Original Article

Prevalence, risk factors and association with glycemic levels of presbyopia in South Indian population

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Purpose: To determine the prevalence of presbyopia and its association with elevated glycemic levels in subjects ≥40 years of age in the South Indian population of Chennai. **Methods:** This was a retrospective study. Subjects were included from the Sankara Nethralaya Diabetic Retinopathy Epidemiology And Molecular genetics Study (SN-DREAMS 1). Demographic data, detailed medical and ocular history, comprehensive eye examination, and biochemical investigations were performed. Glycosylated hemoglobin results were categorized as controls (4%–5.6%), prediabetic (5.7%–6.4%), and diabetic (≥6.5%) groups. The given presbyopic correction was divided into two groups as within and outside donders limit. Prevalence rates and mean values were determined and compared among the three glycemic groups. The Student *t* test, the Chi-square test, and multivariate logistic regression analyses were performed. **Results:** The overall prevalence of presbyopia from our previously conducted SN-DREAMS 1 population of 1414 patients was 79.77% (95% CI: 0.775–0.818). In total, 1128 participants were included for our current secondary analysis with a mean age of 54.40 years (range: 40–83). The number of subjects within and outside donders limit was 1044 (92.55%) and 84 (7.44%), respectively. In each age group (40–49, 50–59, ≥60) regardless of being within or outside donders limits, an increasing trend in the prevalence of presbyopia was noted based on increasing glycemic levels. **Conclusion:** Our study demonstrated a high prevalence of presbyopia in the South Indian population of Chennai. Findings show that the prevalence of presbyopia in different age groups increases with worsening diabetes status.

Key words: Donders limit, glycemic levels, hyperglycemia, presbyopia, prevalence

Refractive errors are the most common ocular condition affecting all age groups. One of the age-related refractive errors is presbyopia. It is a physiological insufficiency of accommodation associated with the aging of the eye, resulting in progressive worsening of the ability to focus clearly on close objects.[1] Theories have been proposed previously that presbyopia occurs due to increasing equatorial diameter of lens, changes in the capsule of lens, ciliary muscles, and/or changes in the vitreous humor.[2] Onset of presbyopia usually occurs during the fourth decade of life. It not only affects the near vision but also impacts daily activities and overall quality of life. Several population-based studies have reported on the prevalence of presbyopia in different populations involving both developing and developed countries. However, few such reports have been based on a South-Asian cohort from India. A systemic review in 2019 reported the prevalence of uncorrected presbyopia in India as 33%.[3] Andhra Pradesh Eye Disease Study (APEDS), a population-based study in South India, reported that the prevalence of presbyopia in the south Indian state of Andhra Pradesh was 55.3%.[4]

Diabetes mellitus has its effects on the refractive state of the human eye. Hyperglycemia is found to be the major cause of the transient refractive change in diabetic patients.[5,6] Previous studies have also reported that elevated glycemic levels affect the amplitude of accommodation,[7-9] which may lead to presbyopia.

The treatment of presbyopia usually involves correction with spectacles for near vision with approximate lens power that lies within an age-based power range (donders limit) as clearly identified by the clinically used donders table.[10] However, this age-based power range might not be suitable for all as some may require a weaker or stronger lens power than expected for their age, which in certain cases is considered acceptable. For example, myopes might need a weaker near-vision correction or no correction at all. Similarly, a stronger near-vision correction may be required in hyperopes or subjects with low vision and those that need to work at a closer working distance than 40 cm to see very tiny objects. Due to the pathological vision changes seen in diabetes, we hypothesized that people with diabetes and prediabetes may have a higher prevalence of presbyopia whose correction would require add's outside the donders age-specific limit.

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To the best of our knowledge, there has been no previous literature that has studied the relationship between elevated glycemic level and presbyopic condition with correction given within and outside donders limit. The aim of this study was to determine the prevalence of presbyopia and its association with elevated glycemic levels in subjects ≥40 years of age with correction given within and outside donders limit in the South Indian population of Chennai. In addition, we wanted to identify potential demographic risk factors for the correction given outside donders limit that might play a role in the abovementioned association.

