J Surg Med. 2018;2(3):273-277.
DOI: 10.28982/josam.429059

Research article
Araştırma makalesi

Journal of Surgery and Medicine

e-ISSN: 2602-2079

The effect of osteoporosis on cochlear function in postmenopausal women: An observational study

Postmenapozal kadınlarda koklear fonksiyona osteoporozun etkisi: Gözlemsel bir çalışma

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Ethics Committee Approval: The study was approved by local Ethics Committee.
Etik Kurul Onayı: Çalışma için onay Etik Kurulundan alınmıştır.

Conflict of Interest: No conflict of interest was declared by the authors.
Çıkar Çatışması: Yazarlar çıkar çatışması bildirmemişlerdir.

Financial Disclosure: The authors declared that this study has received no financial support.
Finansal Destek: Yazarlar bu çalışma için finansal destek almadıklarını beyan etmişlerdir.

Received / Geliş Tarihi: 31.05.2018
Accepted / Kabul Tarihi: 26.06.2018
Published / Yayın Tarihi: 03.07.2018

Abstract

Aim: Hearing loss and osteoporosis are common geriatric syndromes. Evidence suggests that osteoporosis may have an effect on cochlear function in a small number of clinical trials. Here, cochlear function in osteoporosis patients was assessed by otoacoustic emission test (OAET) measurements.

Methods: The study designed as cross-sectional and observational. Forty female patients were included in the postmenopausal period at the age of 40-75 years. Age, body mass index (BMI), vitamin D level were recorded in all patients. Audiometric threshold testing was used to measure air- and bone-conduction hearing sensitivity. Bone mineral density (BMD) of the hip and vertebra was measured using dual-energy X-ray absorptiometry (DEXA). According to vertebra L1-4 t score <-2.5 osteoporosis, -2.5 to -1 osteopenic, the group divided into two and all parameters were compared. Transiently evoked (TE), and distortion-product (DP) otoacoustic emissions were recorded.

Results: The mean age of the whole group was 58.6 ± 7.9 years. Accordingly, TE left was significantly different in the higher frequency in the osteopenic group at 0.75 Hz (p = 0.015). In audiometric tests, only the osteopenic group at 6,000 Hz was significantly different in the higher frequency of both ears (p = 0.049 / p = 0.016).

When the group divided into two according to femur t score <-1.0; TEright_3.5 (p = 0.04), TEright_overall (p = 0.030), TEleft_1.7.5 (p = 0.043) and TEleft_overall (p = 0.046), DPright_1 (p = 0.049) and DPleft_6 (p = 0.039) were observed to occur at higher frequencies in the osteoporotic group. Lomber t score was positively correlated with BMI (p = 0.042 / r = 0.288). BMI was lower in the osteoporotic group. The tympanogram results of all patients were Type A. The TE positivity rate (S / N> 3) was 60.8% and the DP positivity rate (S / N> 3) was 39.2%.

Conclusion: According to hip BMD scores, osteopenic-osteoporotic (T scor <-1) group showed higher frequencies in both cochlear and hearing tests than normal subjects. The high frequencies in both OAET results and odiologic data in osteoporotic group support the adverse effect of osteoporosis on cochlear and hearing function. Individuals with hearing loss should be screened for osteoporosis.

Keywords: Bone mineral density, Osteoporosis, Hearing loss, Cochlear function

Öz

Amaç: İşitme kaybı ve osteoporoz sık görülen geriatrik sendromlardandır. Az sayıda klinik çalışmada osteoporozun koklear fonksiyona etkisi olabileceği yönünde delil bulunmuştur. Burada osteoporoz hastalarında kohlear fonksiyon, otoaküstik emisyon test (OAET) ölçümleri ile değerlendirildi.

