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RESEARCH ARTICLE

Evaluation of dichotic hearing in type 2 diabetic patients

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Abstract

Background and Aim: Diabetes mellitus is a metabolic disease in which various organs of the body, including the ears, are involved. In this regard, less research has been conducted on the auditory system, especially in its central part. Regarding the high prevalence of diabetes and the lack of evaluation of dichotic hearing, this study aimed to assess the dichotic hearing system in people with type 2 diabetes (T2D) without neuropathy using the staggered spondaic word (SSW) test and dichotic digit test (DDT).

Methods: This study included 28 individuals with T2D without neuropathy who were diagnosed according to the protocol of American Diabetes Association (2014) and 24 healthy subjects aged 20 to 60 years old of both genders. Participants were evaluated using spondaic words test and normalized Persian version of the DDT.

Results: The mean and qualitative data in SSW and right ear score, left ear score, and ear advantage were compared between two groups in the DDT test. The results showed that the subjects with T2D, except for ear advantage in DDT test, have a significant difference with the normal group.

Conclusion: Dichotic hearing processing in patient with T2D without neuropathy has a poor function, and, in particular, affects the temporal lobe and brainstem regions.

Keywords: Staggered spondaic word test; dichotic digit test; type 2 diabetes mellitus; neuropathy; dichotic auditory processing

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Introduction

Diabetes mellitus is a chronic metabolic disease that has a destructive effect on various organs of the body, including the auditory system. A limited number of works have been done in diabetic patients about their auditory system, especially the central auditory system [1].

There are various types of diabetes mellitus. Type 1 diabetes is autoimmune that occurs because of the destruction of β-pancreatic cells. Type 2 diabetes (T2D) in the second type of diabetes in which metabolism and insulin uptake are impaired and hereditary background is important. Finally, the third one is gestational diabetes, which is one of the most important types of diabetes. The other types of diabetes

are rare and idiopathic [2].
The prevalence of diabetes varies from region to region [3]. It is estimated that by the year 2022 there will be 300 million of diabetes patients in the world that are twice as likely to be present [4].
Over the past decade, several epidemiological studies have been carried out on the prevalence of T2D in Iran, according to which the T2D population is estimated to be more than 1.5 million people in this country. The results of these studies indicate that the prevalence of T2D in Tehran, the capital city of Iran, and its surrounding areas is between 7-8% [5].
Research has shown that the impact of diabetes on the auditory system is beyond the pure sound auditory threshold as it affects the central auditory system. It has been determined that diabetes affects brain auditory responses and requires neuropsychological and electrophysiological methods to investigate upper and lower levels of central and cognitive disorders [6].
The presence of both peripheral and central hearing loss affects the lives of people with diabetes, and 50% of those with over 40 years of age experience hearing loss. Hence, improving the quality of life and monitoring the auditory system in these people is of high significance [7].
One of the most commonly used central examinations to assess auditory processing is the spondaic word test. This test is a binaural integration test that can evaluate the brain, cortex, and corpus callosum [8].
A dichotic hearing test has been also developed for examining the central auditory processing system [9]. This test is sensitive to abnormalities of the central auditory system [9], brainstem disorder, cortical, and subcortical disorders, and disturbances between the hemispheres. It is also a quick and easy test [10].
In studies that specifically focus on specific aspects of hearing processing, for example Konrad et al., who reviewed noise perception in patients with T2D, and Mishra et al., who studied temporal processing in people with T2D, diabetic people have shown a significant differences in auditory performance with normal people [11,12].
Regarding the high prevalence of diabetes and the lack of evaluation of dichotic hearing in diabetic patients, this study aimed to evaluate the dichotic hearing system in patients with T2D without neuropathy and with speech discrimination score (SDS) of more than 90% using the spondaic word test and double dichotic digit test.

