Amplitude of accommodation is reduced in pre-presbyopic diabetic patients

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Introduction: The prevalence of diabetes mellitus is increasing exponentially often causing an enormous public health burden due to changing lifestyles. People with diabetes have accelerated age-related biometric ocular changes compared with people without diabetes.
Aim: The purpose of this study was to determine the effect of diabetes on the amplitude of accommodation in pre-presbyopic diabetic patients, and compare the results with age-matched healthy individuals.
Methods: The study population consisted of 84 diabetic patients (30–40 years of age, 36 ± 2.5 years and 81 (35 ± 2.7 years) age-matched healthy normal controls. Using the best correction for distance visual acuity, the amplitude of accommodation was measured using the subjective push-up technique. The influence of age and duration of diabetes on amplitude of accommodation were analysed using the regression analysis.
Results: The mean amplitude of accommodation was lower in the diabetic group (6.34 ± 1.39 dioptre (D)) compared with the controls (8.60 ± 2.00 D), which was statistically significant ($p = 0.000$). There was a little negative correlation between the amplitude of accommodation and duration of diabetes (–0.20, $p = 0.069$).
Conclusion: People with diabetes showed lower amplitude of accommodation when compared with age-matched controls. The results suggest that diabetic people will experience presbyopia earlier in life than people without diabetes. Early detection and rehabilitation of diabetic patients with corrective spectacle lenses is recommended.

Keywords: accommodation, diabetes, presbyopia

Introduction

Diabetes mellitus is a clinical syndrome or group of metabolic diseases characterised by a disorder in the metabolism of carbohydrates, resulting from defects in insulin secretion, insulin action or both.[1–3] This disease is determined by a chronic hyperglycaemia associated with long-term damage, dysfunction and failure of different organs, especially the eyes, kidneys and nerves.[4] Worldwide, diabetes continues to be a costly disease with a great healthcare impact due to its increased prevalence and high mortality and morbidity rate.[5,6] According to the World Health Organization,[5] the number of people with diabetes in the world is expected to reach 366 million by 2030. The International Diabetes Federation[6] estimates that the number of people with diabetes mellitus will be 552 million by 2030. This is mainly attributed to poor nutrition, obesity, lack of exercise and urbanisation. Most people with diabetes are between 35 and 64 years of age in the developing countries and more than 64 years of age in the developed countries.[5,6] The prevalence of diabetes is similar in men and women.

Diabetes mellitus is classified according to aetiology into several groups.[4–9] Type 1 diabetes mellitus is characterised by autoimmune destruction of the pancreatic beta-cells in the islets of Langerhans, resulting in absolute or near-total insulin deficiency.[4–8] It is also known as insulin-dependent or juvenile-onset diabetes. Type 1 diabetics are often diagnosed earlier in children and youth, and this represents approximately 5–10% of all patients with diabetes. It is treated with insulin but there is a tendency to ketoacidosis. Currently, type 1 diabetes cannot be prevented, and having a family member with this type of diabetes, pancreas disease and increased mother's age during pregnancy could contribute to its development. Type 2 diabetes mellitus or non-insulin-dependent diabetes mellitus has the higher incidence accounting for 80–90% of all patients with diabetes.[4–8] It involves mechanisms of insulin resistance, impaired insulin secretion and inappropriate levels of circulating glucose, resulting in relative insulin deficiency. This type of diabetes may occur in genetically susceptible individuals with impaired insulin secretion or with insulin resistance and bad regulation of glucose production in the liver. Insulin resistance can be improved by weight loss. Type 2 diabetics do not develop ketoacidosis but an individual may suffer hyperglycaemic coma. The risk of developing type 2 diabetes increases with age, ethnicity, obesity and lack of physical activity.

The third form of diabetes mellitus is called gestational diabetes,[7–9] which results from glucose intolerance during pregnancy in a small number of women.[7] It is characterised by a certain degree of insulin resistance that could be due to a combination of maternal adiposity and desensitising effects of several substances produced by the placenta, resulting in inappropriate elevated glucose levels. Most of the cases usually resolve with birth. The fourth type of diabetes is known as maturity-onset diabetes mellitus of the young characterised by the onset of hyperglycaemia before the age of 25 years.[4–9] It is believed to result from monogenic disorders, genetic beta-cell function defects, genetic syndrome, certain medications or infections and/or is perhaps due to pancreatic diseases. The inability of the body to use glucose resulting from the deficiency of insulin leads to constant hyperglycaemia, which results in many chronic effects, affecting the eye, kidney and nerves.[8]

Diabetes affects the eye, with the most commonly reported chronic changes being cataract and diabetic retinopathy. The optics and biometry of the eye are also altered in people with diabetes.[10] From an optical perspective, diabetes affects the

optics and biometry of the eye and blurring of vision is often the first sign of its presence.[10,11] The crystalline lens of the human eye is one of the determinants of refraction. It is the only human organ that grows throughout the life of an individual.[12–15] The lens becomes thicker with increasing age as new lens fibres are continually added over time. Mitosis provides a constant supply of new lens fibres, which are added externally to earlier generations of fibres. Older generations of fibres compact within the deeper layers of the crystalline lens substances and the lens becomes thicker and more convex.

