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AUDIOLOGICAL PROFILE IN OSTEOPOROSIS IN KASHMIRI POPULATION

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ABSTRACT Osteoporosis is a multifactorial disease characterized by decrease in bone mineral density and disruption of bony architecture. This reduction in bone mineral density is measured using T-score. T-score of ≥1 is normal, -1 to -2.5 is in the osteopenic range and ≤2.5 is in the osteoporotic range. There is lack of studies finding the relationship between osteoporosis and hearing loss in Kashmiripopulation. The present study was undertaken to find the relation between hearing loss and osteoporosis in postmenopausal Kashmiri women. Thirty postmenopausal Kashmiri women in the age range of 38-55 were subjected to bone mineral density (BMD) study and T-scores were obtained. Based on the T-scores, participants were divided into three groups. Group I consisted of 11 normal women, group II consisted of 10 osteopenic women and group III consisted of 9 osteoporotic women. Pure tone audiometry, tympanometry and distortion product otoacoustic emissions (DPOAEs) were carried out. Statistical analysis found that the mean threshold at all frequencies from 250 Hz to 8 kHz were better for normal, poorer for both osteopenic and osteoporotic group. At all frequencies the effect of reduced BMD on hearing loss was significant.Results indicated that thresholds at all frequencies and pure tone average thresholds were significantly different between the three groups with $p < 0.05$. 'A' type of tympanogram was present in all the groups. DPOAEs signal to noise ratio were significantly different at 3 kHz and 4 kHz between normal, osteopenic and osteoporotic group with $p < 0.05$. However, there was no significant difference between the groups at 1 kHz and 2 kHz. Both osteopenic and osteoporotic group showed a greater number of individuals with sensorineural hearing loss. The present study indicates a stronger relation between osteoporosis and hearing loss. Effect of osteoporosis on auditory system using this test battery indicated bilateral sensorineural hearing loss.

KEYWORDS : Kashmiri population,Osteoporosis, osteopenia, bone mineral density, hearing loss, signal to noise ratio.

Introduction

Osteoporosis is defined as a progressive systemic skeletal disorder characterized by low bone mineral density (BMD), deterioration of the microarchitecture of bone tissue, and susceptibility to fracture [1]. Bones are comprised of two major ingredients: minerals (including calcium and phosphorous), and bone cells (consisting of osteoblasts and osteoclasts).

There are two major types of bone: cancellous bone (also known as trabecular bone), which is the inner, softer portion of the bone, and cortical bone, which is the outer, harder layer of bone. Cancellous bone undergoes turnover at a faster rate than cortical bone. As a result, if osteoclast and osteoblast activity become mismatched, cancellous bone is affected more rapidly than cortical bone. In osteoporosis the amount of cortical and cancellous bone is decreased, haversian canals are widened, and the rate of bone resorption exceeds the rate of bone formation.

The temporal bone including otic capsule and internal auditory canal may be one biological factor contributing to hearing loss. Hearing loss may be an under recognized complication of osteoporosis [2-4]. Shafer (2006) studied the relationship between bone loss and dizziness in post-menopausal women, and hypothesized that that bone loss is associated with benign paroxysmal positional vertigo (BPPV) [5]. A research study done by McKenna et al (2004) explored the clinical relationship between osteoporosis and otosclerosis citing a common gene COL1A1 associated with both conditions [6].

Henkin et al (1972) indicated increased sclerosis of cochlear and vestibular labyrinths in four of seven patients with idiopathic osteoporosis [7]. Horner (2009) suggested a possible relationship between recurrent BPPV and a decreased fixation of calcium in bone in postmenopausal women [8]. Yeh et al (2015) found a significant relationship between sudden sensorineural hearing loss and osteoporosis [9]. On the contrary, Babich et al (2009) reported conductive hearing loss in osteoporosis [10]. These findings suggest that there may be a pathology in the middle and/or inner ear of the patients with osteoporosis. In our clinical practice we observed that sensorineural hearing loss was more frequent than conductive hearing loss in patients with osteoporosis. There was lack of studies finding the relationship between osteoporosis and hearing loss in Kashmiri population. Hence the present study was undertaken to find the relation between hearing loss and

osteoporosis in postmenopausal Kashmiri women. The aim of the study was to profile the bilateral audiological findings including pure tone average, type of tympanogram, otoacoustic emissions in osteoporotic and osteopenic patients and to see if it varies with that of age matched controls.

Materials and methods

Thirty post-menopausal Kashmiri women in the age range of 38-55 were included in the study. Women were eligible to participate if they did not have a prior history of ear surgery, otosclerosis and excessive exposure to noise. Instrumentation for the present study included 4 instruments.