Methods

Study subjects were included from the Sankara Nethralaya Diabetic Retinopathy Epidemiology And Molecular genetics Study (SN-DREAMS 1) conducted between October 2003 and April 2006. SN-DREAMS 1 was a cross-sectional, population-based survey conducted to measure the prevalence of diabetes and diabetic retinopathy (DR) in Chennai, India with a population of 4.3 million in 155 corporate divisions. From a random selection of 10 zones, 5999 subjects ≥40 years of age from the general population were enumerated by multistage random sampling. Of the 5999 subjects enumerated, 1414 patients were identified with diabetes (known and newly diagnosed) based on the WHO criteria and were ultimately selected and analyzed. The study design and research methodology of SN-DREAMS 1 have been described in detail elsewhere.[11] The study was approved by the institutional review board (Ethics Committee), Vision Research Foundation, and a written informed consent was obtained from the subjects per the tenets of the Declaration of Helsinki.

Of the total 1414 subjects from SN-DREAMS 1, 286 participants who had undergone refractive surgery or with aphakic or pseudophakic eyes were excluded. As a result, 1128 participants were included in our current study. Demographic data, detailed medical and ocular history, and a comprehensive eye examination were performed. This included measurement of distance visual acuity with logMAR chart and near vision was assessed with a near vision chart at a working distance of ~35–40 cm followed by refraction for best-corrected visual acuity, slit-lamp examination, and intraocular pressure assessment. In addition, retinal photographs were taken after pupillary dilatation with 45° four-field stereoscopic fundus photography (Carl Zeiss fundus camera; Visucamlite, Jena, Germany) and biochemical investigations (blood sugar, high-density lipoproteins, total serum cholesterol, hemoglobin, serum triglycerides, and glycosylated hemoglobin) were taken. Diabetic retinopathy was clinically graded using Klein's classification (Modified Early Treatment Diabetic Retinopathy Study scales). All retinal photographs were graded by two ophthalmologists in a blinded manner. HbA1c fractions were estimated by using Merck Micro Lab 120 semi-automated analyzer (Bio-Rad DiaSTAT HbA1c Reagent Kit). In this study, HbA1c (%) results were used and categorized according to the American Diabetes Association classification as control (4%–5.6%), prediabetic (5.7%–6.4%), and diabetic (≥6.5%) groups. We defined presbyopia if a subject required an addition of at least 1.0 D in addition to best-corrected distance vision to improve near vision. The given presbyopic correction was divided into two groups as within donders limit and outside donders limit. Donders *et al.*[10] described the age-related norms of accommodation amplitude while Pointer provided the add powers for different age groups, which are used as a reference in a clinical setting to prescribe the presbyopic corrections today. An addition of more than that mandated in the age-specific range based on age-related norms was considered as outside donders limit.

SPSS Statistics 21 (IBM Corp., Armonk, NY) was used for analysis. Demographic characteristics were described based on prevalence rates and mean values along with their confidence intervals and compared among the three glycemic groups, namely control, prediabetics, and diabetics. The data were tested for normality using the Shapiro–Wilk test. The results were expressed as number and percentage for categorical data, and continuous data were expressed as mean with standard deviation. One-way ANOVA/Kruskal–Wallis test and the Chi-square test were used to compare the continuous and the categorical demographic parameters between the three groups in Table 1. Based on univariate analysis, covariates were chosen and multivariate logistic regression analyses were performed to study the effect of various risk factors. $P \leq 0.05$ was considered significant.

Results

In our study, 1128 participants were included with a mean age of 54.40 years (range: 40–83); 615 (54.52%) were men and 513 (45.47%) were women. Socioeconomic conditions were divided into low, middle, and high economic status comprising 123 (10.9%), 789 (69.94%), and 216 (19.14%) subjects, respectively.