Accommodation is an increase in the dioptric or refractive power of the eye that enables near objects to be focused on the retina.[16–18] The increase in power of the eye occurs because of an increase in the anterior and posterior surfaces of the crystalline lens resulting from contraction of the ciliary muscle.[16] Amplitude of accommodation is the maximum amount of accommodation that can be exerted. Amplitude of accommodation decreases with age leading to presbyopia, which presents clinically with difficulty in near visual tasks, starting to occur at the age of about 40 to 45 years.[18]

The crystalline lens in young pre-presbyopic patients with diabetes has been noted to be thicker and more convex when compared with non-diabetics. In many respect, the diabetic eye acts like an older normal eye. With increasing age, the crystalline lens becomes thicker and more curved (convex). A presbyopic patient would require spectacle lens power to see near objects clearly. Diabetic eyes act like a presbyopic eye. With increasing age, the elasticity of the crystalline lens decreases and the amplitude of accommodation is reduced.

The purpose of this study was to examine and compare the subjective push-up amplitude of accommodation in pre-presbyopic diabetic patients with age-matched healthy non-diabetic controls in order to better understand the effect of diabetes mellitus on accommodation.

Methods

This study was a cross-sectional hospital-based survey carried out in the Department of Ophthalmology, University of Pretoria, Steve Biko Academic Hospital from June 2015 to December 2016. A total of 84 diabetic patients were recruited from the general diabetic clinic and 81 age-matched control subjects from the optometry clinic. All subjects were between 30 and 40 years of age.

The study complied with or adhered to the tenets of the Helsinki Declaration. All subjects provided or gave informed consent and confidentiality was maintained. Inclusion criteria for diabetics group were patients aged between 30 and 40 years with normal anterior segment and corrected visual acuity better than 6/9. Exclusion criteria were evidence of cataract, non-proliferative and proliferative diabetic retinopathy, previous ocular surgery, ocular trauma, systemic diseases, medication with an anticholinergic drug, current medications that could modify or are known to affect the accommodative mechanism for both groups and no history of glaucoma.

Detailed ophthalmological examination including visual acuity, subjective refraction, colour vision assessment, anterior and posterior segment imaging using the Pentacam® (Oculus, Wetzlar, Germany) and fundus camera (Nidek RS-330 Retinal Camera, GENOP, South Africa) were obtained on both groups.

Procedure

Subjective amplitude of accommodation was measured with an RAF rule (CE 0120 HS Clement Clarke International, Harlow, United Kingdom) using the push-up method. The RAF rule is well established in clinical practice and research. The push-up method is the most common and simple clinical technique to measure amplitude of accommodation.[19] In this method subjects monocularly viewed the N5 letter line while wearing their distance correction determined from the results of subjective refraction. The target (N5) was placed in front of the subject's eyes at 40 cm and the subject asked to focus on the target with the right eye while the left eye was occluded. Each subject was instructed to focus on the letter line as the target was moved closer, until the letter line could no longer be held in clear focus, and to report when it first became and remained blurred. The examiner pushed the target at a rate of approximately 5 cm/second. The endpoint of the test was the first sustained blur.

Statistical analysis

Data were collected and analysed using the Statistical Package for the Social Science (SPSS®) version 23 (IBM Corp, Armonk, USA). The normality of the data distribution was checked with the Kolmogorov–Smirnov test. Results were presented as means in both groups. Independent sample t-test and repeated measures of ANOVA were applied to determine the differences in amplitude of accommodation between groups. Correlation between the amplitude of accommodation and duration of diabetes and age were established using the Pearson correlation.

Results

As mentioned earlier, the study included 84 diabetics and 81 control subjects. The age range for all subjects was 30–40 years. Table 1 presents the characteristics of both the diabetics and control subjects. The mean age in the diabetic group was 35.73 ± 2.5 years, and 34.63 ± 2.7 years in the control group.

Subjects with diabetes had lower or reduced amplitude of accommodation (6.34 ± 1.30 D) as compared with subjects without diabetes (8.60 ± 2.00 D). the difference between mean amplitude of accommodation was statistically significant between groups, $p = 0.000$. Mean amplitude of accommodation for males and females in both groups is included.

