

# Auditory Temporal Resolution in Individuals with Diabetes Mellitus Type 2

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## Abstract

**Introduction** “Diabetes mellitus is a group of metabolic disorders characterized by elevated blood sugar and abnormalities in insulin secretion and action” (American Diabetes Association). Previous literature has reported connection between diabetes mellitus and hearing impairment. There is a dearth of literature on auditory temporal resolution ability in individuals with diabetes mellitus type 2.

**Objective** The main objective of the present study was to assess auditory temporal resolution ability through GDT (Gap Detection Threshold) in individuals with diabetes mellitus type 2 with high frequency hearing loss.

**Methods** Fifteen subjects with diabetes mellitus type 2 with high frequency hearing loss in the age range of 30 to 40 years participated in the study as the experimental group. Fifteen age-matched non-diabetic individuals with normal hearing served as the control group. We administered the Gap Detection Threshold (GDT) test to all participants to assess their temporal resolution ability.

**Result** We used the independent *t*-test to compare between groups. Results showed that the diabetic group (experimental) performed significantly poorer compared with the non-diabetic group (control).

**Conclusion** It is possible to conclude that widening of auditory filters and changes in the central auditory nervous system contributed to poorer performance for temporal resolution task (Gap Detection Threshold) in individuals with diabetes mellitus type 2. Findings of the present study revealed the deteriorating effect of diabetes mellitus type 2 at the central auditory processing level.

## Keywords

- ▶ temporal auditory area
- ▶ diabetes complications
- ▶ auditory stimulation

## Introduction

Diabetes mellitus is a multisystem disorder. It is a disorder of carbohydrate metabolism which occurs because of absolute or relative insulin deficiency. Along with metabolic disturbance, various pathologic changes in the human body have been seen. Previous literature reported that the hearing impairment seen in diabetes mellitus is a progressive bilateral sensorineural hearing loss of gradual onset, which mainly affect higher frequencies,

similar to age-related hearing loss.<sup>1</sup> We also found that hearing loss may be unilateral, sudden, with and without vestibular disorder. Evidence showed that endolymphatic sac vasculature plays an important role in the pathogenesis of sensorineural hearing loss.<sup>2,3</sup> The main cause of hearing loss in diabetic patients is vascular insufficiency to the cochlea. Uncontrolled diabetes may cause vasculopathy in stria vascularis of the cochlea. Researchers have reported diffused thickening of basilar membrane observed in vascular endothelium, which is called

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diabetic microangiopathy.<sup>4,5</sup> Several studies also reported that microangiopathy is responsible for hearing loss in diabetic individuals<sup>6,7</sup> and on the participation of smaller vessels in the inner ear that leads to hypoxia and cause hearing loss.<sup>4,8</sup> Maia et al reported that diabetic neuropathy and microangiopathy can cause high frequency hearing loss.<sup>9</sup>

Moreover, hearing loss was present at all frequencies from 250Hz to 8000Hz in diabetic individuals.<sup>8</sup> Studies on hearing thresholds on subjects with diabetes revealed mild to moderate high-frequency sensorineural hearing loss,<sup>10</sup> whereas other studies showed higher thresholds in individuals with diabetes mellitus at all frequencies tested. Previous literature also reported no difference in speech discrimination scores among diabetic patients and the normal population.<sup>11</sup> A study by Bajaj et al reported poor speech perception in noise among diabetic patients.<sup>12</sup> Researchers also reported poor perception of speech in noise in individuals with high frequency hearing loss.<sup>13,14</sup> Poor perception of speech in noise in individuals with high frequency hearing loss may be due to poor auditory processing of the signal at a given frequency region due to loss of audibility.<sup>15</sup> Cochlear lesion can also affect intensity and frequency coding, as investigated by various researchers.<sup>16,17</sup> Previous studies have mostly been conducted with hearing loss evaluation and speech perception ability in diabetic populations.

There is a dearth of literature regarding auditory temporal resolution skill in individuals with diabetes mellitus with high frequency hearing loss. Temporal resolution refers to the ability of the auditory system to identify rapid changes in the envelop of a sound stimulus over time.<sup>18</sup> The Gap Detection Threshold (GDT) test is a valuable, cost effective tool to assess the ability of an individual to detect minimal small gap between two stimuli of equal characteristics. The GDT can be defined as the shortest duration of gap within a sound that individual can detect. This test is useful and cost effective in assessing auditory temporal resolution skill.<sup>19</sup> GDT have been used by previous researchers to study cortical lesion.<sup>20</sup> Musiek et al reported GDT is a valuable tool in assessing temporal resolution deficit in brainstem, as well as cortical lesions.<sup>21</sup> Therefore, the present study aimed to compare auditory temporal resolution skill in individuals with diabetes mellitus with high frequency hearing loss with age-matched normal hearing subjects by assessing Gap Detection Threshold (GDT) between the two groups (experimental and control).

