuncu 2018, Pawlak-Osińska et al., 2018; Haider et al., 2020)
Antioxidant supplementation	Increased risk of tinnitus		
	Decreased severity of tinnitus, discomfort of tinnitus, and stress score	(Savastano et al., 2007; Gopal et al., 2015; Petridou et al., 2019; Oppitz et al., 2022)	
	Attenuated tinnitus loudness/masking level		
	Decreased VAS and THI score		
Physical activity	Inadequate physical activity or sedentary lifestyle	Increased risk of tinnitus, prevalence of tinnitus, and severity of tinnitus	(Carpenter-Thompson et al., 2015b; Kim et al., 2019)
		Increased THI and depression score	
	Light-intensity physical activity	Decreased risk and severity of tinnitus	(Loprinzi et al., 2013; Michiels et al., 2019)
	Increased quality of life score		
	Protective effects against tinnitus symptoms		
	Physical activity intervention	Decreased tinnitus level and tinnitus symptoms	(Carpenter-Thompson et al., 2015b; Köksoy et al., 2018, Bazoni et al., 2019; Niedziałek et al., 2019; Özbey-Yücel et al., 2021; Özbey-Yücel et al., 2022)
		Attenuated tinnitus severity, stress, and TFI/THI score	
		Increased quality of life score	

above study results, the severity of tinnitus also decreased with a decrease in body fat and waist circumference after 8 weeks of dietary intervention in individuals with obese tinnitus (Özbey-Yücel et al., 2022).

According to the results of all these studies, both general and abdominal obesity negatively affect tinnitus symptoms. Accordingly, weight loss should be recommended to obese individuals with tinnitus in order to reduce the symptoms of tinnitus.

3. Physical activity and tinnitus

Every movement that is performed using skeletal muscles and requires energy expenditure is defined as physical activity. In order to increase the quality of life and maintain health, various physical activity guidelines have been prepared and an active lifestyle has been encouraged (Piggin 2020). In addition to physical activity guidelines, the World Health Organization (WHO) conducts public health campaigns to encourage physical activity and emphasizes the importance of increasing the number of steps (Luzak et al., 2017). The reason physical activity is highly encouraged is that many diseases have been associated with physical inactivity (Sallis et al., 2012). In recent years, tinnitus has also been associated with physical inactivity and new approaches have been put forward on the subject (Bazoni et al., 2019).

The effects of physical activity on tinnitus are explained by possible cochlear and non-cochlear models (Loprinzi et al., 2013, Shaw et al., 2011). According to the cochlear model, biochemical changes in the central auditory system cause damage to the inner and outer hair cells. The resulting damage may lead to the onset of tinnitus or increase the level of perceived sound by causing insufficient nerve conduction and blood supply. In this case, physical activity is expected to accelerate the circulation in the auditory system by increasing blood circulation and reducing the symptoms of tinnitus (Loprinzi et al., 2013). The noncochlear model is mostly explained by neuropsychological factors. Opioid peptide, which is formed due to stress and accelerates neural activity in the cochlea, can trigger tinnitus symptoms. In particular, a decrease in the level of opioid peptide, which is also known to increase with an increase in depressive symptoms, is expected to reduce tinnitus symptoms (Loprinzi et al., 2013). Here what is expected from physical activity is to reduce the opioid response by reducing the level of stress and anxiety because it is known that stress and depression exacerbate tinnitus or directly cause its onset (Loprinzi et al., 2013) (Fig. 1). Another non-cochlear factor is explained by the positive effects of physical activity on the emotional state and mood. The endorphin hormone reduces the stress and anxiety levels of an individual and therefore the symptoms of tinnitus (Savastano et al., 2007). An increase in the level of endorphins after physical activity is also expected to reduce the symptoms of tinnitus with similar effects. Due to the low cost and effective results of physical activity, it is increasingly taking its place among the recommendations given to individuals with tinnitus (Carpenter-Thompson et al., 2015a).