The prevalence of presbyopia in the studied sample was 79.77% (95% CI: 0.775–0.818). The given presbyopic correction was divided into two groups as within and outside donders limit. The number of subjects within and outside donders limit was 1044 (92.55%) and 84 (7.44%), respectively. Table 1 describes and compares the baseline characteristics of our sample population, including the age group-specific prevalence of presbyopia in control, prediabetic, and diabetic groups. A positive correlation of increasing prevalence of presbyopia and increasing glycemic status was found with statistical significance. In the age group of 40–49 years, a total of 373 patients were found to be presbyopic, with 7.5% belonging to the control group, 15.28% belonging to the prediabetic group, and 77.21% belonging to the diabetic group ($P < 0.001$). In the age group of 50–59 years, a total of 428 patients were found to be presbyopic, with 8.8% belonging to the control group, 14.71% belonging to the prediabetic group, and 76.4% belonging to the diabetic group ($P < 0.001$). In the age group of ≥60 years, a total of 327 patients were found to be presbyopic, with 6.4% belonging to the control group, 14.06% belonging to the prediabetic group, and 79.51% belonging to the diabetic group ($P < 0.001$).

Fig. 1 shows the comparison of presbyopic correction within and outside donders limit between control, prediabetes, and diabetes groups. In the case of within donders limit, there was a statistically significant difference between the three groups (control, prediabetic, and diabetic) in all age groups (40–49, 50–59, and ≥60). In the case of outside donders limit, there was a statistically significant difference in age groups 40–49 and 50–59 except ≥60 years. In each age group regardless of being within or outside donders limits, an increasing trend in the prevalence of presbyopia was noted based on increasing glycemic levels. Supplementary Table 1 shows the age group comparison of cataract grade between control, prediabetic, and diabetic groups. There was no significant difference in cataract grade in relation to the age groups (40–49, 50–59, and ≥60).

Multivariate logistic regression analysis used to study the effect of various risk factors for the correction given outside donders limit in the control, prediabetes, and diabetes groups is shown in Table 2. The regression model included age, gender, duration of diabetes, BMI, cataract grading, intraocular pressure, and DR stages as covariates representing the various risk factors. In control group, there was no significant association found except for gender. Females had 10.39 times greater chance

Table 1: Comparison of baseline characteristics between control, prediabetic, and diabetic groups

Parameters	Control group (*n*=87)	Pre-diabetic group (*n*=166)	Diabetic Group (*n*=875)	P
Age (years), mean (SD)	53.05±8.34	54.29±9.26	54.56±9.24	0.340
Prevalence of presbyopia in specific age group, *n* (%)				
40-49	28 (7.50)	57 (15.28)	288 (77.21)	<0.001
50-59	38 (8.87)	63 (14.71)	327 (76.40)	<0.001
≥60	21 (6.42)	46 (14.06)	260 (79.51)	<0.001
Gender, *n* (%)				
Male	44 (50.57)	84 (50.60)	487 (55.65)	<0.001
Female	43 (49.42)	82 (49.39)	388 (44.34)	<0.001
Duration of diabetes (years), Mean (SD)				
<10	79 (90.80)	154 (92.77)	731 (83.54)	<0.001
≥10	8 (9.19)	12 (7.22)	144 (16.45)	<0.001
[!]BMI, *n* (%)				
Normal	29 (33.33)	50 (30.12)	338 (38.62)	<0.001
Lean	10 (11.49)	7 (4.21)	50 (5.71)	<0.001
Overweight	34 (39.08)	75 (45.18)	363 (41.48)	<0.001
Obese	14 (16.09)	34 (20.48)	124 (14.17)	<0.001
Cataract grading, Mean (SD)				
No cataract	2.27 (1.21)	2.35 (1.23)	2.41 (1.25)	0.556
Nuclear	2.10 (1.54)	2.06 (1.41)	2.21 (1.61)	0.461
Cortical	1.17 (1.05)	1.20 (1.49)	1.40 (1.43)	0.119
PSC	0.92 (0.98)	0.95 (1.67)	1.00 (1.52)	0.843
[#]IOP, *n* (%)				
<21 mm Hg	84 (96.55)	162 (97.59)	846 (96.68)	<0.001
≥ 21 mm Hg	3 (3.44)	4 (2.40)	29 (3.31)	<0.001
[$]DR stages, *n* (%)				
No DR[$]	80 (91.95)	160 (96.38)	753 (86.05)	<0.001
Mild NPDR[@]	5 (5.74)	1 (0.60)	67 (7.65)	<0.001
Moderate NPDR[@]	1 (1.1)	4 (2.40)	40 (4.57)	<0.001
Severe NPDR[@]	1 (1.1)	1 (0.60)	9 (1.02)	0.003
[^]PDR	-	-	6 (0.68)	-