Omnisense instrument was used for assessment of BMD. This instrument consists of a desktop system and small handheld probes of differing sizes to measure the different sites. The probe includes both the transmitter and the receiver. A two channel clinical audiometer consisting

of supra-aural headphones with ear cushions was used for obtaining pure tone audiogram. The audiometer was calibrated to conform to ANSI standards. Calibrated middle ear analyzer GSI-Tympstar was used for doing tympanometry. Calibrated Otoread was used for measurement of distortion product otoacoustic emissions (DPOAEs). All the audiological testing was carried in a sound treated room and

noise levels were within the permissible limits as per ANSI (1991) [11].

All the participants underwent a BMD assessment by quantitative ultrasound method. BMD is simple non-in- Osteoporosis may be classified as primary osteoporosis and secondary osteoporosis.

Generally, osteoporosis is asymptomatic until a fracture occurs. Tests that measure the bone strength and diagnoses at an early stage are of importance. Bone mineral density (BMD) study has been reported to correlate for more than three quartiles of total bone strength. The reduction

in BMD is measured using T-score. WHO criteria defines T-score of more than -1 as normal, -1 to -2.5 as osteopenic and less than -2.5 as osteoporotic. Osteopenia is a milder form of bone loss and it is thought to be a precursor of osteoporosis.

Results and discussion

Data obtained were analyzed using generalized linear model statistical analysis to compare the thresholds across frequencies, pure tone average (PTA) and SNRs of otoacoustic emissions across frequencies between normal hearing individuals, osteopenic and osteoporotic individuals and to evaluate ear difference.

Pure tone audiometry

Results of mean threshold and standard deviation (SD) of frequencies and PTA obtained for normal, osteopenic and osteoporotic for right and left ear are shown in Table 1.

Table 1 shows that mean thresholds at all frequencies from 250 Hz to 8 kHz were better for normal women with a mean pure tone average threshold of 16 dBHL for right ear, 16 dBHL for left ear. Both osteopenic and osteoporotic group had poorer threshold compared to normal. Osteopenic group had poorer mean thresholds at all frequencies with a mean pure tone average threshold of 26 dBHL for right ear and 24 dBHL for left ear.

The osteoporotic group also had poorer mean threshold at all frequencies with a mean pure tone average threshold of 22 dBHL for right ear and 20 dBHL for left ear. It is evident from Figure 1 that normal groups had a better threshold at all frequencies and PTA compared to osteopenic and osteoporotic group. To assess the difference in the thresholds of all the frequencies and PTA across three different groups and across two ears, two way ANOVA was done. At all frequencies the effect of reduced bone mineral density on hearing loss was significant with $p < 0.05$. Results of two way ANOVA are shown in Table 2. Results indicated that thresholds at all frequencies and pure tone average thresholds were significantly different between the three groups with$p$ <0.05. However, the effect of ear and the interaction effect of ear and groups were not significant at all the frequencies and PTA with $p > 0.05$. To evaluate significant differences in the three different groups, Scheffe's post hoc comparison was used. Results of Scheffe's post vasive procedure and was performed by an orthopedician. Bone mineral density test measures the absolute amount of bone which generally correlates with bone strength and its ability to bear weight. BMD was measured in the participants using Omnisense (Sunlight) instrument and the T-scores were obtained in the distal radius bone by measuring the speed of the sound along a fixed distance of bone parallel to its axis. Thrice the measurements were done and a graph was displayed with the T-score. Based on the T-scores, participants were divided into three groups. Group I consisted of 11 normal women with T-score of ≥1. Group II consisted of 10 osteopenic women with T-score between -1to -2.5. Group III consisted of 9 osteoporotic women with T-score ≤2.5. Case history was taken for the participants and questions were asked regarding subjective hearing loss, dizziness, tinnitus, and prior ear trauma or surgery. The following categories of information were obtained: demographics (age, phone number), medical history [age at menopause, medical disorders (thyroid disease, diabetes)], and medication used (chemotherapy, diuretics, oestrogen for hormone replacement therapy (HRT)], nutritional status (use of calcium supplementation). Initially pure tone audiometry was done. Air conduction thresholds were determined across octave frequencies from 250 Hz to 8000 Hz and bone conduction thresholds were obtained from 250 Hz to 4000 Hz for both the ears. The thresholds were obtained using modified version of Hughson and Westlake procedure [12]. Tympanometry was obtained for 226 Hz probe tone to evaluate the middle ear status for all the subjects. An otoacoustic emission test was done. DPOAE SNR were measured using 2 primary tones with frequencies of f1 and f2. The ratio of frequencies of the 2 primaries (f1/f2) was constant at 1.2. The f2 frequency varied from 1.5kHz to 4kHz and the intensity levels of primaries was maintained at 65dBSPL and 55dBSPL respectively for f1 and f2 [13] to produce optimum results.