Kim et al. (2019), using Korean National Nutrition and Health Research (KHANES) data, found that the physical activity levels of individuals with tinnitus were lower than those without tinnitus ($p < 0.01$) (Kim et al., 2019). Loprinzi et al. (2013) reported that each minute of increase in physical activity decreased the prevalence of tinnitus by 4.0%. Mild-intensity physical activity was found to be protective against tinnitus symptoms, especially in elderly individuals (Loprinzi et al., 2013). Michiels et al. (2019) found that mild-intensity physical activity had positive effects on tinnitus symptoms and increased the quality of life (Michiels et al., 2019). In another study conducted on 1030 adults with tinnitus, it was found that the quality of life score of individuals with high physical activity level was higher than those with low physical activity level, and active life was protective against depressive symptoms of tinnitus (Michiels et al., 2019).

According to the results of the study given above, interventions to increase the level of physical activity in individuals are expected to reduce tinnitus symptoms. In a study conducted with 32 individuals with tinnitus, the participants were divided into 2 groups according to their tinnitus levels. In the magnetic resonance scan results, it was found that increased physical activity level in both groups stimulated more frontal cortex activity while decreasing the tinnitus level (Carpenter-Thompson et al., 2015b). Bazoni et al. (2019) found that regular physical activity significantly reduced tinnitus symptoms (especially headache) and improved the quality of life (Bazoni et al., 2019). Köksoy et al. (2018) included 12 individuals with tinnitus in a yoga program consisting of exercise and meditation for 3 months. At the end of the study, tinnitus symptoms of the individuals were significantly reduced compared to the baseline (Köksoy et al., 2018). In the study of Niedziałek et al., after 12 weeks of yoga training (2–4 times a week/30 min) applied to individuals with chronic tinnitus, the tinnitus functional index (TFI) score of the individuals decreased significantly. According to results compared with the control group, it was found that yoga decreased the severity of tinnitus by both reducing stress and increasing physical endurance (Niedziałek et al., 2019). In the study of Yücel et al. (2022) every 1000-step increase in the number of steps of individuals with tinnitus who received physical activity intervention led to a 0.750 (CI:0.221–0.956, $p = 0.001$) unit decrease in the tinnitus handicapped inventory (THI) score (Özbey-Yücel et al., 2022) (Table 1).

In the light of all these studies and results, it is thought that physical activity has protective effects against tinnitus symptoms. Therefore, recommending regular physical activity to individuals with tinnitus shall be very useful in reducing tinnitus symptoms.

4. Macronutrient consumption and tinnitus

4.1. Carbohydrate consumption and tinnitus

The inner ear is a quite complex structure with a comprehensive metabolic mechanism. With its known effects; comorbid diseases, lifestyle, and diet can disrupt the structure of the inner ear causing physiological changes (Dawes et al., 2020). The effects of nutrition on auditory system are mostly explained by the changes that occur as a result of the metabolism of nutrients (Spankovich et al., 2017). In particular, carbohydrate and fat metabolism disorders are frequently associated with inner ear damage, and some nutritional recommendations are given to individuals to reduce these damages (Jung et al., 2019).

Type-2 Diabetes mellitus, which occurs as a result of carbohydrate metabolism disorder, can cause vascular damage and microangiopathy through high blood glucose concentrations (Maranta et al., 2021). These microangiopathy and vascular atrophies in the inner ear can directly cause tinnitus or a higher perception of the sound heard in tinnitus (Taneja 2017). Changes in perceived sound and tinnitus levels may also reduce the quality of life of individuals. Another hypothesis regarding the relationship between carbohydrate metabolism and tinnitus is that high blood glucose levels cause neuropathy in the auditory nerves, making individuals more sensitive to tinnitus. The resulting neural sensitivity can cause sensory hearing loss and increase the incidence and severity of tinnitus (Holcat 2007) (Fig. 1).

