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Hearing Thresholds and Cochlear Integrity in Patients with Multiple Sclerosis: A Case-Control Study

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ABSTRACT

Background: Multiple sclerosis (MS) is one of the common causes of disability in young adults. Despite the increasing prevalence and growing burden of MS, aspects such as auditory pathway involvement remain under-researched.
Objectives: To evaluate the most common auditory complaints among patients with MS, determine the most frequently affected pure tone audiometric frequencies, and assess the integrity of the peripheral auditory pathway using transient evoked otoacoustic emissions (TEOAE).
Materials and methods: A case-control study was conducted involving 60 MS patients and 60 age- and sex matched healthy controls. All participants underwent neurological examination, ear, nose, and throat examination, tympanometry, pure tone audiometry (PTA), auditory brainstem response (ABR), and transient evoked otoacoustic emission (TEOAE) testing.
Results: The most common auditory symptoms among MS patients included hyperacusis (65%), speech discrimination difficulties (53.3%), tinnitus (48.3%), and hearing loss (35%). MS patients had elevated PTA thresholds (P-value < 0.05) at all frequencies except 250, 1000, and 2000 Hz, with notable influence from sex, but not from disease duration or treatment type, significantly prolonged wave III, wave V, and interpeak latencies in MS ears compared to controls (P-value < 0.05), and significant differences in TEOAE signal-to-noise ratio between study groups at 2000, 3000, and 4000 Hz frequencies (P-values of 0.016, 0.0001, 0.0001 respectively).
Conclusion: Hyperacusis, speech discrimination difficulties, tinnitus, and hearing loss appear to be among the most frequently reported auditory complaints in MS patients. The disease tends to affect all audiometric frequencies, with a particular predilection for high and low frequencies. The peripheral auditory pathway appears to be subtly affected, particularly at the high frequencies, highlighting the need for routine audiological testing in this population.
Keywords: Cochlear Integrity; Hearing Threshold; Multiple Sclerosis; Pure tone audiometry; Transient evoked otoacoustic emissions.

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INTRODUCTION

Multiple sclerosis (MS) is a chronic inflammatory, multifactorial autoimmune disorder that causes white matter demyelination, together with neuronal and axonal damage in extra-lesional tissues [1]. It mainly affects individuals between 20 and 40 years old, with females being more likely to be affected than males [2]. Diagnosis typically relies on clinical evidence and magnetic resonance imaging (MRI) verification, supported by laboratory tests, according to the Revised McDonald's criteria [3]; however, neurophysiological tests like auditory brainstem response (ABR) may offer additional information [2]. ABR can provide objective evidence of auditory pathway lesions and evaluate treatment effectiveness in MS [4]. Although MS patients rarely present with hearing complaints, several studies have reported the occurrence

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of sensorineural hearing loss (SNHL) [5]. However, the loss is highly variable, occurring early or later in disease progression, and can be progressive or sudden, transient or permanent [6].

Assessing auditory function in multiple sclerosis requires both behavioral and objective methods. Pure tone audiometry (PTA) is a valuable behavioral tool for determining the type and degree of hearing loss [7], while otoacoustic emissions (OAE), generated by the outer hair cells of the cochlea, provide an objective evaluation of cochlear health and integrity [8].

Despite the extensive studies on the central auditory pathway in MS, limited studies have investigated peripheral auditory pathway function in this population. Additionally, conclusions regarding audiometric changes in MS remain inconclusive, and the effect of factors such as treatment status and disease duration was rarely addressed in previous research [5]. The current study can contribute to a better understanding of auditory manifestations in MS, help detect subclinical auditory pathway involvement, and add to the general knowledge of threshold abnormalities in this population.

The objectives of the current study were to estimate the most common auditory complaints among patients with MS, identify the most frequently affected pure tone audiometric frequencies in these patients, and assess the integrity of the peripheral auditory pathway using transient evoked otoacoustic emission (TEOAE).

