**Article**

# Rates and Determinants of Eyecare Utilization and Eyeglass Affordability Among Individuals With Visual Impairment in a Multi-Ethnic Population-Based Study in Singapore

Preeti Gupta[1,*], Shivani Majithia[1], Eva K. Fenwick[1,2], Alfred T. L. Gan[1],
Yih-Chung Tham[1], Stanley Poh[1], Sahil Thakur[1], Charumathi Sabanayagam[1,2,3],
Tien Yin Wong[1,2,3], Ching-Yu Cheng[1,2,3], and Ecosse L. Lamoureux[1,2,*]

[1] Singapore Eye Research Institute and Singapore National Eye Centre, Singapore
[2] Duke-NUS Medical School, Singapore
[3] National University of Singapore, Singapore

**Purpose:** The purpose of this study was to determine the rates of, and factors associated with, eyecare utilization and spectacle affordability among Singaporeans with vision impairment (VI).

**Methods:** We included adults with VI from their second visit of the Singapore Epidemiology of Eye Disease Study. Data on eyecare utilization and spectacle affordability were collected. Low eyecare utilization was defined as no eye check ever or eye checks not even once per year in reference to at least once per year. Difficulty affording glasses was defined as glasses being rated as expensive in reference to not expensive.

**Results:** There were 985 adults (14.5%; 415 Malays, 260 Indian, and 310 Chinese; mean age [SD]: 69.5 [10.2] years; 55.4% women) with VI who answered the above questions, were included. Of these, 624 (63.4%) wore glasses. The rates of low eyecare utilization and difficulty affording eyeglasses were 31% and 63%, respectively. Compared to Chinese (23.8%) and Indians (18.8%), Malays (57.4%) had the highest rates of low eyecare utilization ($P < 0.001$), and most difficulty affording eyeglasses (47.2% vs. 26.1% and 26.6% in Chinese and Indians, respectively; $P < 0.001$). Younger age, low socioeconomic status, absence of diabetes, absence of self-reported eye conditions, and poor vision were independently associated with low eyecare utilization, whereas older age and female sex was associated with difficulty affording glasses.

**Conclusions:** In this multi-ethnic population with VI, almost one-third had low eyecare utilization and nearly two-thirds reported difficulty affording eyeglasses.

**Translational Relevance:** This will inform strategies, such as tailored eyecare utilization awareness campaigns and awareness of available subsidy schemes for at-risk Singaporeans, such as Malays.

## Introduction

Visual impairment (VI) is a considerable public health challenge with 285 million people affected globally.[1] It is associated with diminished vision-specific quality of life (QOL),[2–4] loss of independence,[5] adverse health outcomes,[6,7] and imposes substantial economic burden.[8] Routine eye examinations are, therefore, important for the timely detection and management of vision issues. As the major causes of VI and blindness are treatable, appropriate use of eyecare services, such as regular eye examinations, is a key factor in optimizing national eye health.[9]

High eyecare utilization rates (60–70%) have been reported in high income countries, such as the United States, Australia, and Canada.[10–12] Fewer such data are available in Asia, but in some low-middle income

1

countries, such as India, Bangladesh, and Pakistan, studies have reported lower rates (30–40%).[13,14] Fewer such data are available in high income countries in Asia, such as Hong Kong, Korea, Japan, and newly developed high-income countries, like China.[15]

Singapore is a multi-ethnic city-state comprising of Chinese (76.8%), Malays (13.9%), and Indians (7.9%), three major ethnic groups in Asia.[16] Importantly, previous research by our group has reported a considerable disparity in the prevalence of VI, blindness, major eye diseases, and rates of eye surgeries among these ethnic groups in Singapore,[17–21] where Malays were found to have highest prevalence (19.7%)[22] of bilateral presenting VI compared to 17.7% and 14.2% in Chinese and Indians, respectively.[23,24] Moreover, a higher proportion of Malays compared to Chinese or Indians had undiagnosed eye diseases, such as glaucoma,[19] visually significant cataract,[20] diabetic retinopathy (DR),[25] and vision-threatening DR. One potential reason for these disparities could be related to differences in the utilization and affordability of eyecare services, and associated barriers and facilitators among different ethnic groups in Singapore. However, this information is currently lacking, making it difficult to estimate continued unmet healthcare needs to help guide future public health priorities.