Studies have shown that tinnitus prevalence is higher in individuals with carbohydrate metabolism disorders such as type-2 diabetes, while a low glycemic index diet reduces tinnitus symptoms (Tomanic et al., 2020; Lavinsky et al., 2004). Therefore, less carbohydrate and low glycemic index diets are recommended for individuals with tinnitus to prevent fluctuations in blood glucose (Maranta et al., 2021). In the study of Tomanic et al. (2020), in which they examined the relationship between diet and tinnitus in 1003 individuals, it was found that increased consumption of white bread (OR:1.715 (CI:1.115–2.638) $p = 0.014$) and sugary drinks (OR:1.249 (CI:1.014–1.538) $p = 0.036$) increased the risk of tinnitus (Tomanic et al., 2020). According to the results, consumption of white bread is an important risk factor for tinnitus compared to whole grain bread.

Lavinsky et al. (2004) found that more than half of the individuals with tinnitus had a significant decrease in tinnitus severity after a diet program with reduced total calorie and sugar content ($p < 0.05$) (Lavinsky et al., 2004). Similarly, in the study of Basut et al. tinnitus severity decreased after a low glycemic index diet given to 52 hyperglycemic individuals with tinnitus for 4 months ($p < 0.01$) (Basut et al., 2003). Accordingly, individuals were advised to avoid foods with a high glycemic index. In another study, individuals with tinnitus were given nutrition education and their diets were followed for 7 months. At the end of the study, it was observed that the severity of tinnitus decreased in 71.5% of the individuals. According to this, it was concluded that correct eating habits reduced the severity of tinnitus by improving blood glucose levels (Almeida et al., 2009). In another study, in which the effects of dietary intervention were observed in obese tinnitus patients, individuals were given a low carbohydrate for 12 weeks. At the end of the study, the decrease in carbohydrate consumption showed a positive correlation with the decrease in tinnitus discomfort score ($p < 0.05$) (Özbey-Yücel et al., 2022) (Table 1).

Considering the results of studies given above, it will be beneficial for individuals with tinnitus to stay away from foods with a high glycemic index in reducing tinnitus symptoms.

4.2. Fat consumption and tinnitus

Another macronutrient that is often associated with tinnitus is fats. High-fat diet and hyperlipidemia can cause vascular narrowing and platelet aggregation, leading to a decrease in the oxygen-carrying capacity of the blood and thus to systemic hypoxia (Almeida et al., 2009) (Fig. 1). Decreased oxygenation in the cochlea causes damage to the central auditory system and inner ear. In addition, increased lipid levels in the circulation may cause ischemic damage to the cochlea through inflammatory cytokines. All these damages can cause tinnitus to occur or increase its severity (Martines et al., 2015).

Tinnitus can sometimes be the first indicator of hyperlipidemia and atherosclerosis. In these cases, low-fat, low-cholesterol diet treatments are recommended for individuals (Almeida et al., 2009). In the study by Dawes et al. (2020), in which they examined the relationship between tinnitus and nutrition style in 34,576 individuals, high fat consumption was associated with an increased risk of tinnitus according to the results of the food consumption record (OR:1.33 (CI: 1.09–1.62) $p < 0.05$) (Dawes et al., 2020). According to the results of the research, it was reported that reducing oil consumption was protective against tinnitus symptoms. In another study conducted with tinnitus patients with hyperlipidemia, it was shown that tinnitus severity of individuals decreased after 24 months of low cholesterol diet treatment (Sutbas et al., 2007).