Yöntemler: Çalışma kesitsel gözlemsel olarak düzenlendi. Çalışmaya 40-75 yaş aralığında postmenapozal dönemde 50 kadın hasta dahil edildi. Tüm hastalarda yaş, vücut kitle indeksi (BMI), vitamin D düzeyi kayıt edildi. Hava ve kemik iletimli işitme hassasiyetini ölçmek için odiyometrik eşik testi kullanıldı. Kalça ve omurganın kemik mineral yoğunluğu (BMD) dual enerji X-ışını absorpsiyometri (DEXA) kullanılarak ölçüldü. Vertebra L1-4 t skor<-2,5 osteoporoz, -2,5 ila -1 arası osteopenik olarak grup ikiye ayrıldı ve tüm parametreler karşılaştırıldı. Geçici olarak uyarılmış (TE) ve distorsiyon ürünü (DP) otoakustik emisyonları kaydedildi.

Bulgular: Tüm grup yaş ortalaması 58,6±7,9 yıl idi. Buna göre TE left 0.75 Hz'de osteopenik grupta daha yüksek frekansda anlamlı farklı idi (p=0,015). İşitme testlerinde sadece her iki kulak 6.000 Hz'de osteopenik grup daha yüksek frekansda anlamlı farklı idi (p=0,049 / p=0,016).

Femur t skor<-1,0 göre grup ikiye ayrıldığında TEright_2.5 (p=0,015), TEright_3.5 (p=0,04), TEright_overall (p=0,030), TEleft_1.7.5 (p=0,043), TEleft_overall (p=0,046), DPright_1 (p=0.049), DPleft_6 (p=0,039) osteoporotik grupta daha yüksek frekanslarda sonuçlar olduğu gözlendi. Lomber t skor BMI ile pozitif korele (p=0,042/r=0,288) idi. Osteoporotik grubda BMI daha düşük idi. Hastaların tamamında timpanogram sonuçları Tip A idi. TE pozitiflik oranı (S/N>3) %60,8, DP pozitiflik oranı (S/N>3) %39,2 idi.

Sonuç: Kalça BMD skorlarına göre, osteopenik_osteoporotik grup (T skor<-1) hem koklear hem da işitme testlerinde normal kişilere göre yüksek frekanslar gösterdiler. Osteoporotik grupta hem OAET sonuçları hemde odiyolojik verilerin daha yüksek frekanslarda olması osteoporozun koklear ve işitme fonksiyonuna olumsuz etkisini desteklemektedir. İşitme kaybı olan bireyler osteoporoz yönünden taranmalıdır.

Anahtar kelimeler: Kemik mineral yoğunluğu, Osteoporoz, İşitme kaybı, Koklear fonksiyon

How to cite / Atıf için: Sağıroğlu S, Koca TT. The effect of osteoporosis on cochlear function in postmenopausal women: An observational study. J Surg Med. 2018;2(3):273-277.

Introduction

Osteoporosis is the most common metabolic bone disease worldwide and leads to physical, psychosocial and economic consequences. It can be seen in both genders and at any age, usually with older women. Low bone mass and bone tissue result in increased bone fragility with impaired microstructure. It is usually insidious and diagnosed after the fracture has occurred. Because of postural kyphosis, balance problems are frequently observed by gravity center change. The quality of life of the elderly population is negatively affected by pain and physical disability [1-3].

Autoacoustic emissions (OAE) are mildly acoustical energy emissions from cochlear sources that are detected from the external auditory canal of humans and animals. In 1948 Gold became the first to speak of the fact that cochlear is not only a voice-receiving organ, but also produces acoustic energy. However, this mechanism was revealed only 30 years later by the British physicist Kemp (1978) [4-6]. In hearing screenings, hearing loss due to noise, presbyacusis, familial hearing loss, idiopathic sensorineural hearing loss, Meniere and acoustic neurinoma are used to determine the cochlea component [7,8]. OAE response with aging is statistically significant [5]. This reduction is not only related to age, but also to the level of hearing [6]. It may be possible to prevent the loss of hearing when the etiology causing the hearing loss is revealed and treated.