To address this gap, in this population-based study of Singaporean Chinese, Malay, and Indian adults, we determined the rates of, and factors associated with, low eyecare utilization and spectacle affordability. Given that the different ethnic groups in Singapore vary in their rates of VI, education, and socioeconomic status,[26] we hypothesize there may be differences in the rates of and factors associated with eyecare utilization and spectacle affordability in Singapore.

## Methods

### Study Population and Design

The Singapore Epidemiology of Eye Disease (SEED) study is a population-based, cohort study, comprising three major ethnic groups, namely Malays, Indians, and Chinese, with baseline and follow-up assessments conducted between 2004 and 2011 (SEED-1) and 2010 and 2016 (SEED-2), respectively. Details of the SEED study design and methodology have been reported elsewhere.[21,27–30] In brief, the study protocol comprised a comprehensive, standardized examination to collect clinical and questionnaire data.[28,29]

For the current study, we included the cross-sectional data from the SEED-2, as the information on eyecare utilization and spectacle affordability was

only collected then. SEED-2 invited 2636, 2914, and 3033 eligible Mayas, Indians, and Chinese participants, respectively, from the baseline examinations. There were 1901 of the 2636 (72.1% participation rate) Malays, 2200 of the 2914 (75.5% participation rate) Indians, and 2661 of the 3033 (87.7% participation rate) Chinese participants who attended the follow-up studies. Thus, the overall response rate for the 6-year follow-up examination was 78.4%. Of the 6762 SEED-2 participants, 1012 (15.0%) were visually impaired (defined as presenting visual acuity [PVA] <0.3 logarithm of the minimum angle of resolution (LogMAR) in the better seeing eye, see details below). After excluding 27 individuals with incomplete data, we included 985 adults (415 [42.1%] Malays, 260 [26.4%] Indian, and 310 [31.5%] Chinese), who were visually impaired, and answered the questions on eyecare utilization and eyeglass affordability. Of these, 624 (63.4%) wore glasses and were considered for eyeglass affordability analyses. The study was conducted at the Singapore Eye Research Institute research clinic located at the Singapore National Eye Centre. All protocols followed the principles of the Declaration of Helsinki and received approval by the SingHealth Institutional Review Board (CIRB, Reference #NMRC/CIRG1417/2015, NMRC/CIRG1317/2013, and NMRC/0796/2003). Written informed consent from participants was obtained prior to participation in the study.

### Assessment of Eyecare Utilization and Eyeglass Affordability

Eyecare utilization and eyeglass affordability outcomes were assessed via an interviewer-administered questionnaire by trained interviewers fluent in English, Chinese, Malay, and Tamil. For eyecare utilization assessment, participants were asked "*How often do you have your eyes checked?*" and chose from the following categories: *once a quarter*, *twice a year*, *once a year*, *whenever being infected*, *when being seriously infected*, *when having a vision problem*, *when being seriously injured*, and *never*. "Low eyecare utilization" was defined as no eye checks or eye checks less than once per year (included categories: whenever being infected, when being seriously infected, when having vision problem, when being seriously injured, and never) in reference to at least once per year (included response options: once a quarter, twice a year, or once a year).

Those who wore glasses were also asked "*In comparison to your income, are glasses expensive?*", and were given the following four choices: *too expensive cannot*

*afford*, *expensive but affordable*, *not expensive, and cheap*. Difficulty affording glasses was defined as glasses being rated as expensive (included categories: too expensive cannot afford and expensive but affordable) in reference to not expensive (included categories: not expensive and cheap).

## Assessment of Other Covariates

Questionnaires to collect sociodemographic information, lifestyle factors, medical history, information on private health insurance, and awareness of common eye conditions, were administered by trained interviewers. Awareness of eye conditions was assessed using an in-house question "Have you ever heard of the following eye problems?" Response options included refraction-related problems, cataract, glaucoma, diabetic eye disease, and age-related macular degeneration (AMD). Low socioeconomic status (SES) was defined as primary or lower education, individual monthly income less than SGD $2000, and living in a 1 to 2-room apartment or smaller. We believe that defining SES with its individual components may be too liberal as proxies for low SES, as it may dilute the effect of low SES by including a lot more individuals who satisfy just one criterion. Our combined definition of low SES (comprising all three SES variables), therefore, is true representative of socioeconomically disadvantaged people in our population. This definition of low SES has been widely used in our local population-based study, the SEED studies.[27,28]