MATERIALS AND METHODS

This was a case-control study conducted at the Multiple Sclerosis Center, Department of Neurology, and the National Center for Hearing and Speech in Medical City, Baghdad, Iraq, over a period of five months, from October 10, 2024, to March 10, 2025. The study was granted ethical approval by the Scientific Committee of the Surgery Department at Mustansiriyah University, College of Medicine (Reference number 8040 on 8-10-2024). Informed consent was obtained from all participants. The sample size was calculated based on the following formula:

$$N = \frac{(Z_{\alpha/2} + Z_{\beta})^2 \times [p_1(1-p_1) + p_2(1-p_2)]}{(p_1 - p_2)^2}$$

where: Z$\alpha/2$ = 1.96 for a 95% confidence level, Zβ = 0.84 for 80% power, P1 = expected proportion of MS patients with hearing impairment, P2 = expected proportion of healthy controls with hearing impairment. Assuming P1 = 0.5 (conservative estimate due to lack of prior data) and P2 = 0.25, based on previous population-based studies in Iraq [9]. The estimated sample size was about 55 participants per group. To enhance precision and accommodate possible data loss, 120 participants (60 per group) were recruited.

The case group included a consecutive sample of 60 patients with a definitive diagnosis of MS, aged 20-45 years, of both sexes, and clinically stable (no history of relapse or expanded disability status scale (EDSS) score change in the last three months), who attended the Multiple Sclerosis Center for follow-up visits.

The control group consisted of a convenient sample of 60 volunteers, with no signs or symptoms of MS, no neurological or psychiatric diagnosis, no family history of MS, and a normal neurological examination, matched with the case group for both age and sex, recruited from hospital staff.

Participants with previous exposure to loud noise, ototoxic or central nervous system interfering medications usage, active or recurrent ear infections, tympanic membrane perforation, abnormal tympanometry, family history of hearing impairments, or comorbid conditions such as diabetes mellitus, hypertension, or other autoimmune diseases were excluded from the study.

Participants were first interviewed, and data gathered from MS patients, including demographic information, disease type [relapsing remitting MS (RRMS), primary progressive MS (PPMS), and secondary progressive MS (SPMS)], treatment history, disease duration, and other clinical details, were cross-checked with existing medical records to ensure accuracy. Patients were classified based on the efficacy of their disease-modifying therapy (DMT) as follows: no treatment, first-line treatment (moderate efficacy DMTs, including interferon β and teriflunomide), and second-line treatment (high efficacy DMTs, including rituximab, natalizumab, and fingolimod) for further analysis [2]. Subsequently, all participants underwent a neurological examination. The EDSS was assessed for each participant in the case group, and they were then referred for a comprehensive ear, nose, and throat (ENT) and audiological evaluation, including tympanometry, PTA, ABR, and TEOAE testing.

Tympanometry was conducted using an Interacoustics Titan/IMP440 tympanometer (Interacoustics A/S, Middelfart, Denmark) for exclusion purposes; participants with conductive impairments or tympanometry results other than type A were excluded from the study.

PTA was conducted using a calibrated Madsen A450 Audiometer (Otometrics Natus Medical Denmark). The testing procedure followed the standard guidelines by the American Speech-Language-Hearing Association (ASHA) and the American National Standards Institute (ANSI), utilizing the Modified-Hughson Westlake method. Air conduction thresholds were tested using TDH-39 earphones at standard octave and inter-octave frequencies from 0.25 to 8 kHz. Bone conduction thresholds were tested using the B-71 bone vibrator at frequencies from 0.5 to 4 kHz. Hearing thresholds were established at each tested frequency, the audiogram shape was identified, and the type of hearing loss was documented, if present. PTA abnormality was defined as hearing thresholds exceeding 25 dB HL at one or more tested frequencies, and the grading of hearing loss was based on Goodman's classification [7].

ABR was tested using a two-channel Eclipse EP15 system (Interacoustics A/S, Middelfart, Denmark). During testing, subjects were lying comfortably supine in a sound-treated room. The skin was cleaned thoroughly, and electrodes were placed on the upper forehead (active), right and left mastoids (reference), and lower forehead (ground), using conductive paste; impedances were kept under 3kOhms at all trials. The stimulus used was a short-duration click of alternating polarity, at an intensity of 80 dB normal hearing level (dB nHL, representing the average behavioral threshold of normal-hearing individuals for clicks) delivered via insert earphones at a rate of 19.9 per second. The filters used were a 100 Hz high-pass and a 3000 Hz low-pass filter, and a 15 msec recording window was set. A minimum of 2000 sweeps per trial, with at least two trials for each ear, was applied. The absolute latencies of waves I, III, and V were measured, along with I-III, III-V, and I-V interpeak latencies (IPLs).