Methods

The inclusion criteria of the present cross-sectional study were having T2D without neuropathy, being within the age of 20 to 60 years of age, having a history of diabetes less than 10 years, being right-handed, normal, and lack of epilepsy, migraine, other diseases of the central nervous system (CNS), stroke, anesthesia, neuropathy, history of head trauma, tinnitus, seizure cardiovascular disorders, symptoms of cerebrovascular accidents, history of exposure to high levels of noise, history of taking ototoxic drugs such as reserpine, alpha methyl dopa, phenytoin or nitrofurantoin, ear infections, and other diseases of the ear conductive or sensorineural systems, lack of use of drugs affecting the CNS 48 hour before the test, and having an SDS score above 90%. The exclusion criteria were a history of severe blood glucose drop leading to hospitalization, fatigue during the tests, and reluctance to cooperation.
Initially, according to the latest US Diabetes Association protocol (2014), an endocrinologist was asked to identify the following issues in the subjects: 1) to record at least one randomized glucose level above 200 mg/dl with classical diabetes symptoms 2) a fasting plasma high blood sugar equal or above 126 mg/dl (fasting means 8 h of not consuming any calories before performing the test), 3) hemoglobin HbA1C above 6.5, and 4) the result of a 75-gram oral glucose tolerance test of 200 mg/dl [4].
Neuropathy was also diagnosed by a specialist physician using diabetic neuropathy symptom (DNS) questionnaire. The questionnaire includes sensory neuropathy and cartilage examination using a 10 g Semmes-Weinstein monophilament, 128-Hz tuning fork, assessing the sen-

sation of surface pain by strength sensing a collision, pinprick object, muscle test, reflex examination of head and neck muscles and quadriceps, and Achilles muscles of the left and right lower extremities. An overall score of 6 means the presence of neuropathy [4]. Otoscopy examinations were performed to determine the normal status of the external ear canal and tympanic membrane. Tympanometry was performed by the Danplex tymp produced in Denmark 87 and pure tone audiometry (PTA) was carried out at octave frequencies of 250-8000 Hz with a two channel clinical audiometer (Interacoustic AC40, Denmark) to examine the hearing status of the subjects. The maximum threshold of 25 dB at frequencies of 250-8000 Hz, the tympanogram of type A, and acoustic reflex with a threshold of less than 100 dBHL were considered normal; otherwise, the subjects were considered with the peripheral hearing loss. All tests were conducted in an acoustic room in Audiology clinic, School of Rehabilitation, Tehran University of Medical Sciences. The evaluation of the equipment (calibration) was carried out at the beginning of each session to ensure correct signal guidance, channel balance, and volume settings. The Staggered Spondaic Word (SSW) is a dichotic test in which spondaic words are used as stimuli. This test consists of 40 items that are at 50 dB above the speech threshold. Each term consists of two spondaic words. In addition to the meaning of spondaic words, it also means independently in each item. The first and last syllabi of each item should also form a meaningful spondaic [13].

The interpretation and calculation of the SSW are based on 8 cardinal numbers, which represent the sum of errors in eight states [13]. Following the preparation and training of the participants, the headphones were placed on the ears and then the Persian version of the SSW test was presented at the most comfortable level (MCL). After doing the test, the SDS was reduced from the raw SSW results and the corrected SSW (C-SSW) was calculated, followed by verifying the ear effect and the type and reversal of the sequence and type, and all of the samples. The quantity method of SSW includes C-SSW scores, and the response bias is attributed to quality method. The response bias includes reversals (the order of repeating words inverse to what had been heard, >2 errors is, considered abnormal), ear effect (comparing total errors when beginning the item from right ear with when beginning from the left ear, if the difference is more than 5 errors it will be considered abnormal), type A pattern (one of the eight cardinal numbers in columns B or F is twice as large as each of the others, and there are at least two or three differences), and type B pattern (one of the eight cardinal numbers in columns C or G is twice as large as each of the others, and there are at least two or three differences) [14].