Clinical covariates were obtained via a standardized clinical examination. Visual acuity (VA) was measured monocularly using a LogMAR number chart (Lighthouse International, New York, NY, USA) at a distance of 4 meter. The PVA was ascertained with the participant wearing their "walk-in" optical correction (i.e. spectacles or contact lenses), if any. Best-corrected visual acuity (BCVA), in which refraction (if PVA was <0.3 LogMAR) was corrected by trained and certified study optometrists, was also obtained. Presenting VI was defined according to the US definition as PVA <0.3 LogMAR in the better seeing eye. Diabetes mellitus (DM) was defined as random glucose ≥11.1 mmol/L, HbA1c≥6.5% (≥48 mmol/L), subjects' self-reported use of diabetic medication and/or a reported history of physician-diagnosed DM.[31]

## Statistical Analyses

All analyses were performed using Stata version 15.0 (Statacorp, Lake Station, TX, USA). Baseline characteristics of study participants with VI by eyecare utilization and eyeglass affordability, were computed using *t*-tests for continuous variables and $\chi^2$ statistics for categorical variables (Tables 1 and 2). Logistic regression was performed to determine the factors associated with low eyecare utilization and difficulty affording glasses among individuals with VI (Tables 3 and 4). Key covariates included age, sex, race, SES, private health insurance, PVA (better eye), use of glasses, presence of eye conditions (cataract, refractive error, AMD, glaucoma, and/or DR), and presence of DM. We reported model estimates with 95% confidence intervals (CIs) and considered a *P* value of <0.05 statistically significant.

## Results

Our study sample included 985 adults (415 Malays, 260 Indians, and 310 Chinese; mean age [SD]: 69.5 [10.2] years; 55.4% women). Of these, 624 (63.4%) wore glasses and were included for the second study aim about spectacle affordability. The rate of low eyecare utilization among individuals with VI was 30.8% (303 of 985). Compared to those with optimal eyecare utilization, individuals with low utilization were younger; of Malay ethnicity; had lower SES; poorer PVA (better eye); less likely to have private health insurance, DM, and self-reported eye conditions; and had lower awareness of eye conditions (Table 1).

Table 2 shows the characteristics of study participants with VI stratified by eyeglass affordability. Among individuals with VI, 63.2% found spectacles difficult to afford. Compared to those who could afford glasses, those who reported finding them unaffordable were more likely to be older, female, of Malay ethnicity, not married, have self-reported eye conditions, and were less likely to have private health insurance.

We checked the variance inflation factors (VIFs) for collinearity between all determinants of eyecare utilization and eyeglass affordability, including age, sex, race, education, income, housing, low SES, private health insurance, diabetes, glasses use, self-reported eye condition, and presenting VA in the better eye in the same regression model. Estimated VIFs for all variables ranged between 1 and 1.5, with the exception of housing and low SES, which had VIFs >4 suggesting strong collinearity between them. This is not surprising as small housing was one of three criteria for low SES, and all individuals classified as having low SES stayed in a one to two-room Housing and Development Board (?HDB) flat or smaller compared to only 1% individuals not classified as having low SES. In view of these results, we examined the associations

**Table 1.** Sociodemographic and Clinical Characteristics of Study Subjects with Visual Impairment by Eyecare Utilization ($n = 985$)

| Variables | Mean ± SD or $n$ (%) | | | |
| --- | --- | --- | --- | --- |
| | Overall ($n = 985$) | Optimal Eyecare Utilization ($n = 682$) | Low Eyecare Utilization ($n = 303$) | P Value |
| Rates of eyecare utilization | | 682 (69.23) | 303 (30.76) | **<0.001** |
| Age, years | 69.5 ± 10.2 | 70.4 ± 9.9 | 67.4 ± 10.6 | **<0.001** |
| Female | 546 (55.4) | 379 (55.6) | 167 (55.1) | 0.894 |
| Race | | | | |
|    Malay | 415 (42.1) | 241 (35.3) | 174 (57.4) | **<0.001** |
|    Indian | 260 (26.4) | 203 (29.8) | 57 (18.8) | **<0.001** |
|    Chinese | 310 (31.5) | 238 (34.9) | 72 (23.8) | **<0.001** |
| Low socioeconomic status[a] | 107 (10.9) | 56 (8.2) | 51 (16.8) | **<0.001** |
| Currently married | 610 (61.9) | 419 (61.4) | 191 (63) | 0.633 |
| English is the spoken language | 210 (21.3) | 150 (22) | 60 (19.8) | 0.438 |
| Presenting VA (better eye) | 0.5 ± 0.3 | 0.5 ± 0.2 | 0.6 ± 0.3 | **0.002** |
| Presenting VA (worse eye) | 0.8 ± 0.6 | 0.8 ± 0.6 | 0.8 ± 0.6 | 0.905 |
| Wears eyeglasses of any kind | 629 (63.9) | 436 (63.9) | 193 (63.7) | 0.944 |
| Has private health insurance | 161 (16.3) | 98 (14.4) | 63 (20.8) | **0.012** |
| Diabetes, yes | 368 (37.4) | 298 (43.7) | 70 (23.1) | **<0.001** |
| Any self-reported eye condition[b] | 449 (45.6) | 349 (51.2) | 100 (33.0) | **<0.001** |