[!]BMI - Body mass index; [#]IOP - Intraocular pressure; [$]DR - Diabetic retinopathy; [@]NPDR - Nonproliferative diabetic retinopathy; [^]PDR - Proliferative diabetic retinopathy

of developing presbyopia compared to males within the control group (*P* = 0.01). In the diabetic group, subjects with age ≥60 had a 86% lesser likelihood of presbyopia (*P* = 0.02) compared to patients within the age group of 40–49. However, no significant change in risk of developing presbyopia was noted in the age group of 50–59. Within the diabetic group, we also noted that those who are diagnosed with severe nonproliferative diabetic retinopathy (NPDR) had a 7.31 times higher risk in comparison with no DR (*P* = 0.01). In the prediabetic group, no significant association within the covariates was noted.

Discussion

The present study is a secondary analysis of the dataset produced by our previously conducted population-based cross-sectional study that included the years from 2003 to 2006 among the residents of Chennai, South Indian population aged 40 years and above. The overall prevalence of presbyopia from our previously conducted cross-sectional study population of 1414 patients was 79.77% (95% CI: 0.775–0.818). This population of presbyopics from the previous study amounted to 1128 participants for our current secondary analysis. The only other population-based study of presbyopia in the Indian population was APEDS, which found a prevalence of 55.3%. However, they included subjects 30 years or older (range: 30–102), which could

account for the lower prevalence, despite reporting that the age of onset of presbyopia in India may be primarily from the fourth decade onward.[4] It is believed that different populations have different prevalence of presbyopia, including those in rural northern China (67.3%),[12] rural Tanzania (61.7%),[13] Brazil (54.7%),[14] Swaziland (70%),[15] East Africa (89.2%),[16] Philippine (76.4%),[17] and Nigeria (75%).[18] These differences could be due to varying ethnicity, geographical location, lifestyle, dietary habits, and/or associated comorbidities.

In this study, the prevalence of presbyopia was compared among individuals belonging to varying glycemic categories, namely control, prediabetic, and diabetic. We also wanted to confirm the positive correlation between presbyopia and increasing glycemic state.

After stratifying based on age, we found that in the within-donders-limit category, the prevalence of presbyopia was higher in prediabetics compared to controls and the prevalence among diabetics was even greater than the prediabetic population. A similar trend was noted between diabetics and control in the outside-donders-limit category as well. Li *et al.*[19] evaluated the effects of glycemic control on refraction in diabetic patients and found that higher HbA1c had a larger maximum hyperopic change, indicating that the degree of hyperopia is
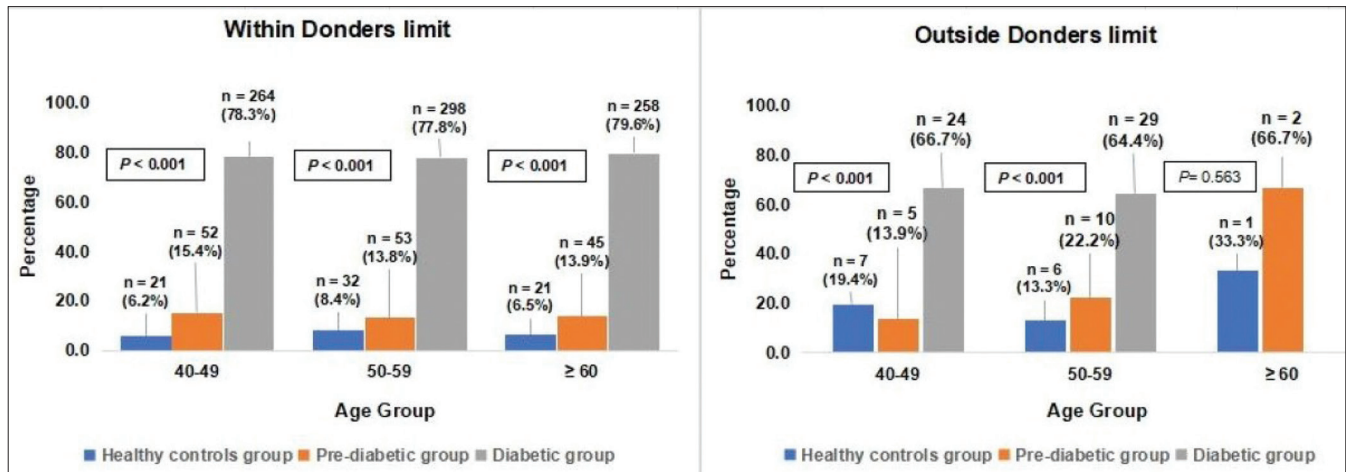
Figure 1: Comparison of presbyopic correction within and outside donders limit between controls, prediabetes, and diabetes groups