TEOAEs were tested using the Interacoustics Titan TEOAE 440 module (Interacoustics A/S, Middelfart, Denmark). Testing was performed in a sound-treated room, and the probe was checked and verified for adequacy before start-

ing data collection. TEOAEs were evoked by employing a non-linear click stimulus at frequencies from 1 to 4 kHz, with a sound level of 83 peak equivalent dB sound pressure level (SPL), a stimulus rate of 50.0 stimuli/second, and a recording window ranging from 4 to 12.5 milliseconds. The level of accepted noise was set at 47 dB SPL. The signal-to-noise ratio (SNR) at each frequency was reported.

The data were analyzed using the Statistical Package for Social Sciences SPSS version 26 (IBM Corporation, Armonk, New York, USA). The data were presented as means ± standard deviations or median and interquartile range, frequencies, and percentages. The Shapiro-Wilk test was employed to assess data normality. An independent t-test was used to compare normally distributed continuous variables, while the Mann–Whitney U test was applied for non-normally distributed data. The Chi-square test was used to assess the association between categorical variables. A P-value < 0.05 was considered a statistically significant difference.

RESULTS

Sixty MS patients and sixty control subjects participated in the current study. Table 1 displays no statistically significant differences (P-value > 0.05) in the age and sex distribution between the study groups.

Table 2 summarizes the types, duration, treatment status, and auditory symptoms of MS patients. RRMS was the most common type (n = 55, 91.7%). The largest group had MS for less than 5 years (n = 30, 50%). Most patients were receiving second-line treatment (n = 39, 65%). Among auditory symptoms, hyperacusis was the most frequently reported (n = 39, 65%). The EDSS ranged from 0 to 8, with a mean of 1.81 ± 2.0.

PTA thresholds were significantly higher (P-value < 0.05) in MS patients than in controls at all frequencies except 250, 1000, and 2000 Hz, as shown in Table 3.

Males in the MS group had significantly higher PTA thresholds than controls at all frequencies except 250, 500, 750, 1000, and 1500 Hz. Similarly, females in the MS group showed significantly higher PTA thresholds than controls at all frequencies except 1000, 1500, and 2000 Hz, as displayed in Table 4.

In the MS group, PTA thresholds at 3000 Hz were significantly higher in patients with a disease duration of less than five years compared to those with a duration of five years or more (P-value = 0.029), as presented in Table 5.

Regarding PTA configuration, flat-shaped audiograms were most common among the MS group (78.3%), followed by sloping (16.7%), notched (4.2%), and steeply sloping (0.8%) audiograms. All control participants had flat audiograms.

PTA results were abnormal in 47 ears (39.17%) and normal in 73 ears (60.83%) in the MS group; no ears in the control group had abnormal PTA results.

Table 6 presents the distribution of PTA abnormalities among MS patients according to treatment status. No statistically significant differences were found between the three groups (P-value > 0.05).

Except for wave I, absolute latencies and IPLs were significantly prolonged in MS ears compared to the control ears, as shown in Table 7. Additionally, no significant differences were noted between the right and left MS ears, except III-V IPL, which was significantly prolonged in the left ear (P-value = 0.02). There were statistically significant differences (P-value < 0.05) in TEOAE SNR values between the study groups' ears at 2000, 3000, and 4000 Hz frequencies. No significant differences were observed at the other tested frequencies (Table 8).

Table 1. Demographic characteristics of the study groups. MS: Multiple sclerosis*.

Characteristics	MS group (n=60)	Control group (n=60)	P-value
Age (years)	36.43 ± 10.00 (22-45)	34.11 ± 10.3 (20-44)	0.213
Sex			
Males	17 (28.3%)	18 (30.0%)	0.841
Females	43 (71.7%)	42 (70.0%)	

* Data are presented as mean ± SD (range) or frequency (percentage).