## Methods

### Participants

For this study, we recruited thirty participants that provided their informed written consent. We divided them in two groups (Experimental and Control). The experimental group consisted of 15 individuals (8 men and 7 women) with diabetic mellitus type 2 in the age range of 30 to 40 years (mean age of 37.3 years). The control group, in turn, consisted of 15 age-matched non-diabetic individuals (8 men and 7 women) in the age range of 30 to 40 years (mean age of 38.1 years). The rationale behind selecting this age range was to avoid the effect of age related hearing loss.

### Participants Selection Criteria

All the participants in Group 1 (Experimental) had reduced hearing sensitivity (from mild to severe degree) in both ears as defined by pure tone thresholds greater than 15 dBHL at 2000, 4000, and 8000 Hz, with normal hearing sensitivity at 250, 500 and 1000 Hz. Slope was steep when higher than 25dB/octave. All subjects had normal middle ear functioning as revealed by an A-type tympanogram and presence of acoustic reflexes at all frequencies except 2000 Hz and 4000 Hz for both ipsi and contralateral stimulation. There was no history or presence of any other otological, neuromuscular, or neurological problem among both groups. Neither was there any history of noise exposure.

As for Group 2 (Control), all the participants had normal air conduction and bone conduction thresholds ( $\leq 15$  dB HL) at all octave frequencies from 250 Hz to 8000 Hz. They all presented normal middle ear functioning with A-type tympanogram at 226 Hz probe tone having normal acoustic reflexes (Ipsilateral and Contralateral) in both ears.

### Test Environment

We conducted all the tests in a sound treated.

### Instrumentation

We used a calibrated dual channel Madsen MA-53 clinical audiometer (Gn Otometrics A/S, Taastrup, Denmark) for pure tone audiometry. We used a calibrated GSI-Tympstar Immittance meter (GSI, Eden Prairie, U.S.A.) for tympanometry and reflexometry. We used a personal computer loaded with Matlab R 2011a software (Mathworks, Natick, U.S.A.) for GDT (Gap Detection Threshold).

### Procedure

Pure tone thresholds were obtained using modified versions of the Hughson and Westlake procedure (Carhart & Jerger, 1959) across octave frequencies from 250 Hz to 8000 Hz for air conduction and from 500 to 4000Hz for bone conduction.<sup>22</sup> We used the middle ear analyzer (GSI-Tympstar, Eden Prairie, U.S.A.) to carry out tympanometry using a probe tone frequency of 226 Hz and to obtain ipsilateral and contralateral acoustic reflexes thresholds at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. Gap detection threshold was assessed using 750 milliseconds gaussian noise including a gap in its temporal center. Gap duration varied according to listener performance using maximum likelihood procedure. The noise had 0.5 milliseconds cosine ramps at the beginning and end of the gap. In the three alternative forced choice task, the reference stimulus was always a 750 milliseconds white noise without gap, whereas the variable stimulus contained a gap. We took the minimum gap duration required to perceive a gap in noise as threshold.

### Statistical Analysis

We conducted descriptive statistics to find mean and standard deviation of GDT of the groups. We used an independent *t*-test to compare between the experimental and the control group for GDT.

**Table 1** Mean and SD of gap detection threshold (GDT) for Group 1 (experimental) and Group 2 (control)

Measures	Groups			
	Group 1 (Experimental)		Group 2 (Control)	
	Mean	SD	Mean	SD
GDT (ms)	6.49	0.81	3.33	0.79

Abbreviation: GDT, gap detection threshold; SD, standard deviation.

## Results

In the present study all participants underwent Gap Detection Threshold test. We analyzed the data using SPSS software Version 18 (IBM Corporation, Armonk, U.S.A.).

### Gap Detection Threshold (GDT) Test

We conducted the GDT test for both groups. ►Table 1 shows mean and standard deviation (SD) of gap detection threshold. Descriptive statistical analyses showed that GDT was better for Group 2 when compared with Group 1. ►Fig. 1 shows a graphical presentation of the outcome.