In a study examining the relationship between tinnitus and nutrition in adolescents, consumption of fried foods, margarine, and mayonnaise was found to be positively associated with the presence of tinnitus. Especially frequent consumption of fatty fast foods significantly increased the risk of tinnitus (OR: 1.355 (CI: 1.011–1.816) $p = 0.042$) (Tomanic et al., 2020). In another study examining the relationship between serum lipid level and tinnitus, triglyceride levels of individuals with tinnitus (177,76 mg/dL) were found to be significantly higher than the control group (124.43 mg/dL) (Avcı 2021). In a large population study using KHANES data, increased fat consumption was found to be associated with increased tinnitus risk ($p < 0.05$) (Spankovich et al., 2017). In the study of Yücel et al. (2021), it was found that after a 12-week dietary intervention applied to individuals with tinnitus, a decrease in saturated fat intake was positively correlated with the decrease in tinnitus severity, visual analogue scale (VAS) severity and VAS discomfort score (Özbey-Yücel et al., 2021).

Because of vascular problems caused by high consumption of fat and fatty foods (especially saturated fat), individuals with tinnitus should be advised to avoid excessive fat consumption, taking into account the results of the above study.

4.3. Protein consumption and tinnitus

Studies on the relationship of protein, another macronutrient, with tinnitus are very limited. In a study examining the relationship between hearing disorders and dietary protein intake, it was found that low protein intake increased the risk of hearing disorders (OR: 0.81 (CI: 0.67–0.96) $p = 0.017$) (Kim et al., 2015). This situation is associated with insufficient intake of protein-rich sources (meat, fish, eggs, etc.) causing vitamin D and B12 deficiency. Because vitamin D and B12 deficiency can lead to an increase in audiological symptoms (Dawes et al., 2020).

In a study examining the relationship between dietary factors and tinnitus in 12,658 adults, it was found that the protein intake of individuals with tinnitus (72.55 ± 40.63 g) was lower than those without tinnitus (76.48 ± 41.95 g) ($p < 0.01$). Each gradual decrease in dietary protein intake increased the risk of tinnitus ($p < 0.01$) (Kim et al., 2019). In the study of Dawes et al. (2020), the re-

relationship between nutrition and tinnitus in 34,576 individuals was examined which concluded that increased protein intake was found to be associated with a decreased risk of tinnitus (OR:0.90 (CI:0.82–0.99) $p = 0.004$) (Dawes et al., 2020). In another study examining the relationship between nutrition and tinnitus, it was found that an increase in protein intake decreased the level of tinnitus discomfort (OR:0.995 (CI:0.992–0.999) $p = 0.009$) (Lee and Kim 2018). However, there are also studies in which there is no relationship between the change in protein intake and the severity of tinnitus (Özbey-Yücel et al. 2021, 2021z, Özbey-Yücel et al., 2022). Therefore, more studies are needed on the effect of protein consumption on tinnitus.

5. Inadequate antioxidant intake, inflammatory response and tinnitus

The increase in the inflammatory response in the auditory canal can affect the surrounding areas by changing the pH balance of the inner ear. In this case, there may be changes in transfer process of sound from ear to the cochlea, and tinnitus may begin with the feeling of fullness in ear (Demir 2021). After anti-inflammatory medical treatments, it is expected that tinnitus will also decrease with inflammation. However, tinnitus may be permanent as a result of the failure of expected treatment to be ineffective or the frequent recurrence of inflammation (Haider et al., 2020). The effect of obesity here is explained by the inflammatory cytokines caused by the increased adipose tissue. Especially, the increase of free fatty acids and triglycerides in circulation can cause vascular damage in the cochlea and increase tinnitus (Rodríguez-Hernández et al., 2013).

High levels of proinflammatory cytokines such as TNF- α , IL-1, and IL-6 in the circulation may affect the occurrence or severity of tinnitus (Torun et al., 2016). Haider et al. (2020) found that IL-1 levels were higher in individuals with tinnitus than in those without tinnitus. In the same study, the anti-inflammatory IL-10 levels of individuals with tinnitus were also found to be lower than those without tinnitus (Haider et al., 2020). In another study conducted with elderly individuals with tinnitus, polymorphisms were found in the IL-6 gene area. Accordingly, oxidative stress is thought to be highly effective in the occurrence of tinnitus (Doi et al., 2015) (Fig. 1).