After a short rest, the Persian version of the double dichotic digit test (DDT) was done on the samples. In this test, the scores of the right ear, the left ear, and the ear advantage were evaluated [15]. The numbers were delivered simultaneously to both ears via a two channel audiometer connected to the player via CD Player at the most comfort level (MCL). The patients were instructed as follows: Two numbers will be presented in each of your ears at the same time. Repeat each of the four numbers. If you are not sure about the number please guess. Individuals' responses were recorded on the score sheet regardless of the sequence of numbers. The right ear and left ear scores were calculated for each listening situation in percentage. The ear advantage was achieved by subtracting the left ear score from the right ear. The positive ear advantage indicated the advantage of the right ear and the negative ear advantage signaled the advantage of the left ear [14].

The blood glucose levels were measured by GlucoDr glucometer before testing to ensure that people did not lose blood sugar.

The data collected in this research were analyzed using descriptive statistics methods for calculating central inclination (mean and standard deviation), dispersion indices (range of changes), and determining the interval of confidence. Independent t-test was used for analytical operations after assuring the normal distribution of data using K-S test. The confidence interval

in this study was 95%. Also, Fisher's exact test was used to compare the frequency of qualitative variables between the two groups. The correlation between parameters of DDT and SSW and age, duration of diabetes, blood glucose, and HbA1C was examined using the Spearman and Pearson test.

Results

In this study, 28 subjects with T2D without neuropathy, measured blood glucose, and without glucose drop and 24 normal individuals all being 20 to 60 years of age were evaluated using DDT and SSW. The mean (standard deviation) age of participants in the normal individuals and patients was 33.51 (SD=12.86) and 48.69 (SD=7.56) years, respectively. They were also both male and female (5 females in the normal group and 8 females in T2D group. The HbA1C test results showed the lowest and highest levels of HbA1C 6.7 and 11 with a mean of 8.3 (SD=1.41) in T2D group.

Using glucometer, the blood glucose levels were measured before and after the test in both groups to ensure that blood glucose did not drop. The lowest and highest blood glucose levels in the two groups of normal and T2D were 82 and 103 and 109 and 348 mg/dl, respectively. The mean (SD) blood glucose in the normal and T2D groups was 87.22 (SD=9.23) and 18.19 (SD=49.47), respectively.

The correlation between quantitative and quantitative parameters of SSW and DD tests was investigated with the level of blood glucose, age, HbA1C, and duration of T2D in T2D group. The correlation level was significantly higher in all cases except for the ear advantage (Table 1).

Also, the correlation with these cases was significantly higher in this study (Table 2). The frequency of the ear effect, order effect, type and reversal in the two groups of normal, and T2D were as follows: Normal group did not show any of these, but the T2D group showed ear effect in 6, order effect in 8, type A in 1, type B in 3, and reversals in 11 participants. P-values of these parameters in comparison to two groups were 0.01, 0.00, 0.04, 0.2, and 0.03, respectively.

In this research, the DDT was also used to examine the dichotic hearing system as a test that examines this part of the auditory processing. In this test, factors such as right ear score left ear score, and the degree of advantage of the ear was evaluated. The mean, standard deviation, and minimum and maximum data in both groups are shown in Table 3.

The quantitative results in SSW in T2D group were significantly higher than the normal group. The frequency of ear effect, order effect, reversal, and type T2D group was significantly higher than that in the normal group; with p value in all cases being greater than 0.05. The summed score of two ears was also mild in people with T2D. Furthermore, DDT test results were found to be abnormal in the T2D group. In the left and right scores of this test, there is a significant difference between the two groups, but there was no significant difference in the level of the advantage of the ear. As shown in Table 3, in the right and left ear score, the p-value was greater than 0.05, while the advantage of the ear was less than 0.05.

Discussion

The aim of this study was to investigate dichotic hearing loss in patients with T2D without neuropathy using SSW and DD tests. Overall, the results of the study indicated a significant difference in the quantitative and qualitative results of the SSW test between T2D patients and normal subjects, and the total number of ears in diabetic patients is in a mild range. In the DDT, the right and left ear scores differ significantly in subjects with T2D and normal subjects ($p<0.05$); however, the DDT score in T2D patients does not have a significant difference with normal people ($p> 0.05$).

