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 (r = −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
optics and biometry of the eye and blurring of vision is often the first sign of its presence.\textsuperscript{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.\textsuperscript{12–14} 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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{19} In this method subjects monocularly viewed the NS letter line while wearing their distance correction determined from the results of subjective refraction. The target (NS) 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.\textsuperscript{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
The results of our study agree with previous studies. Those by 30 years rather than the more commonly stated mid-40s. Data at the age of 30 years, such that presbyopia would occur at least 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 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. Those studies also reported lower amplitude of accommodation in people with diabetes than in healthy age-matched controls. Pawelski and Glien compared the amplitude of accommodation between white American diabetic and healthy control subjects of young age using the push-up method. They found a decreased amplitude of accommodation in diabetic subjects. Moss et al. 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 9.80 D versus 11.80 D). Razavi et al. 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. 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., especially for the diabetic group. Our results were higher than those from the study by Adnan et al. but similar to those of Pawelski and Glien, Braun et al. and Razavi et al.

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. 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. 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. 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. 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 ionic pump. 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 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.](image-url)
The mean amplitude of accommodation in the diabetic group was measured using the push-up technique. Adnan et al. did a study on 61 subjects whose ages ranged from 9 to 16 years and investigated the amplitude of accommodation in 43 diabetic patients (30–40 years of age) and 28 age-matched controls, aged under 47 years, using the subjective push-up and objective methods. The mean amplitude of accommodation in females was 2.70 ± 1.6 D for diabetics and 4.1 ± 2.1 D for normal subjects. They found a mean amplitude of accommodation of 5.92 ± 1.75 D and 10.95 ± 2.16 D in diabetics and healthy normal subjects. The results of our study are much lower than those of Palewski and Glein,25, Braun et al.22 but similar to those of Moffat et al.23, Atchison DA, Pope JM. Explanation of the lens paradox. Optom Vis Sci. 2002;79(3):148–50. http://dx.doi.org/10.1097/00006324-200203000-00008

50 6.25 8.75

Table 1: Distribution of data collection.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Diabetic Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
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<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Females</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

**Figure 1:** Comparison of amplitude of accommodation in diabetics and healthy control subjects.

**Figure 2:** Box plots for the amplitude of accommodation as a function of sex.

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

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**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.

**Authors’ contribution** – The authors were equally responsible and contributed equally to the preparation and writing of this article.

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**References**

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