Table 2. Types, duration, treatment status, and auditory symptoms in MS patients*.

Characteristics	MS group (n=60)	Number	Percent
Type of MS	RRMS	55	91.7
	PPMS	5	8.3
Duration of MS	< 5 years	30	50.0
	5–10 years	12	20.0
	> 10 years	18	30.0
Treatment status	No treatment	5	8.3
	First-line treatment	16	26.7
	Second-line treatment	39	65.0
Auditory symptoms	Hyperacusis	39	65.0
	Speech discrimination difficulty	32	53.3
	Tinnitus	29	48.3
	Hearing loss	21	35.0

* RRMS: Relapsing remitting multiple sclerosis (MS), PPMS: Primary progressive MS.

Table 3. Comparison of PTA thresholds across frequencies between study groups' ears*.

Frequency (Hz)	PTA threshold (dB HL)		P-value
	Case(n=120) Mean ± SD	Control(n=120) Mean ± SD	
250	14.04 ± 8.4	12.37 ± 6.2	0.083
500	15.75 ± 7.3	12.66 ± 6.1	0.001*
750	14.41 ± 6.4	12.29 ± 5.5	0.007*
1000	12.29 ± 6.2	11.87 ± 5.6	0.584
1500	13.87 ± 6.5	12.29 ± 5.2	0.039*
2000	15.37 ± 8.9	13.45 ± 6.6	0.059
3000	18.87 ± 10.2	14.00 ± 5.8	0.001*
4000	21.50 ± 10.7	14.16 ± 6.0	0.001*
6000	22.12 ± 10.6	14.50 ± 6.0	0.001*
8000	23.50 ± 12.1	15.16 ± 6.3	0.001*

* P-value < 0.05 is considered statistically significant. PTA: Pure tone audiogram.

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Table 4. Comparison of PTA thresholds across frequencies between study groups' ears by sex*.

Frequency (Hz)	Threshold (dB HL) Male			Threshold (dB HL) female		
	Case (n=34) Mean ± SD	Control (n=36) Mean ± SD	P-value	Case (n=86) Mean ± SD	Control(n=84) Mean ± SD	P-value
250	12.64 ± 9.3	12.91 ± 7.3	0.894	14.59 ± 8.0	12.14 ± 5.8	0.023*
500	14.41 ± 9.0	13.61 ± 7.5	0.689	16.27 ± 6.5	12.26 ± 5.5	0.001*
750	13.48 ± 8.1	12.22 ± 6.4	0.479	14.76 ± 5.7	12.32 ± 5.2	0.004*
1000	12.94 ± 7.6	11.94 ± 6.1	0.549	12.03 ± 5.6	11.84 ± 5.4	0.821
1500	15.29 ± 8.5	11.94 ± 5.9	0.062	13.31 ± 5.5	12.44 ± 4.9	0.278
2000	18.82 ± 11.6	12.63 ± 6.6	0.009*	14.01 ± 7.2	13.80 ± 6.6	0.849
3000	20.44 ± 12.1	13.88 ± 5.6	0.006*	18.25 ± 9.4	14.04 ± 5.9	0.001*
4000	23.67 ± 13.3	15.00 ± 5.7	0.001*	20.63 ± 9.4	13.80 ± 6.1	0.001*
6000	24.26 ± 12.7	15.13 ± 5.3	0.001*	21.27 ± 9.6	14.22 ± 6.3	0.001*
8000	27.05 ± 13.7	15.69 ± 5.4	0.001*	22.09 ± 11.2	14.94 ± 6.7	0.001*

* P-value < 0.05 is considered statistically significant. PTA: Pure tone audiogram.

Table 5. Comparison of PTA thresholds across frequencies in MS ears according to disease duration*.

