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## ORIGINAL STUDY

# Auditory temporal processing abilities in patients with diabetes mellitus type 1 and type 2

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## Abstract

**Introduction:** Diabetes mellitus (DM) is most common chronic disease characteristic by carbohydrate metabolic disorder in which absolute or relative deficiency in insulin and various pathological changes in the body system. The central nervous system disorders is among system affected by toxic effect and hyperglycemia. Auditory temporal processing is one of the important abilities of the central nervous system which may be affected by diabetes. However, the extent and nature of the central manifestations are still unknown.

**Objective:** The aim of this study was to compare auditory temporal processing in these patients (DM type 1 and Type 2) with normal patients through temporal auditory processing tests: auditory fusion test-revised (AFT) which investigate the temporal resolution and gap detection, as well as Pitch Pattern Test (PPT) and Duration Pattern Test (DPT) for testing temporal ordering and sequencing of tonal stimuli.

**Patients and method:** This study was carried out on three groups of patients including 20 patients with DM type II, 20 with DM type 1 and 20 normal hearing patients not suffering from diabetes. Anova-test was used to compare the mean of numerical values between normal and DM patients and Pearson correlation coefficient test was used to check the correlation between age of patient and duration of diabetes on auditory temporal processing test.

**Results:** Statistically significant difference was found between DM type 2 and the two other groups for all tests of temporal processing.

**Conclusion:** Temporal resolution and temporal ordering is affected in individuals with DM type 2 compared with DM type 1 and control group, finding which is attributed to age and duration of diabetes in these patients.

**Keywords:** Auditory fusion test (AFT-R), Auditory temporal processing, Diabetes mellitus DM, Duration pattern test (DPT), PPT (pitch pattern test)

## 1. Introduction

Diabetes mellitus (DM) is one of most common chronic disease characteristic by carbohydrate metabolic disorder associated with pathological changes and failure of various organs especially the eyes, kidneys, nerves, heart, and blood vessels [1]. The inner ear dysfunctions in DM have been increased reports including dizziness, tinnitus, and hearing loss [2]. The pathological changes which responsible the inner ear dysfunctions in DM is microangiopathy [3,4] and on the participation of smaller vessels in the inner ear that leads to hypoxia and causes hearing loss [5,6].

Auditory temporal processing can be defined as the perception of sound or of the alteration of sound within a restricted or defined time domain. Temporal processing is the underlying component of most auditory processing capabilities. Strongly supporting this is that many characteristics involving auditory information are in some way influenced by time [7].

Type 1 Diabetes is one of the most common chronic autoimmune diseases in young adult that occurs as a result of destruction or damage to beta cells in the Langerhans. The pathological changes occurring in type 1 diabetes including insulin deficiency, hypoglycemia, as well as toxic effects of

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hyperglycemia which responsible for development of central nervous system disorders [8], whereas Type 2 diabetes known as adult onset diabetes is a form of diabetes that is characterized by high blood sugar, insulin resistance and relative lack of insulin [9].

Auditory temporal processing ability responsible for comprehension of speech which mainly depends on the integrity of temporal envelope, that is, on the temporal variations of spectral energy. For the identification of phonemes, syllables, words, and sentences depend on the information contain within temporal envelope [10].

The processing acoustic cues of speech sounds depends on the proper perception of the duration and frequency of stimuli and as a sequence of events [11]. In addition, perception of sounds sequence in the acquisition and temporal patterns of sound and the acoustic properties of speech and understanding of language limited to the basic components of duration and frequency [12].

The association between DM and its effects on peripheral hearing loss have been investigated in many studies [13]. On other hands, high prevalence of DM and its effect on auditory temporal processing abilities, there are few studies investigating these effect. Disorders phonemic discrimination caused by disorders spectral cues or temporal (timing) cues of speech [14]. Temporal aspects of audition include temporal resolution, temporal integration, temporal ordering and temporal masking [12].

## 2. Methods

### 2.1. Participants

For this study, we recruited 60 participants that provided their consent for participation in study.

Study was conducted in the Audio-Vestibular Department at Hearing and Speech Institute, a total number of 60 patients with age range of 18–60 years was included.

The control group (group A) consisted of 20 patients with bilateral normal peripheral hearing and free from any symptom of diabetes.

The study group consisted of 40 patients subdivided into two groups, group B (20 patients with DM type 2) and group C (20 patients with DM type 1).