The data collected from participants was tabulated. A commercially available statistical package for social sciences (SPSS-version 15.0) was used for statistical analysis.

Table 1. Mean and standard deviation of frequencies and pure tone average of normal, osteopenic and osteoporotic for right and left ear in dBHL

	Normal group				Osteopenic group				Osteoporotic group			
	Right ear		Left ear		Right ear		Left ear		Right ear		Left ear	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
250 Hz	16	7	15	6	27	9	24	12	16	7	15	6
500 Hz	17	8	19	7	27	9	26	9	23	8	24	15
1 kHz	15	5	15	5	25	9	24	7	23	8	21	8
2 kHz	14	3	15	5	27	14	21	9	24	9	21	11
4 kHz	15	5	15	9	34	14	27	12	28	12	28	11
8 kHz	19	13	17	8	39	21	40	24	36	13	28	13
PTA	16	4	16	5	26	9	24	8	22	8	20	8

PTA, pure tone average; SD, standard deviation.

Immittance Cross tabulation was done. Results can be summarized in terms of type of tympanogram obtained in normal, osteopenic and osteoporotic individuals as shown in Table 4. Table 4 shows that among the types of tympanogram obtained in the participants, A type was present in 23 ears in normal, 21 ears in osteopenic and 18 ears in osteoporotic group. Ad type was present in 1 ear in each of the groups. As was present in 1 ear in osteoporotic group.

Otoacoustic emission

DPOAEs SNR obtained in three different groups across two ears were compared. Table 5 shows DPOAEs SNR were similar across the three groups in both right and left ear for 1.5 kHz and 2 kHz, better in normal compared to osteopenic and osteoporotic group at 3 kHz and 4 kHz. Figure 2 shows that DPOAEs SNR are better in normal compared to osteopenic and osteoporotic in DPOAEs SNR across the three different groups for two ears, two way ANOVA was done. Results of tests indicated that DPOAEs SNR were significantly different at 3 kHz and 4 kHz between normal, osteopenic and osteoporotic group with $p < 0.05$. However, there was no significant difference between the groups at 1 kHz and 2 kHz with $p > 0.05$. The effect of ear alone and the interaction effect of ear and group were not significant with $p > 0.05$. Results of two way ANOVA are shown in Table 6.

To evaluate the significant difference between the three groups Duncan's post hoc comparison was administered. Results of Duncan's post hoc test showed that DPOAEs SNR for osteopenic and osteoporotic group were poorer compared to normal group. However, there was no significant difference between osteopenic and osteoporotic group. Results of post hoc test are shown in Table 7. Type of hearing loss is shown in Table 8 with cross tabulation.

Table 8 shows that among the type of hearing loss whichwas obtained, 17 ears had normal hearing and 7 ears had minimal hearing loss in normal group, whereas 7 ears had minimal hearing loss, 14 ears had sensorineural hearing loss and 1 ear had normal hearing in osteopenic group. In the osteoporotic group, 5 ears had minimal hearing loss, 12 ears had sensorineural hearing loss and 3 had normal hearing.

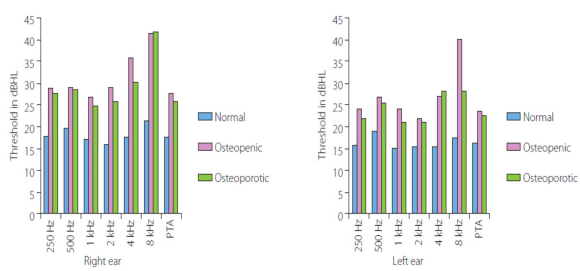

Figure 1. The mean threshold across all frequencies and pure tone average for right and left ear for normal, osteopenic and osteoporotic individuals.

Table 2. F value and significance values: between groups, across ears and for interaction of group and ear

	Frequencies	F value	Significance (p)
Between groups (normal, osteopenic and osteoporotic)	250 Hz	5.88	.005
	500 Hz	5.19	.008
	1000 Hz	10.0	.000
	2000 Hz	6.4	.003
	4000 Hz	11.5	.000
	8000 Hz	9.8	.000
	PTA	8.176	.001
Across ear (right and left)	250 Hz	1.10	.297
	500 Hz	.001	0.97
	1000 Hz	0.37	0.54
	2000 Hz	1.000	0.32
	4000 Hz	.901	.346
	8000 Hz	.688	.410
	PTA	.859	.358
Interaction of group and ear	250 Hz	.145	.865
	500 Hz	0.081	0.9
	1000 Hz	0.06	0.93
	2000 Hz	0.702	0.50
	4000 Hz	.612	.545
	8000 Hz	.407	.667
	PTA	.429	.653

However, there was no significant difference between osteopenic and osteoporotic group. Table 3 shows the result of the Scheffe's test.