Table 2: Comparison of risk factors of presbyopia for the correction given outside donders limit with within donders limit as the reference group

Risk Factor	Control group			Prediabetic group			Diabetic group		
	Odds Ratio	95% CI	P	Odds Ratio	95% CI	P	Odds Ratio	95% CI	P
Age									
40-49	1	-	-	1	-	-	1	-	-
50-59	0.47	0.08-2.60	0.38	1.71	0.48-6.02	0.41	1.35	0.72-2.52	0.34
≥60	0.00	0.00	0.99	0.10	0.00-1.62	0.11	0.15	0.03-0.71	0.02
Gender									
Male	1	-	-	1	-	-	1	-	-
Female	10.39	1.64-65.75	0.01	1.28	0.33-4.86	0.76	1.73	0.93-3.20	0.08
Duration of diabetes									
<10	1	-	-	1	-	-	1	-	-
≥10	0.00	0.00	0.10	0.00	0.00	0.10	0.74	0.24-2.18	0.58
ⁱBMI									
Normal	1	-	-	1	-	-	1	-	-
Lean	0.75	0.04-11.18	0.83	0.00	0.00	0.10	0.89	0.18-4.23	0.88
Overweight	0.17	0.03-1.16	0.07	0.36	0.08-1.43	0.15	0.72	0.37-1.41	0.34
Obese	0.13	0.01-2.27	0.16	0.25	0.04-1.45	0.12	0.73	0.30-1.79	0.49
Cataract grading									
No cataract	0.94	0.26-3.42	0.92	1.26	0.40-3.66	0.73	0.81	0.55-1.19	0.28
Nuclear	0.89	0.37-2.18	0.81	1.37	0.54-3.46	0.51	0.95	0.75-1.22	0.70
Cortical	2.49	0.38-16.33	0.34	0.99	0.43-2.25	0.98	0.84	0.61-1.16	0.28
PSC	0.64	0.12-3.47	0.60	0.78	0.34-1.77	0.55	1.20	0.93-1.55	0.16
#IOP									
<21 mm Hg	1	-	-	1	-	-	1	-	-
≥21 mm Hg	0.00	0.00	0.10	1.34	0.10-18.78	0.83	0.95	0.12-7.58	0.97
$DR stages									
No DR$	1	-	-	1	-	-	1	-	-
Mild NPDR@	0.00	0.00	0.10	0.00	0.00	0.10	0.96	0.32-2.90	0.95
Moderate NPDR@	0.25	0.00	0.10	0.00	0.00	0.10	0.00	0.00	0.10
Severe NPDR@	0.19	0.00	0.10	0.00	0.00	0.10	7.31	1.49-35.72	0.01
^PDR	-	-	-	-	-	-	0.00	0.00	0.10

ⁱBMI - Body mass index; #IOP - Intraocular pressure; $DR - Diabetic retinopathy; @NPDR - Nonproliferative diabetic retinopathy; ^PDR - Proliferative diabetic retinopathy

highly dependent on the degree of hyperglycemia. Based on their results, there seems to be a potential association of increased need for near correction, thus in turn increasing the prevalence of presbyopia within donders limit in the diabetic subjects.