Physical and mental changes in the elderly population can affect the changing living conditions, increased age, and the experience of living alone with hearing loss. The complex nature of aging-related hearing problems involves changes in the auditory environment and in the central mechanisms that process the sound input [9]. The association of osteoporosis and pediatric disorders has been the subject of various investigations [10]. Hearing loss is thought to be one of the clinical manifestations of metabolic bone diseases. Demineralization can cause ossicular mass to decrease. Paget's disease may cause a decrease in mineral density in cochlear bones. According to some researchers, osteopenia and osteoporosis may be associated with idiopathic benign positional vertigo (BPV). It is thought that osteoporosis can affect the audiological functions due to changes in structural and cochlear metabolism (calcium homeostasis) in the ear bones. The high incidence of hearing loss in metabolic bone diseases can lead to bone densitometry screening in people with hearing loss [9,10].

Odiologic complaints are common risk factors with common geriatric syndromes. For this reason, osteoporosis patients require a well-defined and multi-faceted approach to the otologic examination. It is supported by current publications that osteoporosis is a risk factor for age-related hearing loss. Here, the effects of osteoporosis to cochlear function were analyzed in elderly women.

Materials and methods

The study designed as cross-sectional and observational. Forty female patients were included in the study between the ages of 40-75 years in the postmenopausal period. The inclusion criteria for the study are being between 40 and 75 years age, being female, being in the postmenopausal period and not having any odiological problems before. Age, body mass index (BMI), vitamin D levels were recorded in all patients. Measurements of vertebra and femur bone mineral density (BMD) were performed with dual energy x - ray absorptiometry (DEXA). L1-L4 total T score from vertebral measurements; femur measurements were based on total T score. According to vertebra L1-4 t score <-2.5 osteoporosis, -2.5 to -1 osteopenic, the group divided into two and all parameters were compared.

Known neuropsychiatric disease, radiotherapy, malignancy, acute infection or inflammatory rheumatic disease and hearing loss due to acute and chronic otitis media, ear surgery, acoustic schwannoma, meningioma, sudden hearing loss, acoustic trauma, Meniere's disease and other causes were excluded.

Dual-energy x-ray absorptiometry (DEXA)

DEXA measurement is the gold standard for the assessment of bone mass index. DEXA provides the patient's T-score, which is the BMD value compared with the control of the BMD. According to the World Health Organization (WHO), the normal T score is defined as 1 standard deviation (SD) of the mean BMD of a healthy young adult. T-score of -1 to -2.5 SD indicates osteopenia, and T-score indicates less than -2.5 SD indicates osteoporosis. The T score is used to predict the risk of developing a fracture. The Z-score shows the standard deviation of your bone mineral density when compared to individuals of the same sex, same age, same weight, as you. A Z score of less than -2 decades suggests an abnormal bone loss other than aging, and your doctor may be able to detect the underlying problem [11-16].

Audiological Evaluation

Subjects with normal external ear canal and normal tympanic membrane on the otoscopic examination were included in the study. Tympanograms, stapes acoustic reflexes, pure audio audiometry, speech audiometry, otoacustic emission test (OAE) tests (transiently evoked OAE (TEOAE) and distortion product OAE (DPOAE) were applied in the clinic of the audiology.

Impedance audiometry tests were performed with the "AZ-26 Impedance Audiometer" (Interacoustics, Denmark) and tonal audiometry examinations with the "AC-40 Clinieal Audiometer" (Interacoustics, Denmark). Pure voice hearing tests were performed at 125 hz and 8000 hz intervals. For each set of tests, the mean values of air and bone conduction at each frequency value were calculated for both groups. OAE Test with TE and DP with Madsen Capella OAE device. The sound / noise (S / N) ratio arithmetic mean values were taken. The S / N data obtained above indicates the 3-point DPOAE and TEOAE positivity.

