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ScienceDirect
Journal of Otology xx (2017) 1–7
www.journals.elsevier.com/journal-of-otology/

Impairment of extra-high frequency auditory thresholds in subjects with elevated levels of fasting blood glucose

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Received 30 August 2017; revised 9 October 2017; accepted 17 October 2017

Abstract

This study was performed to assess whether there is an association between elevated Fasting Blood Glucose (FBG) and hearing impairment in Bangladeshi population. A total of 142 subjects (72 with elevated FBG; 70 control) were included in the study. The mean auditory thresholds of the control subjects at 1, 4, 8 and 12 kHz frequencies were 6.35 ± 0.35, 10.07 ± 0.91, 27.57 ± 1.82, 51.28 ± 3.01 dB SPL (decibel sound pressure level), respectively and that of the subjects with elevated FBG were 8.33 ± 0.66, 14.37 ± 1.14, 38.96 ± 2.23, and 71.11 ± 2.96 dB, respectively. The auditory thresholds of the subjects with elevated FBG were significantly ($p < 0.05$) higher than the control subjects at all the above frequencies, although hearing impairment was most evidently observed at an extra-high (12 kHz) frequency. Subjects with a long duration of diabetes (>10 years) showed significantly ($p < 0.05$) higher level of auditory thresholds at 8 and 12 kHz, but not at 1 and 4 kHz frequencies, compared to subjects with shorter duration of diabetes (≤10 years). In addition, based on the data of odds ratio, more acute impairment of hearing at the extra-high frequency was observed in diabetic subjects of both older (>40 years) and younger (≤40 years) age groups compared to the respective controls. The binary logistic regression analysis showed a 5.79-fold increase in the odds of extra-high frequency hearing impairment in diabetic subjects after adjustment for age, gender and BMI. This study provides conclusive evidence that auditory threshold at an extra-high frequency could be a sensitive marker for hearing impairment in diabetic subjects.

Keywords: Fasting blood glucose; Hearing impairment; Auditory thresholds; Extra-high frequency

1. Introduction

Diabetes mellitus, commonly known as diabetes, is a group of metabolic diseases that affect insulin production or impair the sensitivity of cells to insulin leading to an increase in blood sugar (Gardner and Shoback, 2011). A nationwide survey in Bangladesh estimates that around a tenth of the adult population suffer from this chronic disease (Akter et al., 2014). Diabetes is perhaps the single most important metabolic disease that can affect almost every organ system in the body. Diabetes-mediated complications related to organ dysfunction include heart and blood vessels, eyes, kidneys, nerves, pancreases, limbs etc (Martins, 2015). Despite enormous progress in research on diabetes-related complications, the relationship between diabetes and hearing impairment still remains controversial.

Hearing loss is regarded as a communication disorder, which is not directly life threatening, but may impair quality of life due

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Peer review under responsibility of PLA General Hospital Department of Otolaryngology Head and Neck Surgery.

https://doi.org/10.1016/j.joto.2017.10.003

to social withdrawal, loss of confidence, and increased frustration and anxiety (Huang and Tang, 2010). Hearing organs generally undergo aging-associated degenerative changes and the process of aging is considered as the most frequent cause of hearing loss in adults worldwide (Wilson et al., 1999; Cruickshanks et al., 1998; Smith et al., 2011). In addition to aging, a variety of environmental factors including noise exposure, lifestyle, use of MP3 player, medication, cigarette smoking may also cause hearing impairment (Kim et al., 2009; Mohammadi et al., 2010; Kim, 2010; Ohgami et al., 2011; Sumit et al., 2015). Numerous studies have evaluated the relationship between diabetes and hearing loss; however, the findings are not always consistent. Several studies showed a positive correlation between diabetes and hearing impairment (Kurien et al., 1989; Ferrer et al., 1991; Mitchell et al., 2009; Diniz and Guida, 2009; Bainbridge et al., 2010; Jang et al., 2011; Forogh et al., 2013), while others failed to confirm such association (Sieger et al., 1983; de Espana et al., 1995; Dalton et al., 1998).