Blood antioxidant status has also been frequently associated with tinnitus in recent years. Because endothelial damage and micro-macro lesions caused by insufficient antioxidant level can damage the vestibular nervous system and lead to hearing loss and tinnitus (Petridou et al., 2019). The fact that antioxidant markers in individuals with tinnitus were found to be lower than in the control group in some studies also supports this view (Pawlak-Osińska et al., 2018; Celik and Koyuncu 2018). In the study of Çelik and Koyuncu (2018), total antioxidant status (TAS) of individuals with tinnitus was found to be significantly lower than those of the control group, while total oxidant levels status (TOS) was found to be significantly higher ($p < 0.05$) (Celik and Koyuncu 2018). Similarly, in another study, it was found that the status of superoxide dismutase (SOD) and glutathione peroxidase (cGPX), one of the antioxidant enzymes, was lower in individuals with tinnitus than in the control group ($p < 0.05$) (Pawlak-Osińska et al., 2018).

Due to the negative effects of oxidative stress, it is recommended to strengthen the antioxidant barrier in the treatment of tinnitus (Pawlak-Osińska et al., 2018). In a randomized controlled double-blind study, 35 individuals with tinnitus were given antioxidant nutritional supplements for 3 months and the results were compared with the control group. At the end of the study, the tinnitus severity and VAS scores of the supplemented group were significantly reduced compared to the control group ($p < 0.05$) (Petridou et al., 2019). In the study of Savastano et al. (2007), 31 individuals with tinnitus were given oral β -carotene, vitamin C and E supplements for 18 weeks. At the end of the study, the blood Reactive oxygen species (ROS) levels, VAS, and tinnitus scores of the individuals decreased significantly compared to the baseline ($p < 0.05$) (Savastano et al., 2007). In another randomized controlled study examining the effectiveness of antioxidant therapy in individuals with tinnitus, 100 mg of acai extract was given to 15 individuals for 3 months. At the end of the study, the tinnitus discomfort and THI scores of the intervention group were significantly reduced compared to the placebo group (Oppitz et al., 2022) (Table 1). In a case study examining the effect of the antioxidant acetyl-L-carnitin (ALCAR) on tinnitus, individuals were supplemented with 500 mg ALCAR for 30 days. At the end of the study, the tinnitus discomfort level of the individuals decreased ($p < 0.05$) (Gopal et al., 2015). However, the results of some studies are not consistent with the above results (Polanski et al., 2016; Farahani et al., 2022; Canis et al., 2011).

According to the results of many studies, the results of which are given above, antioxidant consumption has protective effects on tinnitus due to its anti-inflammatory effects, but considering some inconsistent results, more studies are needed.

6. Conclusions

Although there are many hypotheses about the etiology of tinnitus, there is no generally accepted theory. In recent years, obesity and physical inactivity, which are the result of changing diet and lifestyle factors, have been significantly associated with tinnitus. There are many results showing that tinnitus frequency and tinnitus severity are higher in obese/sedentary individuals than in normal individuals. In addition, the decrease in tinnitus severity after diet and physical activity interventions applied to individuals with tinnitus also support these results.

It is also known that the consumption of antioxidant foods has been decreasing with the expansion of Western style diet, and in recent years, blood antioxidant levels has been associated with tinnitus. In many studies, blood antioxidant levels of individuals with tinnitus were found to be lower compared to the control group. In addition, the decrease in the tinnitus severity of individuals after antioxidant supplementation treatments also reflects the importance of antioxidant support.

As a result diet, obesity, and physical activity have important effects on tinnitus. The negative effects of incorrect eating habits (processed, sugary and high-fat foods) on tinnitus should be explained to individuals who apply to audiology clinics, and obese tinnitus patients should be directed to a nutritionist for an appropriate diet and physical activity program.

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Author contribution statement

UOY and AU conceptualized the present review. UOY prepared the article by reviewing the literature. AU provided ideas and revised the paper.

Declaration of competing interest

The authors declare that they have no conflicts of interest.

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