Otoacustic emission tests (OAETs)

Otoacoustic emission test (OAET) instruments are now entering routine audiological practice. Otoacoustic emissions measured in the external ear canal describe responses that the cochlea generates in the form of acoustic energy. For the convenience of discussing their principal features, emitted responses can be classified into several categories according to the type of stimulation used to evoke them. On this basis, four distinct but interrelated classes can be distinguished including spontaneous, transiently evoked (TE), stimulus-frequency, and

distortion-product (DP) otoacoustic emissions. The transient OAE type of method has proved very effective in screening applications, particularly in neonates. It is possible to perform noninvasive screening acoustic cochleography in about a minute. The technique is also useful for characterizing cochlear mechanical status prior to long term monitoring [17,18].

Statistics analysis:

Analyses were performed using Statistical Package for the Social Sciences 22 (IBM SPSS for Windows version 22, IBM Corporation, Armonk, New York, USA). Continuous data were presented as mean±SD and categorical variables were summarized as percentages. Kolmogorov Smirnov test was used for the evaluation of normal distribution. Comparisons between groups were made using chi-square tests for categorical variables, independent samples Student's t tests for normally distributed continuous variables and Mann-Whitney U tests when the distribution was skewed. Spearman test is used for correlation analysis. A p value <0.05 was considered statistically significant.

Results

The mean age of the whole group was 58.6 ± 7.9 years. According to vertebra L1-4 t score <-2.5 osteoporosis, -2.5 to -1 osteopenic, the group divided into two and all parameters were compared. According to this, the age, BMI, vitamin D level of both groups were similar (p = 0.9 / 0.3 / 0.6) (Table 1). Only TE left 0.75 Hz was significantly different with higher frequency in the osteopenic group (p = 0.015). No significant difference was observed in other parameters (Table 2, 3). In audiometric tests, only the osteopenic group at 6,000 Hz was significantly different with higher frequency of both ears (p = 0.049 / p = 0.016) (Table 4).

Table 1: Distribution of demographic data of both groups

	Osteoporosis (N=21)	Osteopenia (n=29)	P
Age (year)	58.6±8.1	58.6±7.8	0.9
BMI (kg/m2)	29.3±4.7	30.5±3.9	0.3
Lomber L1-L4 t score:*	-3.2±0.5	-1.3±1.2	0.00
Femur total t score:	-1.5±1.1	-1.2±0.79	0.22
Vitamin D (ng/mL)	24.7±23.9	21.4±23.5	0.6

BMI: body mass index, * statistically significant difference.

Table 2: Distortion products (DP) results of the groups

Hearing Frequency	Osteoporosis t score<(-2.5)	Osteopenia t score=(-2.5)-(-1.0)	P
DPright0.75	0.6±6.6	2.2±7.1	0.43
DPright1	1.9±9.9	3.3±5.7	0.52
DPright1.5	4.7±5.3	2.1±7.8	0.21
DPright2	4.2±5.9	3.6±6.6	0.73
DPright3	4.2±7.2	4.7±6.5	0.81
DPright4	3.7±7.7	4.3±6.9	0.76
DPright6	0.7±6.9	1.6±8	0.67
DPright8	0.4±4.5	0.85±6.6	0.83
DPleft0.75	0.6±6.5	2.2±5.2	0.38
DPleft1	2.7±5.7	3.6±5.1	0.59
DPleft1.5	4±6.03	4.5±5.4	0.79
DPleft2	4.9±3.7	1.5±7.6	0.078
DPleft3	5.2±5.2	4±7.1	0.52
DPleft4	4.5±5.2	4±9.5	0.82
DPleft6	0.7±5.9	2.2±7.6	0.48
DPleft8	1.5±5.3	2.3±6.4	0.7

DP: Distortion products, * statistically significant difference.