Table 3. Results of the Scheffe's test for thresholds at all frequencies and PTA across the three groups

Frequencies	Groups	Osteopenic	Osteoporotic
250 Hz	Normal Osteopenic	Significant*	Significant* Not significant
500 Hz	Normal Osteopenic	Significant*	Significant* Not significant
1000 Hz	Normal Osteopenic	Significant*	Significant* Not significant
2000 Hz	Normal Osteopenic	Significant*	Significant* Not significant
4000 Hz	Normal Osteopenic	Significant*	Significant* Not significant
8000 Hz	Normal Osteopenic	Significant*	Significant* Not significant
PTA	Normal Osteopenic	Significant*	Significant* Not significant

*p<0.05.

Table 4. Type of tympanogram: count and percentage obtained in each group

Type	Value	Group			Total
		Normal	Osteopenic	Osteoporotic	
A	Count	23	21	18	62
	%	95.8	95.5	90.0	93.9
A_S	Count	0	0	1	1
	%	0	0	5	1.5
A_D	Count	1	1	1	3
	%	4.2	4.5	5	4.5
Total	Count	24	22	20	66
	%	100	100	100	100

Table 5. Mean and standard deviation of DPOAEs SNR in dB across the three groups and across right and left ear

	Normal group				Osteopenic group				Osteoporotic group			
	Right ear		Left ear		Right ear		Left ear		Right ear		Left ear	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1.5 kHz	11	7	15	6	10	6	12	8	12	6	14	6.9
2 kHz	17.6	6	18	6	11.8	9.5	13.6	9.7	15	7.8	15	7
3 kHz	18.3	5.5	18.2	5.0	13.0	8.2	13.2	7.6	13.6	7.9	14.1	7.7
4 kHz	12.6	5.3	15.6	4.9	6.9	6.2	11.4	8.0	10.1	4.7	9.7	7.6

SD, standard deviation.

Table 6. F value and significance values of DPOAEs between groups, across ears and for interaction of group and ear

	Frequencies	F value	Significance
Between groups (normal, osteopenic and osteoporotic)	1500 Hz	0.565	0.572
	2000 Hz	2.841	0.067
	3000 Hz	3.57	0.03
	4000 Hz	4.26	0.01
Across ear (right and left)	1500 Hz	2.201	0.143
	2000 Hz	0.005	0.944
	3000 Hz	0.013	0.90
	4000 Hz	2.37	0.12
Interaction of group and ear	1500 Hz	0.052	0.949
	2000 Hz	0.516	0.599
	3000 Hz	0.009	0.991
	4000 Hz	0.848	0.434

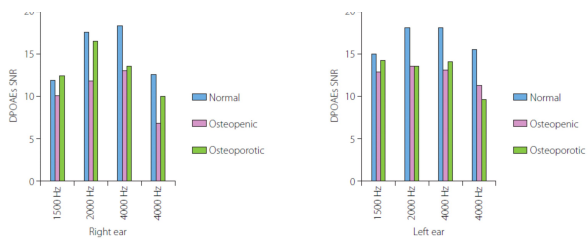

Figure 2. Mean DPOAEs SNR across frequencies between normal, osteopenic and osteoporotic groups in right and left ear.

Table 7. Results of the Scheffe's test for DPOAEs SNR at different frequencies across the three groups

Frequencies	Groups	Osteopenic	Osteoporotic
1500 Hz	Normal Osteopenic	Significant*	Significant* Not significant
2000 Hz	Normal Osteopenic	Significant*	Significant* Not significant
3000 Hz	Normal Osteopenic	Significant*	Significant* Not significant
4000 Hz	Normal Osteopenic	Significant*	Significant* Not significant

*p <0.05.

Table 8. Type of hearing loss: count and percentage in the three different groups

Type	Value	Group			Total
		Normal	Osteopenic	Osteoporotic	
Normal hearing	Count	17	1	3	21
	%	70.8	4.5	15.0	31.8
Minimal HL	Count	7	7	5	19
	%	29.1	31.8	25.0	28.7
Sensorineural HL	Count	0	14	12	26
	%	0	63.6	60.0	39.3
Conductive HL	Count	0	0	0	0
	%	0	0	0	0
Total	Count	100	100	100	100
	%	24	22	20	66

HL, hearing loss.