Figures 1–3 show the boxplots (or box-and-whisker plots) of the amplitude of accommodation in diabetics and non-diabetics, in different sexes of both diabetic and non-diabetic groups and in the two types of diabetes for the diabetic group. The length of the box represents the inter-quartile range of the measurement of the amplitude of accommodation. A bold horizontal line inside the box indicates the median. Whiskers are drawn to the minimum and maximum values of each end of the box.

Regression analysis was performed to show the association between the duration of diabetes and amplitude of accommodation. The correlation was low ($r = 0.001$, $p = 0.990$).

Discussion

The crystalline lens of the human being accounts for 20% of the total eye's refractive power.[16] Any alteration in the structure or morphology of the crystalline lens is associated with changes in the refractive status. Comparing the diabetic subjects with non-diabetic controls revealed the impact of diabetes on the
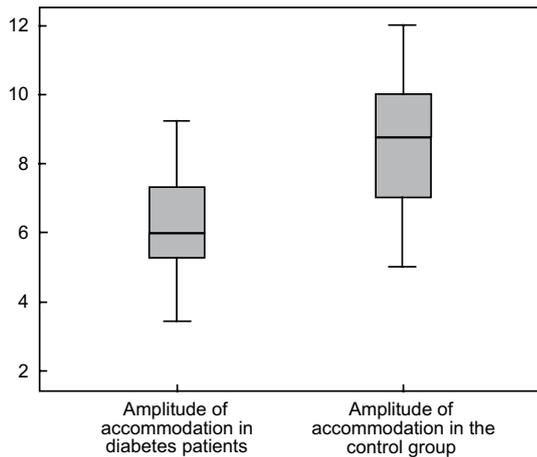
Figure 1: Boxplots for the amplitude of accommodation for the diabetic and control groups. The y axis represents distribution of the measurements of the amplitude of accommodation.

amplitude of accommodation measurements.

The mean amplitude of accommodation in the diabetic group was lower when compared with the mean of the age-matched controls (see Table 1 and Figure 1). The results of our study show that diabetic patients between the ages of 30 and 40 years would have a mean amplitude of accommodation of approximately 3.00 D at the age of 30 years, such that presbyopia would occur at least by 30 years rather than the more commonly stated mid-40s.

The results of our study agree with previous studies.[20–25] Those studies also reported lower amplitude of accommodation in people with diabetes than in healthy age-matched controls. Pawelski and Glien[25] compared the amplitude of accommodation between white American diabetic and healthy control subjects of

Table 1: Statistics for the characteristics of subjects for amplitude of accommodation measurements.

Statistic	Diabetes	Control
Sex: male/female	49/35	41/40
Mean age in years	36 ± 2.5	35 ± 2.7
Mean amplitude	6.34 ± 1.39 D	8.60 ± 2.00 D
95% CI of the difference	Upper: 6.65	Upper: 9.04
	Lower: 6.04	Lower: 8.17
Mean amplitude of accommodation:		
Males	6.20 ± 0.20 D	8.56 ± 0.28 D
Females	6.51 ± 0.23 D	8.66 ± 0.36 D
Mean type 1 diabetes	6.18 ± 1.58 D	
Mean type 2 diabetes	6.46 ± 1.24 D	
Mean duration of diabetes	4.99 ± 3.12	
	95% CI: 4.31–5.67	
Skewness	0.306	−0.050
Kurtosis	−0.671	−1.026
Percentile		
25	5.25	7.00
50	6.25	8.75
75	7.50	10.25