Table 3: Transiently evoked (TE) results of the groups

Hearing frequency	Osteoporosis t score<(-2.5)	Osteopenia t score=(-2.5)-(-1.0)	P
TE right 0.75 Hz	5.1±5.5	4.1±5.6	0.53
TE right 1.25	8.1±6.3	6.3±5.5	0.3
TE right 1.75	3.8±7.9	5±6.3	0.54
TE right 2.5	3.2±7.9	2.8±7.1	0.84
TE right 3.5	2.4±7.9	1.3±7	0.59
TE right overall	5.5±4.7	4.4±4	0.46
TE left 0.75 Hz*	2.9±5.2	6.6±.8	0.015
TE left 1.25	8±5.4	8±6.4	0.99
TE left 1.75	4.6±4.9	4.5±5.5	0.98
TE left 2.5	1.3±6	3.1±5.7	0.30
TE left 3.5	1.2±7	0.8±5.4	0.82
TE left overall	2.6±4.3	4.8±4	0.14

TE: transiently evoked, * statistically significant difference.

Table 4: Audiologic evaluation of the groups

Hearing frequency (db)	Osteoporosis t score<(-2.5)	Osteopenia t score=(-2.5)-(-1.0)	P
R_250	13.8±7.2	14.6±7.6	0.69
L_250	13±4.8	15.6±7.8	0.18
R_500	13.5±5.9	13.6±7.1	0.98
L_500	13±5.5	15±8.4	0.37
R_1000	16.4±8.5	17±10.6	0.82
L_1000	14±5.8	18.6±11	0.09
R_2000	16.4±10.3	22.2±15.5	0.143
L_2000	16.4±10.3	23.9±14.6	0.049
R_4000	23.3±11.7	28.6±20.7	0.3
L_4000	22.8±11.6	30.6±20.3	0.12
R_6000*	26.9±15.2	38.1±21.8	0.049
L_6000*	27.8±14.6	40.1±18.7	0.016
R_8000	29.7±16.9	41.3±25.8	0.79
L_8000	32.3±19.5	41.8±20.7	0.10

R: right; L: left, * statistically difference.

TEright_3.5 (p = 0.04), TEright_overall (p = 0.030), TEleft_1.7.5 (p = 0.043) and TEleft_overall (p = 0.046), DPright_1 (p = 0.049) and DPleft_6 (p = 0.039) were significantly higher in the osteoporotic group at higher frequencies.

The lumber T score was positively correlated with BMI (p = 0.042 / r = 0.288) (Figure 1). BMI was lower in the osteoporotic group. The tympanogram results of all patients were Type A. The TE positivity rate (S / N> 3) was 60.8% and the DP positivity rate (S / N> 3) was 39.2%.

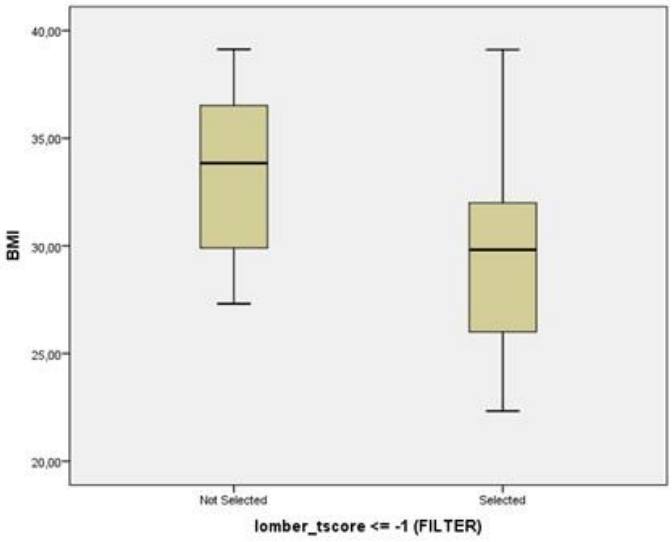

Figure 1: The graphical distribution of BMI according to lomber L1-L4 total T score≤-1,0

Discussion

Osteoporosis is a common metabolic disorder that causes progressive changes in bone structure. The association between menopause and osteoporosis was first described in 1960s [19]. A diagnosis of osteoporosis can be made on the basis of fractures without significant trauma or on the basis of low BMD measured by DEXA. To reduce the risk of osteoporosis, all postmenopausal women should be encouraged to maintain a healthy lifestyle, which includes physical activity and a balanced diet. Smoking and alcohol use should also be addressed. Calcium intake should be encouraged, preferably through diet [20,21].