### 2.2. Test environment

Testing was conducted in a sound treated room.

### 2.3. Instrumentation

We used a calibrated acoustic immittance meter (Interacoustics AZ26) with a probe tone 220 Hz, a

calibrated pure tone clinical audiometer (Inter acoustics model AC40) with headphones TDH39 and bone vibrator B71, and a Computer system with CD-Driver connected to the audiometer adjusted to deliver recorded speech material through loudspeakers adjusted at 40 dB sensation level.

### 2.4. Procedure

All patients were subjected to careful history taking, basic audiological evaluation including pure tone audiometry for both air conduction (for the frequency range 250–8000 Hz) and bone conduction (for the frequency range 500–4000 Hz), Speech reception threshold (SRT), Word discrimination score (WDS), immittancemetry and Temporal auditory processing tests including.

#### 2.4.1. The auditory fusion test-revised (AFT-R)

Auditory fusion test-revised AFT-R is intended to quantify temporal resolution through determination of the Auditory Fusion Threshold (AFT threshold) which measured in milliseconds (msec) and it is determined by the listener attend to a series of pure tones presented in pairs. The duration between each pair (the silent time interval or the interpulse interval, IPI) of tones increases and decreases. The listener indicate whether the stimulus pairs are heard as one or two tones. AFT threshold is the average of the interval at which pair of pairs are perceived as two (when the IPI is increasing) or as one (when the IPI is decreasing) [15].

#### 2.4.2. Pitch patterns test (PPT)

PPT is comprised of 60 sequences of three tones bursts with low (L) (880 Hz) and high (H) (1122 Hz) frequencies. Each of the tones has 10 msec rise time and 10 msec fall time and duration of each tone is 150 msec and 200 msec separate each tones within a sequences. This makes possible of six different tone sequences: HHL, HLH, HLL, LLH, LHL, and LHH. PPT assesses temporal ordering task and frequency pattern recognition in both hemispheres.

#### 2.4.3. Duration patterns test (DPT)

DPT is comprised of 60 sequences of three tones bursts with long (L) (500 msec) time and short (S) (250 msec) duration of the frequencies one of which is either longer or shorter than the other the two. The frequency of the test tone is constant at 1000 Hz, each tone has a rise time 10 msec and 10 msec fall time and 300 msec separate each tones within a sequences. This makes possible of six different tone sequences: LLS, LSL, LSS, SLL, SLS, and SSL.

### 2.5. Statistical analysis

Statistical analysis of the results was done using SPSS system (Statistical package for social sciences) (version 23), IBM Corporation, USA. As regards temporal auditory processing tests for both control and study groups Paired sample *t*-test and independent sample test were used.

SPSS system (Statistical package for social sciences) (version 23), IBM Corporation, USA were used for analysis the results. Regarding tests of temporal auditory processing for both control and study groups. Utilized were Paired sample *t*-test and independent sample test.

### 3. Results

The present study comprised 60 adult patients. The mean age for the control group (group A) was 39.65 years  $\pm$  1.66 years with an age range of 25–52 years. The mean age for the DM type 2 (group B) was 52.45  $\pm$  1.10 years with an age range of 44.00–60.00 and the mean onset of duration of DM in group B was 14  $\pm$  1.16 years. The mean age for the DM type 1 (group C) was 24.30  $\pm$  9.89 years with an age range of 18.00–33.00, and the mean onset of duration for DM in group C was 9  $\pm$  1.19 years. All patients had normal tympanograms (type A) normal acoustic reflex threshold and speech discrimination scores were matched with pure tone average.

In **Table 1**: Diabetes mellitus type 2 (group B) had sensorineural hearing loss at high frequencies from 2 through 8 KHz.

In **Table 2**: Diabetes mellitus type 2 (group B) had sensorineural hearing loss at high frequencies from 2 through 8 KHz.

**Table 3** showed statistically significant difference between control group (group A) and study group B (diabetes mellitus type 2) and no statistically significant difference control group and study group C (diabetes mellitus type 1) in all tests.

### 3.1. Effect of age on temporal auditory processing tests for study groups

The (**Table 4**) showed statistically significant age effect of diabetes mellitus type 2 on results of AFTR, PPT, and DPT.

Effect of duration of DM on temporal auditory processing tests for study group.