Discussion

The results demonstrate an inverse relation between BMD and hearing loss. Both osteopenic and osteoporotic women had poorer thresholds than normal women. Findings from the present study show the presence of sensorineural hearing loss in patients with osteopenia and osteoporosis. The mechanisms showing the relationship between sensorineural hearing loss and osteoporosis is quite complex. Studies theorized that inflammation and bone demineralization may contribute to the association between weakening bones and sudden sensorineural hearing loss [9]. On the other hand, according to some researches, it has been shown that there is a correlation between BMD loss in osteoporotic patients and conductive hearing loss; in those patients over a specific age, changing the structure of the ossicles or hormonal mechanism in hearing may correlate BMD loss with hearing loss [5,10]. Demineralization of cochlear capsule was found to be correlated with hearing loss in patients with metabolic bone disorders such as Paget's disease and osteogenesis imperfecta [14]. Similar mechanisms might underlie the relationship between sensorineural hearing loss and conosteoporosis.

There are some possible explanations for our findings. Postmenopausal women with reduced bone mineral density are likely to have systemic evidence of illness affecting many bones including those of inner ear. The bone of the cochlear capsule is lamellar bone with few haversian canals and vascular elements, and thus consists of maximally compact bone tissue. Earlier radiological studies done by Henkin et al (1972) showed increased sclerosis of otic capsule in few patients with osteoporosis [7]. Our study hypothesizes that involvement of the otic bone which supports and protects the delicate cochlear and vestibular neuroepithelial structures, could lead to secondary degenerative changes in spiral ligament, stria vascularis

[3] and cochlear hair cells either by local ischemia or by toxic effect caused by the release of enzymes which could lead to sensorineural hearing loss. The results of the present study are in accordance with the study done by Henkin et al (1972), who diagnosed bilateral sensorineural deafness, significantly greater than their age related mean level, in five or seven patients with confirmed osteoporosis who presented with severe bone pain [7]. Osteoporosis may be caused by multiple mechanisms such as cardiovascular risk factors, bone demineralization, inflammation and endothelial dysfunction [9].

Although the exact cause is not known we hypothesize that hearing loss could be due to deficiency in calcium. It could be postulated that reduction in the ionized calcium may affect the cellular function in the inner ear which includes the active mechanism and also the transmission of nerve action potentials generated in cochlea by inhibiting the release of transmitter at the synapses. This gives a possible explanation for the presence of sensorineural hearing loss in osteoporosis. Further experimental researches and clinical trials are needed to validate our hypothesis. The results of the present study showed normal middle ear status with A type tympanogram in almost all of the ears in both osteoporotic group and osteopenic group.

Similar results were mentioned in the study done by Ozkiris et al (2013), who reported that there is no significant difference between normal, osteopenic and osteoporotic group in tympanometric values [15]. We speculate that this could be due to difference in the mineral content of the bone in the ossicles compared to the general skeleton. Calcium and phosphorous content of the woven bone of the ossicles

are significantly greater than that of the ordinary haversian bone of the mastoid cortex and other regions, indicating that there are fundamental metabolic differences in the bone of ossicles compared to general skeleton bones [16]. This metabolic difference between bone of the ossicles and general skeleton could have conferred some degree of protection to the middle ear ossicles.

Hence the middle ear ossicles could be relatively infrequently involved in the osteoporosis.

In our study reduced DPOAE SNR was seen predominantly at high frequencies. In support of the results of the present study, a recent study done by Kahveci et al (2014) reported that DPOAE results of patients with osteoporosis at 6 kHz were significantly lower than those of normal and osteopenic patients [17]. Although the exact mechanism is not known, we theorize that this could be due to susceptibility of basal region of cochlea for more and early damage in general, so the same trend that is damage to the basal region in the early stages of osteoporosis could be followed. However additional studies have to be done to further explore other possibilities.

Conclusion The present study indicates a stronger relation between osteoporosis and hearing loss. The effect of osteoporosis on auditory system using test battery indicates bilateral sensorineural hearing loss. The results in this research, through evidence of association between osteoporosis and hearing loss, can allow for integrated work of an orthopeadician, audiologist, otorhinolaryngologist who are concerned with the alterations caused by osteoporosis. Cochleo-vestibular symptoms are probably often overshadowed by other more generalized features of osteoporosis.

Hence, it is important to disclose the need for preventive processes to minimize the demineralization mechanism of the auditory system caused by osteoporosis, as well as prioritize the early diagnosis of hearing loss in people with osteoporosis. A further study with a large group of population is suggested. Future studies could be done to find the effect of reduced bone mineral density on cochlear potentials.

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