Clinicians and community health associations should be sensitive to the elderly population. Sensory and cognitive changes, falls and weakness are common in these people. Some hearing loss is a part of the normal aging process and indicates a decrease in immunocompetence [22,23]. With the aging of the populations, hearing loss and osteoporosis are increasing. However, the pathophysiological aspect of this relationship has not yet been identified.

Laudisio et al [24] found that osteoporosis in elderly individuals was associated with hearing loss as correlated with high inflammation parameters. Kshithi et al [25] found that sensorineural hearing loss and pure tone thresholds were higher in osteoporotic women and the DPOAE results were significantly different. Upala S et al [26] suggest that there is a possible relationship between hearing loss and BMD in the meta-analysis. Jung DJ et al [27] did not find such a relationship in the study. In our study, there was no significant difference in osteoporotic patients based on the results of the vertebrae. But according to hip scores, osteopenic-osteoporotic (T score <-1) group showed higher frequencies in both cochlear and hearing tests than normal subjects. A significant difference in the results of the hip total T score without any difference in the results of the lumber vertebra total T score can be explained by the presence of degenerative processes such as osteoarthritis affecting the results of the vertebra. In addition, several recent studies have suggested that the widespread belief that obesity is protective against fracture and that obesity is a risk factor for certain fractures [28]. In our study BMI was significantly lower in osteoporotic individuals.

Changes in the bone remodeling process are associated with falls and fractures. Auditory system occurs from skeletal structures and is affected by changes in bone remodeling. In addition, the vestibule is composed of autoconia crystals, a form of calcium, and therefore calcium levels can affect vestibular functions. In many studies, audio-vestibular functions are significantly related to BMD. This association is related to bone mineral density and metabolic changes in the cochlea. [29,30] Demineralization of the cochlear capsule has been associated with healing loss in Paget's disease of the bone and otosclerosis. Osteoporosis may also result in cochlear capsule demineralization. In the study, Helzner et al [31] suggested that the axial and appendicular bone parameters may be modestly associated with hearing loss in older men, but not in women. According to the study by Kahveci et al [32] osteoporosis may be associated with hearing loss in elderly. Metabolic changes and possible degeneration of middle ear ossicles or cochlear capsule may cause hearing loss in patients with osteoporosis. Chen J et al [33] suggests that Ca (v) 1.3.3 calcium channel expression in the cochlea is reduced in the animal model. El-Zarea GA et al [34] found a relation between osteoporosis and hearing loss especially in higher frequencies. Benign paroxysmal positional vertigo (BPPV) is the most common cause of vertigo, which increases the risk of falls by affecting walking, balance in the older age group. Observations suggest an association between idiopathic BPPV and vitamin D deficiency and osteoporosis. Osteoporosis is thought to be a risk factor for the development of BPPV due to estrogen deficiency in postmenopausal period [35].

Limitation of the study

Small sample size (the number of patients is determined by power analysis) and inadequacy of osteoporosis data are the study limitations. Also they should be questioned whether they have taken osteoporosis supplements in the postmenopausal period. Medication may affect the study results, the mean vit D level was found high in our osteoporotic group without any significant difference.

Conclusion

Osteoporosis and hearing loss are common in geriatric syndromes. Osteoporosis can affect both hearing and cochlear function negatively. Screening of individuals with hearing loss for BMD may provide early detection of this insidious onset of illness.