Frequency (Hz)	PTA threshold (dB HL)		P-value
	< 5 years(n=60) Mean ± SD	≥ 5 years(n=60) Mean ± SD	
250	13.33 ± 7.6	14.75 ± 9.2	0.358
500	15.16 ± 6.4	16.33 ± 8.1	0.385
750	13.47 ± 5.5	15.33 ± 7.2	0.116
1000	12.33 ± 5.6	12.25 ± 6.7	0.941
1500	14.16 ± 5.9	13.58 ± 7.1	0.627
2000	16.91 ± 9.7	13.83 ± 7.8	0.057
3000	20.91 ± 11.9	16.83 ± 7.9	0.029*
4000	22.75 ± 12.2	20.25 ± 8.9	0.201
6000	22.33 ± 10.9	21.91 ± 10.4	0.831
8000	22.00 ± 12.2	25.00 ± 11.9	0.175

* P-value < 0.05 is considered statistically significant. PTA: pure tone audiometry, MS: Multiple sclerosis.

Table 6. Distribution of PTA abnormalities among MS ears by treatment status*.

MS drugs used	PTA		P-value
	Normal n(%) n=73	Abnormal n(%) n=47	
No treatment used	4 (40.0)	6 (60.0)	
First-line treatment	16 (50.0)	16 (50.0)	0.08
Second-line treatment	53 (67.9)	25 (32.1)	

* P-value < 0.05 is considered statistically significant. PTA: Pure tone audiometry.

DISCUSSION

The present study is the first to investigate the auditory profile of MS patients in Iraq, combining both subjective and objective audiological measures. The use of a comprehensive test battery, including PTA, ABR, and TEOAE, allowed the detection of both clinical and subclinical auditory pathway involvement. The findings demonstrated a frequent occurrence of auditory symptoms, elevated PTA thresholds, particularly at high and low frequencies, prolonged ABR absolute and IPLs, and subtle cochlear dysfunction revealed by TEOAE testing. Together, these results provide valuable insights into the impact of MS on the auditory pathway and highlight the importance of routine audiological evaluation in this population.

The current study revealed a high occurrence of auditory symptoms in MS patients, supporting a link to MS. Such a link is suggested by numerous studies; evidences were documented revealing a decreased auditory tolerance or hyperacusis, with the possibility of demyelination in the pons or central auditory pathway being responsible [10, 11]. Speech discrimination difficulty is well-reported in MS patients and is believed to originate from abnormal processing with dichotic listening tasks and temporal auditory processing [12, 13]. Tinnitus was reported in approximately half of the MS patients in this study. According to previous studies, tinnitus is a known accompanying symptom of hearing loss in MS [4, 14]. It is believed to originate from central nervous system demyelination, even in cases with clinically normal hearing, or from SNHL, a possible reported outcome of the disease process [15]. Nearly one-third of the case group complained of having hearing loss. Al-Rawashdeh et al. reported a similar rate of subjective hearing loss among MS patients, attributing it to poor speech perception, as the degree of hearing was only slight to mild [16].

This study supported the work of previous research that demonstrated a significant difference in audiometric thresholds between MS patients and controls. The MS group exhibited higher thresholds across all audiometric frequencies, with the most pronounced elevation being at the high and low frequencies. Other research, such as Al-Rawashdeh et al., indicated that individuals with MS had greater hearing thresholds across all frequencies, with the effect being most evident at the high and low frequencies [16]. Uçar et al. reported higher auditory thresholds in MS, particularly at high audiometric frequencies [17]. Rishiq et al. reported higher overall and high-frequency PTA averages in MS compared to controls [18]. In the assessment of 196 ears by Saberi et al., abnormal PTA was found in 15 MS ears, where 10 ears exhibited disturbances at high frequencies and 5 ears at low to mid frequencies [19]. In a scoping review conducted by MacMahon

Table 7. Comparison of ABR mean absolute latencies and IPLs between the study groups*.