[a]Primary or lower education, individual monthly income less than SGD $2000, and 1-2 room flat.
[b]Cataract, myopia, macular degeneration, glaucoma, and/or diabetic retinopathy.
The P values in boldface are statistically significant.

of these covariates with our outcomes (eyecare utilization and eye glass affordability) in separate multivariable models.

In multivariable analyses, younger age, Malay ethnicity, low SES, absence of self-reported eye diseases, absence of DM, and poorer PVA (better eye) were independently associated with low utilization of eyecare among individuals with VI (Table 3).

Compared to those with no difficulty affording spectacles, those with difficulty were more likely to be older, female, and of Malay ethnicity (in reference to Chinese and Indians; Table 4).

The Figure shows the rates of eyecare utilization and eyeglass affordability, stratified by ethnicity. Compared to Chinese and Indians, Malays had the lowest rates of eyecare utilization and reported greatest difficulty affording eyeglasses.

## Discussion

In this multi-ethnic, population-based study of Singaporeans with VI, almost one-third had low eyecare utilization and nearly two-thirds reported difficulty affording eyeglasses. Ethnic disparities were evidenced in both eyecare utilization and eyeglass affordability, where Malays had the lowest rates of eyecare utilization, and most difficulty affording eyeglasses compared to Chinese and Indians. Factors associated with low utilization of eyecare were younger age, low SES, absence of DM, not having any eye diseases, and poor vision, whereas older age, and female sex were associated with difficulty affording glasses. This information is important for clinicians, researchers, and policy planners in designing culturally appropriate eyecare utilization awareness campaigns and awareness of available subsidy schemes for Singaporeans, but particularly for the Malay community. More research to identify the underlying factors contributing to these observed ethnic differences in eyecare utilization and spectacle affordability is needed.

Our low eyecare utilization rate is similar to those reported among the US adults with VI (30–50%).[32] We are unable to compare our findings with Asians, as no data on the eyecare utilization rates among Asians with VI are currently available. Our finding that nearly one-third of Singaporeans with VI (57% due to undercorrected refractive error) did not visit eyecare professionals routinely is of a concern as VI can be prevented

**Table 2.**  Sociodemographic and Clinical Characteristics of Study Subjects with Visual Impairment by Eyeglass Affordability (*n* = 624)

| | Mean ± SD or *n* (%) | | | |
|---|---|---|---|---|
| Variables | Overall (*n* = 624) | Affordable (*n* = 230) | Not Affordable (*n* = 394) | *P* Value |
| Rates of eyeglass affordability | | 230 (36.9) | 394 (63.1) | **<0.001** |
| Age, years | 68.7 ± 10.1 | 67.5 ± 9.8 | 69.5 ± 10.2 | **0.022** |
| Female | 318 (51.0) | 100 (43.5) | 218 (55.3) | **0.004** |
| Race | | | | |
|    Malay | 243 (38.9) | 57 (24.8) | 186 (47.2) | **<0.001** |
|    Indian | 174 (27.9) | 69 (30.0) | 105 (26.6) | **0.001** |
|    Chinese | 207 (33.2) | 104 (45.2) | 103 (26.1) | **<0.001** |
| Low socioeconomic status[a] | 51 (8.2) | 16 (7.0) | 35 (8.9) | 0.397 |
| Currently married | 425 (68.1) | 174 (75.7) | 251 (63.7) | **0.002** |
| English is the spoken language | 157 (25.2) | 52 (22.6) | 105 (26.6) | 0.262 |
| Presenting VA (better eye) | 0.5 ± 0.2 | 0.5 ± 0.2 | 0.5 ± 0.2 | 0.493 |
| Presenting VA (worse eye) | 0.8 ± 0.5 | 0.7 ± 0.3 | 0.8 ± 0.6 | **0.001** |
| Has private health insurance | 111 (17.8) | 51 (22.2) | 60 (15.2) | **0.029** |
| Diabetes, yes | 237 (38.0) | 77 (33.5) | 160 (40.6) | 0.077 |
| Any self-reported eye condition[b] | 305 (48.9) | 95 (41.3) | 210 (53.3) | **0.004** |