References

1. Patricia B. Kricos AE. Holmest Efficacy of Audiologic Rehabilitation for Older Adults. J Am Acad Audiol.1996;7:219-29.
2. Saunders GH, Chisolm TH. Connected Audiological Rehabilitation: 21st Century Innovations. J Am Acad Audiol. 2015;26(9):768-76. doi:10.3766/jaaa.14062.
3. Grenness C, Hickson L, Laplante-Lévesque A, Davidson B. Patient-centred audiological rehabilitation: perspectives of older adults who own hearing aids. Int J Audiol. 2014;53(1):68-75. doi:10.3109/14992027.2013.866280.
4. Martin GK, Probst R, Lonsbury-Martin BL. Otoacoustic emissions in human ears: normative fmdings. Ear Hear. 1990;11:106-20.
5. Trine MT, Hirsch JE, Margolis RH. The effect of middle ear pressure on transient evoked otoacoustic emissions. Ear Hear. 1993;14:401-7.
6. Satoh Y, Kanzaki J, O-Uchi T, Yoshihara S. Age-related changes in transiently evoked otoacoustic emissions and distortion product otoacoustic emissions in normal-hearing ears. Auris Nasus Larynx. 1998;25:121-30.
7. Gates GA, Mills D, Nam B, D'Agostino R, Rubel EW. Effects of age on the distortion product otoacoustic emission growth functions. Hear Res. 2002;163:53-60.
8. Lonsbury-Martin BL, Martin GK, Luebke AE: İşitme ve vestibüler sistemlerin fizyolojisi. Otolaringoloji Baş ve Boyun Cerrahisi. Ballenger JJ (ed), Doğan Şenocak (ç.ed). Nobel Tıp Kitabevi, İstanbul. 2000;879-929.
9. Zatoński T, Temporale H, Krecicki T. [Hearing and balance in metabolic bone diseases].Pol Merkur Lekarski. 2012;32(189):198-201.
10. Parham K, Kuchel GA. A Geriatric Perspective on Benign Paroxysmal Positional Vertigo. J Am Geriatr Soc. 2016;64(2):378-85. doi: 10.1111/jgs.13926. Epub 2016 Jan 25.
11. Schousboe JT, Shepherd JA, Bilezikian JP, Baim S. Executive summary of the 2013 International Society for Clinical Densitometry Position Development Conference on bone densitometry. J Clin Densitom. 2013;16(4):455-66.
12. Gosfield E 3rd, Bonner FJ Jr. Evaluating bone mineral density in osteoporosis. Am J Phys Med Rehabil. 2000;79(3):283-91.