In patients with diabetes, a weakness in the both ear scores was observed, while in the right ear advantage, there was no significant difference with the normal group, indicating the left temporal lobe disorder. It is consistent with our finding that the SSW reversals, ear effect, and order effect in diabetic patients were also greater than those in the normal group [14]. The presence of a c-SSW error in patients with T2D

Table 1. The correlation coefficient between age, blood glucose, HbA1C, and duration of type 2 diabetes and the quantitative measures of the staggered spondaic word and dichotic digit tests in type 2 diabetic patients (n=28)

	DDT						SSW											
	Ear advantage		LE score		RE score		RNC		RC		LC		LNC		TEC		LE		RE	
	r	p	r	p	r	p	r	p	r	p	r	p	r	p	r	p	r	p	r	p
Age	-0.11	0.09	0.71	0.03	0.64	0.03	0.71	0.01	0.68	0.03	0.79	0.001	0.41	0.02	0.62	0.04	0.75	0.005	0.52	0.02
Glucose	0.18	0.21	0.69	0.01	0.60	0.006	0.69	0.01	0.58	0.03	0.65	0.01	0.62	0.02	0.62	0.04	0.64	0.01	0.77	0.01
HbA1C	-0.07	0.08	0.54	0.02	0.59	0.02	0.72	0.01	0.52	0.01	0.89	0.02	0.72	0.01	0.62	0.02	0.81	0.01	0.72	0.02
Duration	-0.04	0.15	0.62	0.01	0.57	0.03	0.74	0.005	0.57	0.009	0.52	0.03	0.64	0.02	0.57	0.02	0.53	0.02	0.64	0.03

DDT; dichotic digit test, SSW; staggered spondaic word; LE; left ear, RE; right ear, RNC; right non-competing, RC; right competing, LC; left competing, LNC; left non-competing, TEC; total, ear, condition

Table 2. The correlation between age, blood glucose, HbA1C, and duration of type 2 diabetes and qualitative measures of the staggered spondaic word test, in Type 2 diabetic patients (n=28)

	Type		Reversal		Order effect		Ear effect	
	r	p	r	p	r	p	r	p
Age	0.61	0.03	0.61	0.01	0.52	0.04	0.72	0.006
Glucose	0.46	0.02	0.53	0.01	0.88	0.01	0.58	0.01
HbA1C	0.72	0.04	0.57	0.03	0.55	0.01	0.61	0.03
Duration	0.55	0.03	0.50	0.02	0.59	0.02	0.66	0.02

also indicates brain stem injury [16].

In previous studies, a dichotic hearing has not been studied in diabetic patients. Accordingly, in this section, the results of this study are compared with ongoing research on people with diabetes. For this purpose, we tried to find out that people with hearing impairment in the normal range to avoid the impact of peripheral hearing loss on the central test results.

In this connection, Durmus et al. studied on insulin -dependent and -independent diabetes patients with normal hearing. They concluded that the latency of I, III, and V waves in diabetic patients was longer than that of the normal ones. The absolute latency of wave I and inter-wave latency of I-III, III-V, and IV in two groups including insulin dependent and independent subjects show a significant difference. The increased thresholds of auditory brainstem response (ABR) waves has been considered as an indication of hearing the loss in people with diabetes, which is why the periodic examination of patients was necessary [17]. The results of Dąbrowski et al. were similar to those of the results of the ABR and otoacoustic emission (OAE) tests in normal people with diabetes. They performed PTA, transient evoked otoacoustic emissions (TEOAEs), and ABR on 31 diabetic patients with no hearing impairment and showed that PTA at high frequencies was significantly higher than normal subjects, while the mean range of TEOAEs was lower and the latency of the V wave and the IV intermittent spacing were longer than those of normal people, which had a reverse relationship with the duration of diabetes [18]. Bajaj et al. [19] examined the speech perception of people with T2D in the presence of noise using the quick speech in noise (SIN) test and concluded that patients who had been particularly over five years of age had a significant decline in perception. They explained this result by the effect of this disease on the central auditory system. Silva et al. [7] examined the threshold of speech and silence in people with diabetes, regardless of their type. They also showed that people with diabetes have worse outcomes. Mishra et al. examined hearing impairment of 15 people with T2D with high-frequency hearing loss using the gap detection threshold and showed a significant difference between these patients and normal people, suggesting the impact of diabetes on the central auditory system. This result is consistent with the results of the present study [12].