young age using the push-up method. They found a decreased amplitude of accommodation in diabetic subjects. Moss et al.[20] did a study on 61 subjects whose ages ranged from 9 to 16 years in diabetic versus normal controls. They found a lower amplitude of accommodation in diabetic subjects (mean 9.90 D versus 11.80 D). Razavi et al.[21] measured amplitude of accommodation in 32 diabetic patients (30–40 years of age) and 28 age-matched healthy normal subjects. They found a mean amplitude of accommodation of 5.92 ± 1.75 D and 10.95 ± 2.16 D in diabetics and normal groups, respectively. Amplitude of accommodation was measured using the push-up technique. Adnan et al.[22] investigated the amplitude of accommodation in 43 diabetic subjects and 32 age-matched controls, aged under 47 years, using the subjective push-up and objective methods. The mean subjective amplitude of accommodation was 4.0 ± 1.70 D for diabetics and 5.6 ± 2.1 D for normal subjects. The objective means were 2.70 ± 1.6 for diabetics and 4.1 ± 2.1 D for normal subjects. However, the results of our study are much lower than those of Moss et al.,[20] especially for the diabetic group. Our results were higher than those from the study by Adnan et al.[22] but similar to those of Palewski and Glein[25], Braun et al.[23] and Zazavi et al.[21]
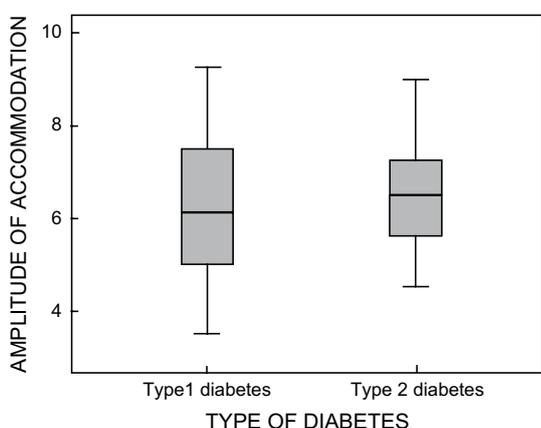
The reduction in the amplitude of accommodation in diabetic patients is unknown but could be due to over-hydration or the continual growth of the lens fibres throughout life. The possible hypothesis to explain this could be that during the periods of hyperglycaemia there is an excess accumulation of glucose in the crystalline lens, which is then converted to sorbitol by the aldose reductase enzyme, and further converted into fructose by the sorbitol dehydrogenase.[26–30] Sorbitol is sugar alcohol and tends to accumulate within the lens fibres, since it is poorly permeable through the lens membranes. When the body of a diabetic person rapidly changes from a hyperglycaemic to a hypoglycaemic state, excess glucose in the crystalline lens flows out into the aqueous humour but the sorbitol remains in the lens for a longer period. This creates an osmotic gradient (difference in osmotic pressure) resulting in the influx of water from the aqueous humour into the lens, producing marked swelling and thickness.

The lens grows throughout life. New cells are continually formed without the older cells being discarded.[11,31–33] As part of this growth, the lens becomes thicker and its surfaces become more curved. There may be more secondary lens fibres (hyperplastic mechanism) or larger secondary lens fibres (hypertrophic mechanism) being formed.[34] In patients with diabetes mellitus the lens has been found to be thicker and more curved compared with normal healthy subjects. One would expect that the lens, hence the eye itself, should become more powerful and that a myopic state will exist. However, the eye changes due to hyperopia.[11] This is called the 'lens paradox'. Another possible explanation for the thickness of the lens in diabetic people could be an increase in cell membrane permeability or deficiency in the ions pump.[14] It seems the lens is mainly responsible for the loss of amplitude of accommodation in diabetic patients; however, there may be other possible contributors, including the loss of ciliary muscle tone, adverse changes to lens zonules or deficit in neural input to the ciliary muscle or changes in geometrical relationship between the lens and accommodative structures. People with diabetes will experience presbyopia earlier in life than people without diabetes.

There was no substantial association between the duration of diabetes and the amplitude of accommodation. Our results differ from other reports which showed that the amplitude of accommodation is reduced as the duration of diabetes
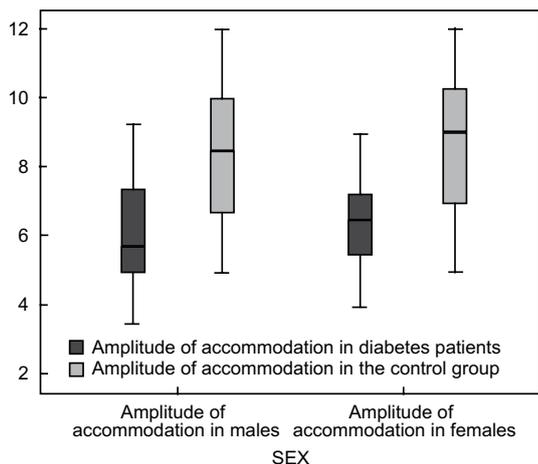
Figure 2: Box plots for the amplitude of accommodation as a function of sex.

Figure 3: Box plots for the different types of diabetes.

increases.[22,33] This could be due to the sample size and the method of data collection.

Weakness of the study

We did not evaluate the effect of HbA1c levels and the amplitude of accommodation. The subjective push-up technique overestimates the true amplitude of accommodation. Comparing means alone might yield erroneous results as both outliers and sample size may affect the conclusion.

Conclusion

This study found lower amplitude of accommodation in people with diabetes than in age-matched healthy controls, with an estimation that people with diabetes might experience presbyopia three years earlier in life than those without diabetes. The eyes of people with diabetes act as older eyes than those of people of the same age without diabetes.

Competing interests – The authors declare that they have no financial interest or personal relationships that might have inappropriately influenced them in writing this article.

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