13. Kanis JA, McCloskey EV, Johansson H, Oden A, Melton LJ 3rd, Khaltaev N. A reference standard for the description of osteoporosis. Bone. 2008;42(3):467-75.
14. Silverman SL. Selecting patients for osteoporosis therapy. Ann N Y Acad Sci. 2007;1117:264-72.
15. Czerwinski E, Badurski JE, Marcinowska-Suchowierska E, Osieleniec J. Current understanding of osteoporosis according to the position of the World Health Organization (WHO) and International Osteoporosis Foundation. Ortop Traumatol Rehabil. 2007;9(4):337-56.
16. Kanis JA. Assessment of fracture risk and its application to screening for postmenopausal osteoporosis: synopsis of a WHO report. WHO Study Group. Osteoporos Int. 1994;4(6):368-81.
17. Kemp DT , Ryan S , Bray P A guide to the effective use of otoacoustic emissions. Ear and Hearing 1990;11(2):93-105.
18. BLL Martin, GK Martin. A review of otoacoustic emissions. The Jour of Acoustic Society of Amer. 1991;89:2027. https://doi.org/10.1121/1.400897
19. Tella SH, Gallagher JC. Prevention and treatment of postmenopausal osteoporosis.J Steroid Biochem Mol Biol. 2014;142:155-70. doi:10.1016/j.jsbmb.2013.09.008.
20. Baccaro LF, Conde DM, Costa-Paiva L, Pinto-Neto AM. The epidemiology and management of postmenopausal osteoporosis: a viewpoint from Brazil.Clin Interv Aging. 2015;10:583-91. doi: 10.2147/CIA.S54614.
21. Diab DL, Watts NB. Postmenopausal osteoporosis. Curr Opin Endocrinol Diabetes Obes. 2013;20(6):501-9. doi: 10.1097/01.med.0000436194.10599.94.
22. Jaul E, Barron J. Age-Related Diseases and Clinical and Public Health Implications for the 85 Years Old and Over Population.Front Public Health. 2017;5:335. doi:10.3389/fpubh.2017.00335.
23. Y İnanç, Y Beckman, Y Seçil, M Başoğlu. The frequency of dementia and mild cognitive disorder in the nursing home population. Int J Surg Med. 2018;4(2):85-7.
24. Laudisio A, Navarini L, Margiotta DPE, Gemma A, Giovannini S, Saviano A, et al. Inflammation as a mediator of the association between osteoporosis and hearing loss in older subjects: a population-based study.Eur Rev Med Pharmacol Sci. 2018;22(5):1451-6. doi:10.26355/eurrev_201803_14492.
25. Kshithi K, Vijendra Shenoy S, Panduranga Kamath M, Sreedharan S, Manisha N, Khadilkar MN, et al. Audiological profiling in postmenopausal women with osteoporosis. Am J Otolaryngol. 2018;39(3):271-6. doi: 10.1016/j.amjoto.2018.03.004.
26. Upala S, Rattanawong P, Vutthikraivit W, Sanguankeo A. Significant association between osteoporosis and hearing loss: a systematic review and meta-analysis.Braz J Otorhinolaryngol. 2017;83(6):646-52. doi: 10.1016/j.bjorl.2016.08.012.
27. Jung DJ, Cho HH, Lee KY. Association of Bone Mineral Density With Hearing Impairment in Postmenopausal Women in Korea. Clin Exp Otorhinolaryngol. 2016;9(4):319-25.
28. Caffarelli C, Alessi C, Nuti R, Gonnelli S. Divergent effects of obesity on fragility fractures. Clin Interv Aging. 2014;9:1629-36. doi:10.2147/CIA.S64625.
29. Singh NK, Jha RH, Gargeshwari A, Kumar P. Altered auditory and vestibular functioning in individuals with low bone mineral density: a systematic review.Eur Arch Otorhinolaryngol. 2018;275(1):1-10. doi: 10.1007/s00405-017-4768-4.
30. Clark K, Sowers MR, Wallace RB, Jannausch ML, Lemke J, Anderson CV. Age-related hearing loss and bone mass in a population of rural women aged 60 to 85 years. Ann Epidemiol. 1995;5(1):8-14.
31. Helzner EP, Cauley JA, Pratt SR, Wisniewski SR, Talbott EO, Zmuda JM, et al. Hearing sensitivity and bone mineral density in older adults: the Health, Aging and Body Composition Study.Osteoporos Int. 2005;16(12):1675-82.
32. Kahveci OK, Demirdal US, Yücedag F, Cerci U. Patients with osteoporosis have higher incidence of sensorineural hearing loss. Clin Otolaryngol. 2014;39(3):145-9. doi: 10.1111/coa.12242.
33. Chen J, Chu H, Xiong H, Yu Y, Huang X, Zhou L et al. Downregulation of Cav1.3 calcium channel expression in the cochlea is associated with age-related hearing loss in C57BL/6J mice. Neuroreport. 2013;24(6):313-7. doi: 10.1097/WNR.0b013e32835fa79c.
34. El-Zarea GA, Abdel-Mottaleb AH, Mustafa Aİ, Hesse ALA. Hearing Function in Osteoporotic Patients. J Am Sci 2017;13(12):76-83.
35. Yamanaka T, Shirota S, Sawai Y, Murai T, Fujita N, Hosoi H. Osteoporosis as a risk factor for the recurrence of benign paroxysmal positional vertigo. Laryngoscope. 2013;123:2813–6. https://doi.org/10.1002/lary.24099