Effects of age, T2D, glucose, and HbA1C on the SSW test were also assessed in the present study. The results show that with increasing the number of cases, the errors in patients were increased and people showed poor performance. Elsewhere Xipeng and Hou examined the effect of HbA1C and the duration of the disease on their auditory findings on diabetes patients on the peripheral and CNS, all of which have reached the same conclusion. Considering the results of these studies and the present study, it can

Table 3. Mean, standard deviation and minimum and maximal values of correct- staggered spondaic word and dichotic digit tests in both groups of type 2 diabetes (n=28) and normal (n=24)

Measures		T2D group			Normal group			95% Confidence Interval of the Difference		
		Mean (SD)	Min	Max	Mean (SD)	Min	Max	Lower	Upper	p
C-SSW	RNC	7.91 (4.51)	-2.5	15.0	0.52 (2.48)	-5.0	7.5	2.36	5.23	0.002
	RC	5.63 (3.62)	-5.0	10.0	0.60 (1.88)	-2.5	5.0	0.42	3.55	0.004
	LC	5.72 (3.80)	-2.5	10.0	0.95 (2.16)	-5.0	10.0	1.24	2.20	0.01
	LNC	6.81 (2.59)	-2.5	10.0	1.20 (3.44)	-2.5	5.0	0.59	2.34	0.02
	RE	6.73 (3.90)	0.00	12.50	0.59 (4.82)	-2.5	7.5	0.34	1.25	0.00
	LE	6.27 (3.43)	-2.5	12.00	1.02 (3.10)	-5.0	7.5	0.28	4.90	0.01
	TEC	6.23 (5.10)	-5.0	10.00	0.87 (2.74)	-5	5	0.10	2.10	0.02
DDT	RE score	78.03 (6.33)	68	92	98.65 (2.33)	90	100	1.69	5.22	0.01
	LE score	76.65 (7.02)	62	88	93.75 (2.88)	84	96	-9.76	-8.74	0.00
	Ear advantage	4.41 (1.78)	-4	6	4.56 (1.21)	2	6	0.05	1.47	0.07

T2D; type 2 diabetic, C-SSW; correct- staggered spondaic word, RNC; right non-competing, RC; right competing, LC; left competing, LNC; left non-competing, RE; right ear, LE; left ear, TEC; total, ear, condition, DDT; dichotic digit test

be concluded that with increasing age, the duration of T2D, the level of blood sugar, and HbA1C, the destructive effect of diabetes on the CNS are aggravated. Therefore, the neural cells and the central auditory system are affected, which makes the patients week in responding to dichotic examinations [20,21].

Periodic diabetes control is emphasized with the use of HbA1C test and also regular blood glucose measurements in fasting state and two hours after food eating by using glucometer device. HbA1C levels less than 7.5 means good control in the affected population and the goal of controlling T2D is to reach that level [2].

Conclusion

The results of SSW and DD tests, which are the perfect tests to examine the central area of auditory system, suggest that T2D affects the dichotic hearing system. Moreover, it is seen that all the specifications of the tests, except for the degree of advantage of the ear in the DDT, are weakened in people with T2D and the magnitude of the errors is significantly increased. Considering the decrease in scores in the DDT and the increased frequency of ear effect, order effect, and reversal in patients with T2D and the fact that the total number of ears in this group is in a mild range, it can be concluded that the probability of injury in temporal lobe of the brain is increased in T2D patients. Hence, it is of high importance to monitor the central processing of hearing, especially dichotic processing, in people with T2D and disease control to prevent increased damage to the auditory system's neurons in various grades.

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Conflict of interest

The authors declared no conflicts of interest.

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