(**Table 5**) statistically significant effect of duration of diabetes mellitus on (type 2) on results of AFTR, PPT, and DPT.

### 4. Discussion

Perception of sound or alteration of sound within a restricted or defined time domain is defined as auditory temporal processing [15]. These ability include includes temporal resolution, temporal masking, temporal integration and temporal ordering. In the present study we assessed temporal resolution through AFT-R and temporal ordering through PPT and DPT.

Data were obtained from 60 adult patients with mean age for the control group (group A) 39.65 years  $\pm$  1.66 years with an age range of 25–52 years. The mean age for the DM type 2 (group B) was 52.45  $\pm$  1.10 years with an age range of 44.00–60.00 years. The mean age for the DM type 1 (group C) was 24.30  $\pm$  0.989 years with an age range of 18.00–33.00 years.

Group A and C had bilateral normal peripheral hearing and speech discrimination scores which were matched with pure tone average, on the other hands group B (DM type 2) had high frequency sensorineural hearing loss bilaterally at high frequencies from 2 through 4 KHz (**Tables 1 and 2**). These findings are in agreement with Konrad-Martin and colleagues [16] who reported a significant difference between the nondiabetic group and the diabetic group (adult onset) around 3 KHz with no difference with the more severe insulin dependent diabetes mellitus group (IDDM group).

Table 1. Pure tone threshold for right ears for three groups

Variable	Right ear								
	group A			group B			group C		
	Mean	SD.	Range	Mean	SD.	Range	Mean	SD.	Range
250 Hz	11	2.05	10–15	21.75	4.66	15–35	19.97	1.97	15–25
500 Hz	14	2.05	10–15	21.75	4.66	15–35	19.97	1.97	15–25
1000 Hz	14.5	1.53	10–15	21.75	4.66	15–35	19.97	1.97	15–25
2000 Hz	14.75	1.11	10–15	29.25	5.19	15–35	26.50	4.32	15–35
4000 Hz	15	0.000	15–15	34.00	5.28	20–40	19.50	2.23	15–25
8000 Hz	13.5	2.23	15–15	29.00	10.20	15–40	19.50	2.23	15–25

Table 2. Pure tone threshold for left ears for three groups

Variable	Left ear								
	group A			group B			group C		
	Mean	SD.	Range	Mean	SD.	Range	Mean	SD.	Range
250 Hz	11.75	2.44	10–15	20.00	5.38	15–35	18.00	2.99	15–25
500 Hz	15	0.00	15–15	20.25	5.72	15–35	18.00	2.99	15–25
1000 Hz	15	0.00	10–15	22.00	4.41	15–35	19.75	1.97	15–25
2000 Hz	15	0.00	10–15	27.25	5.25	15–35	19.50	223	15–25
4000 Hz	12.75	2.55	10–15	33.75	3.93	30–40	19.50	223	15–25
8000 Hz	13.75	2.22	10–15	37.70	4.29	30–49	19.50	223	15–25

Table 3. Anova test for all study groups

Anova for 3 groups									
Temporal auditory processing test	Group A		Group B		Group C		F	P value	
	Mean	S.D	Mean	S.Dà	Mean	S.De			
AFTR									
250 Hz	9.000	0.7779	18.500	1.6955à	11.250	0.666e	18.841	0.000	
500 Hz	13.500	0.6882	20.125	1.9574à	13.875	0.640e	8.811	0.000	
1000 Hz	11.500	0.6882	15.750	1.5925à	12.875	0.521e	4.299	0.000	
2000 Hz	11.500	0.8959	17.250	1.1312à	13.375	0.731e	9.855	0.000	
4000 Hz	12.375	0.7361	20.500	1.4577à	13.125	0.475e	20.906	0.000	
DPT									
Right	96.00	1.124	68.00	3.293à	89.50	1.352e	46.235	0.000	
Left	93.00	1.051	66.50	3.574à	89.50	1.352e	39.575	0.000	
PPT									
Right	95.00	1.147	58.50	3.101à	89.50	1.352e	91.024	0.000	
Left	92.50	0.993	56.00	3.509à	89.50	1.352e	81.403	0.000	

Martin and colleagues (2010) who reported that DM is associated with progressive bilateral sensorineural hearing loss (SNHL) of gradual onset, which mainly affect higher frequencies. SNHL were similar to age-related finding. They hypothesized that vascular insufficiency of the cochlea, main cause of hearing loss in DM patients. Uncontrolled hyperglycemia may result in vasculopathy of stria vascularis Musiek and colleagues [17]. In addition to

cochlear damage, microangiopathy is responsible damage in the stria vascularis, spiral ligament and oedema in stria vascularis leading to poor frequency and intensity coding Schroder and colleagues [18].