ABR index	Side	Case group (n=60)	Control group(n=60)	P-value
Wave I	Right	1.57 ± 0.20	1.55 ± 0.17	0.546
	Left	1.56 ± 0.20	1.57 ± 0.16	0.586
Wave III	Right	3.79 ± 0.32	3.60 ± 0.12	0.001*
	Left	3.78 ± 0.36	3.62 ± 0.14	0.002*
Wave V	Right	5.71 ± 0.46	5.43 ± 0.13	0.001*
	Left	5.63 ± 0.75	5.39 ± 0.41	0.042*
I–III interpeak latency	Right	2.35 ± 0.74	2.06 ± 0.13	0.004*
	Left	2.17 ± 0.26	2.03 ± 0.17	0.001*
III–V interpeak latency	Right	1.93 ± 0.27	1.83 ± 0.14	0.018*
	Left	2.18 ± 0.81	1.84 ± 0.22	0.002*
I–V interpeak latency	Right	4.06 ± 0.57	3.86 ± 0.25	0.017*
	Left	4.19 ± 0.33	3.87 ± 0.21	0.001*

* P-value , 0.05 is considered a statistically significant difference. Values are expressed as mean ± SD. ABR: Auditory brainstem response.

Table 8. Comparison of TEOAE SNR values between the study groups' ears (Mann–Whitney U test)*.

Frequency (Hz)	group	TEOAE SNR (dB)			Mann-Whitney U test	
		Mean	SD	Median	Z	P-value
1000	Case	13.05	7.11	13.50	-1.039	0.299
	Control	12.37	4.19	13.40		
1500	Case	16.56	4.87	16.15	-0.049	0.961
	Control	16.24	5.46	16.15		
2000	Case	15.00	5.97	15.85	-2.406	0.016*
	Control	16.83	4.29	16.00		
3000	Case	12.78	7.27	13.70	-3.779	0.0001*
	Control	15.88	4.73	15.90		
4000	Case	11.06	10.13	10.75	-6.082	0.0001*
	Control	13.00	4.39	14.00		

* P-value < 0.05 is considered a statistically significant difference. TEOAE: Transient evoked otoacoustic emissions, SNR: signal-to-noise ratio.

et al., audiometric changes were noted across all frequencies from 0.25 to 8 kHz [4]. This effect of MS at different audiometric frequencies might suggest that the pathophysiology of the auditory effect of MS is caused by varying degrees of involvement of the inner ear, the eighth nerve, and the brain stem [16].

There is conflicting and limited evidence regarding PTA threshold changes based on sex differences in MS. Some studies report lower average thresholds among females with MS compared to males [20], in contrast other studies suggest improved hearing sensitivity at high frequencies among females with MS [21]. However, the current study demonstrated higher auditory thresholds in both low and high frequencies among females with MS, where as in males, only the high frequencies exhibited significantly higher thresholds than controls. These results are in agreement with Saberi et al., who reported a significant difference in PTA results between MS patients and controls, with the difference being significant in women, not in men, and the lower frequencies being more affected in females than males [19]. These sex-based differences may be attributed to several factors, such as hormonal influences, age, MS type, disease duration, and individual variability.

The current study also revealed that the duration of MS has no discernible impact on PTA thresholds, except for one frequency, 3 kHz, with higher auditory thresholds in individuals with less than five years of disease. These findings agree with previous studies that stated no association between disease duration and hearing loss in MS [16]. However, it contrasts with the findings reported by Rishiq et al., where PTA averages were found to be correlated with disease duration [18]. This pattern implies that rather than a gradual deterioration in hearing status, hearing impairments may have developed as acute occurrences. The higher thresholds at 3 KHz could indicate that this particular frequency is more sensitive to the demyelinating effects associated with the early stages of disease; however, further studies may be needed to support this hypothesis. The most common audiometric configuration among the MS group in the current study was flat, since hearing thresholds were elevated across all audiometric frequencies, which aligns with the previously mentioned studies. However, various configurations were reported by other studies [22].

The current study also reported similar rates of PTA ab-

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normalities among different subgroups of MS patients based on treatment status, suggesting no significant influence of the disease-modifying drugs of MS on PTA thresholds. These findings are in agreement with the only prior study on the topic, which investigated whether interferon β-1a, a first-line medication, can alter PTA thresholds and found statistical support that this drug has no ototoxic effects at frequencies between 0.25 and 6 kHz, although ototoxic effects at 8 kHz could not be ruled out [23]. Further studies are recommended to validate these findings.