In our sample population for the correction given outside donders limit, we observed that in the control group, women were associated with a 10.4 times greater risk of developing presbyopia. Similar findings were corroborated by other studies that showed higher prevalence among females.[4,14,20,21] Nirmalan *et al*.[4] reported that women are more likely to have presbyopia and that gender-based hormonal influences might play a role in the onset of presbyopia. We also found that diabetics ≥60 years of age were associated with lesser odds of developing presbyopia; however, age did not seem to play a significant role within prediabetics and controls. These findings were found to be contradictory when compared to the findings reported by Man *et al*.[22] that older age was associated with a greater likelihood for utilization of near correction. As there were no differences in the morphological types of cataract in different age groups, the lesser odds in the age group of ≥60 years could not be explained by the secondary sight phenomena due to nuclear cataract. The reason for this discrepancy in the age group of ≥60 years is difficult to predict. However, it could be due to the interplay of factors related to changes in lens elasticity, size, and stiffness, as well as pupillary changes, seen with long duration of diabetes and age.

When evaluating risk factors, severe NPDR was found to increase the likelihood of presbyopia by 7.3 times among diabetics and this was noted to be statistically significant. However, no other significant association between other manifestations of diabetic retinopathy and glycemic status was found. We were unable to find any previous literature regarding the association of presbyopia and diabetic retinopathy, and based on our study findings, further exploration in this matter is warranted.

Strength of this study was that it utilized a large population-based sample with a detailed clinical and comprehensive examination protocol. It also had a few limitations. We did not measure the amplitude of accommodation; thus, our estimated prevalence may be an overestimation. Association between potential changes on vision-related quality of life in performing near visual tasks and the need for near add power within and outside donders limit was not assessed. However, our study was not designed to explore this possibility. Future prospective studies are required to address these limitations.

In India, there is a need to create awareness of presbyopia among people in their late 30s. Proper education on vision screening and correction of near vision on a regular basis utilizing community health workers is highly recommended.

Conclusion

Our study demonstrated a high prevalence of diabetics as well as patients diagnosed with presbyopia in the South Indian population of Chennai. Our study findings show that the prevalence of presbyopia within and outside donders limit in different age groups between controls, prediabetic, and diabetic subjects differs significantly and that the prevalence of presbyopia increases with worsening diabetes status.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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Supplementary Table 1: Age-group comparison of cataract grade between control, prediabetic, and diabetic groups

Age group	Cataract grade	Control group Mean (SD)	Pre-diabetic group Mean (SD)	Diabetic group Mean (SD)	P
40-49	No cataract	1.66 (0.82)	1.62 (0.81)	1.57 (0.82)	0.824
	Nuclear	1.39 (0.91)	1.32 (0.89)	1.50 (1.66)	0.698
	Cortical	1.01 (0.90)	0.70 (0.85)	0.78 (1.10)	0.440
	PSC[I]	0.83 (0.73)	0.71 (1.45)	0.65 (1.06)	0.674
50-59	No cataract	2.04 (0.80)	2.20 (0.78)	2.29 (0.91)	0.222
	Nuclear	2.00 (1.63)	1.84 (1.07)	1.98 (1.17)	0.679
	Cortical	1.02 (0.92)	0.98 (1.49)	1.24 (1.32)	0.267
	PSC[I]	0.90 (1.03)	0.68 (1.47)	0.81 (1.38)	0.718
≥60	No cataract	3.50 (1.43)	3.45 (1.39)	3.48 (1.25)	0.985
	Nuclear	3.24 (1.44)	3.26 (1.58)	3.28 (1.48)	0.991
	Cortical	1.65 (1.32)	2.13 (1.73)	2.29 (1.46)	0.156
	PSC[I]	1.08 (1.19)	1.62 (1.99)	1.63 (1.90)	0.430

[I]PSC - Posterior subcapsular cataract