In the current study, Table 3 showed a statistically significant low scores for auditory temporal abilities in patients with DM type 2 compared with patients with DM type 1 and nondiabetic normal hearing patients. The present study showed poor

Table 4

Study groups						
Temporal auditory processing test	Group B		Group C		R	P value
	Mean	S.D	Mean	S.D		
AFTR						
250 Hz	18.500	1.6955	11.250	0.666	0.565	0.000 <sup>a</sup>
500 Hz	20.125	1.9574	13.875	0.640	0.393	0.012*
1000 Hz	15.750	1.5925	12.875	0.521	0.326	0.040*
2000 Hz	17.250	1.1312	13.375	0.731	0.430	0.006
4000 Hz	20.500	1.4577	13.125	0.475	0.562	0.000 <sup>a</sup>
DPT						
Right	68.00	3.293	89.50	1.352	-0.749	0.000 <sup>a</sup>
Left	66.50	3.574	89.50	1.352	-0.742	0.000 <sup>a</sup>
PPT						
Right	58.50	3.101	89.50	1.352	-0.833	0.000 <sup>a</sup>
Left	56.00	3.509	89.50	1.352	-0.833	0.000 <sup>a</sup>

No statistically significant difference (P value > 0.01). Results of temporal auditory processing tests (AFTR, PPT and DPT) in patient with diabetes mellitus type 2 affected by age of patient in addition to duration of diabetes.

\* Means statistically significant difference.

<sup>a</sup> Highly statistically significant difference (P value < 0.01).

Table 5

Study groups	Group B		Group C		r	P value
	Mean	S.D	Mean	S.D		
Temporal auditory processing test						
AFTR						
250 Hz	18.500	1.6955	11.250	0.666	0.374	0.017*
500 Hz	20.125	1.9574	13.875	0.640	0.165	0.310
1000 Hz	15.750	1.5925	12.875	0.521	0.246	0.126
2000 Hz	17.250	1.1312	13.375	0.731	0.434	0.005**
4000 Hz	20.500	1.4577	13.125	0.475	0.327	0.039*
DPT						
Right	68.00	3.293	89.50	1.352	−0.605	0.000**
Left	66.50	3.574	89.50	1.352	−0.581	0.000**
PPT						
Right	58.50	3.101	89.50	1.352	−0.408	0.009**
Left	56.00	3.509	89.50	1.352	−0.429	0.006**

Results of temporal auditory processing tests (AFTR, PPT and DPT) in patient with diabetes mellitus type 2 affected by age of patient in addition to duration of diabetes.

\* Means statistically significant difference.

\*\* Means highly statistically significant difference.

performance in temporal ability tasks for DM patients type 2 which revealed changes in the central auditory system. These agree with Mishra and colleagues [19], who reported poor temporal and auditory processing in individuals with DM. On the other hand Seraji and colleagues [8] reported a significant difference in the duration pattern test comparing the results of patients with DM type 1 and normal patients indicating a defect in the temporal auditory processing abilities in these individuals.

In the present study, in Tables 4 and 5 highly statistically significant differences was noticed for patients with DM type 2 compared with patients with DM type 1 as regard effect of age and duration of DM on temporal auditory processing tests. This may be related to side effect of hypoglycemia on poor performance of central auditory nervous system. These agree with McCrimmon and colleagues [20], who speculated that poor auditory temporal processing in individuals with DM due to hypoglycemia. On other hands, these findings which do not agree with Strachan and colleagues [21], who reported that in DM type 1, acute hypoglycemia causes deterioration in auditory processing abilities.

#### 4.1. Conclusion

Current study showed poor temporal resolution skills and temporal ordering in individuals with DM type 2 compared with DM type 1 and control group. Poor auditory temporal resolution and ordering in patient DM type 2 is related to the effect of age and duration of DM on these patients.

We would suggest routine screening of all DM patients for temporal resolution and ordering to understand the exact mechanism and plan for proper remediation.

#### Conflicts of interest

None declared.

#### Institutional Review Board (IRB) Approval Number

IRB: IHS00029.

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