The preservation of wave I latency on ABR testing, observed in the current study and other studies [18, 24], can be explained by its origin from the distal portion of the auditory nerve, making it less likely to be impacted by demyelination [24]. However, in the assessment of 40 MS ears by Kaytanci et al., significant prolongation of wave I was found in 12.5% of cases [25]. In contrast, the prolonged latencies of wave III and wave V are primarily due to the more central origin of these waves (from the brainstem cochlear nuclei to the inferior colliculus) [24]. Additionally, the observed prolongation of IPLs is caused by decreased transmission and synchronization of neural signals, which disrupts subcortical encoding [18]. Similar results of prolonged ABR latencies were reported in other studies [24, 26]. Although wave III, wave V, I-III IPL, and I-V IPLs showed no significant interaural variations, III-V IPL exhibited considerable asymmetry. This suggests unequal involvement of the central auditory pathways between the pons and midbrain, reflecting the patchy and focal nature of demyelination in MS [2]. The larger sample size in the current study may have increased the ability to detect subtle interaural differences that were not observed in prior studies with smaller sample sizes [24, 27].

Cochlear function assessment using TEOAEs revealed lower SNR values at the high frequencies in MS patients, suggesting cochlear subclinical dysfunction in these patients. These findings contrast with previous studies that reported no significant OAE differences between MS and healthy individuals [19, 25]. Additionally, Mauro et al. reported lower OAE amplitudes in the mid and low frequencies, but not in the high frequencies, in MS patients with normal hearing, pointing to the possibility of a subclinical dysfunction at a cochlear level among patients with RRMS [28].

Cochlear involvement in MS is believed to originate from microglial cells migrating into the inner ear. These microglial cells can convert into the aggressive M1 phenotype, causing demyelination of the cochlea, hair cells, spiral ganglion, and the cochlear nerve [4, 29]. Selective damage to the outer hair cells is believed to contribute to the alteration of OAE responses observed in MS [29]. Other proposed mechanisms are related to inflammation and demyelination affecting the medial olivocochlear bundle, or glutamate buildup and excitotoxicity, which can activate glutamate receptors on hair cells, triggering intracellular events that result in hair cell death [28]. Reduced OAE responses in MS patients can serve as a neurological marker of early cochlear dysfunction in this population, providing a potential non-invasive tool for monitoring the disease in MS.

Significant limitations of the current study include the inability to evaluate beyond conventional high frequencies due to the unavailability of extended PTA, as well as the unavailability of speech audiometry and the standardized Iraqi word list. Other limitations were the study design and the fact that it was a single-center study.

CONCLUSION

Hyperacusis, speech discrimination difficulties, tinnitus, and hearing loss are among the most frequently reported auditory complaints in MS. The disease tends to affect all audiometric frequencies, with a particular predilection for high and low frequencies. The peripheral auditory pathway appears to be subtly affected, particularly at high frequencies, underscoring the need for routine audiological testing in this population. Close follow-up with periodic evaluation using basic audiological tests is recommended for early detection and monitoring of clinical and subclinical auditory dysfunction in MS patients.

ETHICAL DECLARATIONS

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Ethics Approval and Consent to Participate

The study was conducted with ethical approval granted by the Scientific Committee of the Surgery Department at Mustansiriyah University, College of Medicine (Reference number 8040 on 8-10-2024), and Informed consent was obtained from all participants.

Consent for Publication

Not applicable (no individual personal data included).

Availability of Data and Material

Data generated during this study are available from the corresponding author upon reasonable request.

Competing Interests

The authors declare that there is no conflict of interest.

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Use of Artificial Intelligence

The authors used ChatGPT for minor language editing; all scientific content and data interpretation were done by the authors.

Authors' Contributions

N.M, E.Y., and M.T. structured the concept; N.M, E.Y., and M.T. structured the methodology and chose the materials; N.M, E.Y., and M.T. conducted data collection; N.M, E.Y., and M.T. did the analysis and interpretation of data; N.M, E.Y., and M.T. wrote the literature search; N.M, E.Y., and M.T. conducted manuscript writing; N.M, E.Y., and M.T. conducted critical reviews. All authors read and approved the final version of the manuscript.

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