It is worth mentioning that most research showing a relation between diabetes and hearing loss are limited to older people. In addition, most previous studies suggest that persons with diabetes undergo hearing impairment at low/mild or high frequencies (Kakarlapudi et al., 2003; Bainbridge et al., 2010; Rajendran et al., 2011; Jang et al., 2011; Lin et al., 2012; Agarwal et al., 2013; Oh et al., 2014), but not at an extra-high-frequency. More research is therefore necessary to examine whether or not hearing at extra-high-frequency auditory thresholds is impaired in a wider age group of people with diabetes. This study was conducted for the first time to examine a relationship between elevated Fasting Blood Glucose (FBG) and hearing impairment among Bangladeshi population. For this purpose, 142 subjects of different ages were included in this study, among them 72 had elevated FBG levels and the remaining 70 were control. The audiometric measurement was done in three frequency groups: low frequency (1 kHz), high frequency (4 and 8 kHz), and extra-high-frequency (12 kHz). The correlation between diabetes and hearing impairment was analyzed using blood sugar level and the mean ± S.D values of auditory thresholds of the subjects. The study also attempted to find if there was any association between hearing impairment with duration of diabetes, age, gender and body mass index (BMI).

2. Materials and methods

2.1. Study subjects

This study was conducted among 142 subjects who agreed in writing to participate in this study. The subjects with elevated FBG (≥7.0 mmol/L or ≥126 mg/dL) were considered as diabetic and 72 of them were included in this study. The FBG levels of the participants were measured at a local diagnostic center in Dhaka, Bangladesh. Subjects were selected randomly and their ages were between 21 and 64 years. We excluded those subjects who had a previous history of ear diseases or deafness and suffered from other illnesses at the time of conducting this study. Age and sex matched non-diabetic apparently healthy subjects were included as controls (FBG <6.1 mmol/L or <110 mg/dL). Furthermore, there was no specific predilection for race, religion or socioeconomic status. Ethical issues were considered for all of the experiments. The study was approved by the Ethical Review Committee of the Faculty of Biological Sciences, University of Dhaka (Ref. no. 02/BioSci/2015–2016). Data were collected using a self-reporting questionnaire including duration of diabetes as well as demographic information such as age, gender, height and weight of the participants.

2.2. Measurement of hearing level

Hearing levels of all the participating subjects were measured at 1, 4, 8 and 12 kHz frequencies. The audiometric examination was performed in a sound-proof room using a sophisticated iPod with earphones as described previously (Van Tasell and Folkeard, 2013; Sumit et al., 2015). Sound signals at 1, 4, 8 and 12 kHz frequencies were presented to each subject until the threshold of sound that the subjects were just able to perceive was identified. Hearing levels of the subjects were measured by providing an initial 5 dB stimulus followed by a stepwise increase in the sound level by 5 dB. To confirm the reproducibility of the results, examinations were repeated for each of the subjects. The subjects were classified as having low/mild frequency hearing loss if the average of the pure-tone thresholds at 1, 4 and 8 kHz frequencies exceeded 25 dB SPL. Extra high frequency hearing loss was considered if the average of the pure-tone thresholds at 12 kHz frequencies exceeded 40 dB SPL (Ohgami et al., 2011, 2016).

2.3. Analysis of data

Data were statistically analyzed using SPSS program version 22 software (SPSS Inc., Chicago, USA). As the data did not show normal distribution, the difference between each group was analyzed using Pearson's $\chi 2$ (chi-square) method. Descriptive statistics have been presented in the results section. The p-value and odds ratio were measured for each characteristic of the subjects. For further confirmation, binary logistic regression analysis was performed to determine adjusted odds ratio at 95% confidence interval (CI). The regression analysis made use of different predictor variables in the categorical form. Hearing level was taken as a dependent variable, and diabetes (reference: control), age (reference: ≤40 years), gender (reference: male) and BMI (reference: normal weight) were considered as independent variables. The significance of the results was set at $p < 0.05$.

3. Results

3.1. Characteristics of the study participants

Among 142 subjects analyzed in this study, 70 (49.3%) were control and 72 (50.7%) were diabetic with elevated FBG (Table 1). Of the 142 subjects, male and female participants were equal in numbers (71 for each case). The number of male

Please cite this article in press as: Das, A., et al., Impairment of extra-high frequency auditory thresholds in subjects with elevated levels of fasting blood glucose, Journal of Otology (2017), https://doi.org/10.1016/j.joto.2017.10.003