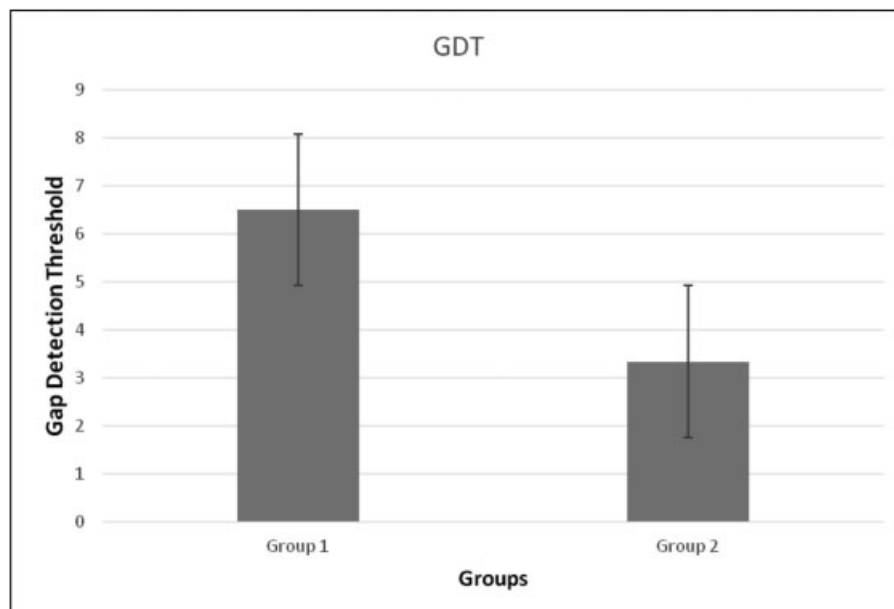
We administered the independent *t*-test to compare GDT between two groups. It showed a statistically significant difference between the groups ( $t = -7.82$ ;  $df = 28$ ;  $p < 0.05$ ).

## Discussion

The results of the present study showed poor auditory temporal resolution skill in patients with diabetes mellitus type 2 having high frequency hearing loss compared with age matched non-diabetic normal hearing subjects. The present study revealed a statistically significant difference in GDT between patients with diabetes mellitus type 2 having high

frequency hearing loss (Group 1) and age-matched non-diabetic normal hearing subjects (Group 2). Absence of the specific literature on GDT in diabetic individuals renders it difficult to explain the result found in the present study. However, widened auditory filter at higher frequencies and poor central auditory processing due to diabetes mellitus type 2 could be a possible explanation for poorer gap detection task.

The present study showed poor performance in temporal resolution task by diabetic patients which revealed changes in the central auditory system. Previous studies on diabetic humans and rats showed hearing impairment mainly caused by edema in stria vascularis and reduction in number of spiral ganglion cells and outer hair cells.<sup>23-25</sup> Hearing loss in HF region suggests that the cochlea may have been damaged by angiopathy in the stria vascularis, spiral ligament, and edema in the stria vascularis, which leads to poor frequency and intensity coding.<sup>16,26,27</sup> Previous literature reports poor auditory brainstem response with prolonged latencies of wave III, V and inter-peak I-III in diabetic population. Prolonged latencies were also noted for wave V and inter-peak III-V, inter-peak I-III, and I-V in diabetic individuals at 90 dBnHL.<sup>28</sup> This possibly suggests the involvement of the relay stations of different order neurons in the central auditory nervous system. The present study supports the study done by McCrimmon et al, which also reported poor temporal and auditory processing in individuals with diabetes mellitus.<sup>29</sup> A similar study done by Sommerfield revealed that tests of immediate verbal and immediate visual memory were significantly poor during hypoglycemia.<sup>30</sup> The adverse effect of hypoglycemia on working memory and delayed memory was more profound. The present study's findings showed poor temporal resolution skill can be due to widening of auditory filter and changes in the central auditory nervous system contributing to the poorer performance on the temporal resolution task in diabetic individuals.

**Fig. 1** Mean values of Gap Detection Threshold (GDT) for Group 1 (Experimental) and Group 2 (Control).

## Conclusion

Present study findings showed poor temporal resolution skills in individuals with diabetes mellitus type 2 compared with control group. Poor auditory temporal resolution may cause poor speech perception in these individuals in quiet, as well as in noise. Findings revealed the deteriorating effect of diabetes mellitus type 2 at the central auditory processing level. Thus, we would suggest screening all patients with diabetes for temporal resolution ability to understand the mechanism underlying speech perception in noise.

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