[a]Primary or lower education, individual monthly income less than SGD $2000, and 1-2 room flat.
[b]Cataract, myopia, macular degeneration, glaucoma, and/or diabetic retinopathy.

by early detection and timely treatment.[33] Moreover, VI is associated with poor health[7] and functional[5] and QOL outcomes.[2] Further qualitative and quantitative studies are needed to understand *why* people with VI are not seeking eyecare so that pertinent eyecare utiliza-tion awareness programs can be outlined. For example, tailored public health education on symptom aware-ness and the importance of seeking regular eye exami-nation to optimize utilization of eyecare services in Singaporeans, particularly those most in need of it,

**Table 3.**  Determinants of Low Eyecare Utilization in Individuals with Presenting Visual Impairment in the Better Eye (*n* = 985) in Multivariable Models

| | Unadjusted | | Multivariable-Adjusted | |
|---|---|---|---|---|
| Variables | OR (95% CI) | P | OR (95% CI) | *P* Value |
| Age (per 10-year decrease) | 1.34 (1.18 to 1.54) | **<0.001** | 1.44 (1.22 to 1.69) | **<0.001** |
| Male | 1.02 (0.78 to 1.34) | 0.894 | 1.08 (0.80 to 1.45) | 0.627 |
| Race | | | | |
|    Malay versus Indian | 2.57 (1.81 to 3.66) | **<0.001** | 2.43 (1.66 to 3.57) | **<0.001** |
|    Malay versus Chinese | 2.39 (1.72 to 3.31) | **<0.001** | 2.46 (1.72 to 3.52) | **<0.001** |
| Primary or below education | 1.10 (0.79 to 1.53) | 0.566 | | |
| Individual monthly income less than SGD $2000 | 0.91 (0.58 to 1.41) | 0.660 | | |
| Lives in a 1 to 2 room flat or smaller | 1.31 (0.92 to 1.85) | 0.131 | | |
| Low socioeconomic status[a] | 2.26 (1.51 to 3.40) | **<0.001** | 1.98 (1.27 to 3.08) | **0.002** |
| Without private health insurance | 1.56 (1.10 to 2.22) | **0.012** | 0.85 (0.57 to 1.29) | 0.453 |
| No diabetes | 2.58 (1.90 to 3.51) | **<0.001** | 2.77 (1.99 to 3.85) | **<0.001** |
| Not wearing glasses | 1.01 (0.76 to 1.34) | 0.944 | | |
| No self-reported eye condition[b] | 2.13 (1.60 to 2.82) | **<0.001** | 1.63 (1.20 to 2.21) | **0.002** |
| Presenting VA in the better eye (per line increase) | 1.08 (1.03 to 1.13) | **0.003** | 1.10 (1.04 to 1.16) | **0.002** |

[a]Primary or lower education, individual monthly income less than SGD $2000, and 1-2 room flat.
[b]Cataract, myopia, macular degeneration, glaucoma, and/or diabetic retinopathy.
OR, odds ratio.

**Table 4.** Determinants for Perception of Less Eyeglass Affordability of Eye Glasses in Individuals with Visual Impairment in Multivariable Regression Models

| Variables | Unadjusted OR (95% CI) | P Value | Multivariable-Adjusted OR (95% CI) | P Value |
|---|---|---|---|---|
| Age (per 10-year increase) | 1.21 (1.03 to 1.42) | **0.023** | 1.21 (1.01 to 1.47) | **0.043** |
| Race | | | | |
|   Malay versus Indian | 2.14 (1.40 to 3.28) | **<0.001** | 2.09 (1.36 to 3.23) | **0.001** |
|   Malay versus Chinese | 3.29 (2.20 to 4.93) | **<0.001** | 3.42 (2.25 to 5.18) | **<0.001** |
| Female | 1.61 (1.16 to 2.23) | **0.004** | 1.60 (1.13 to 2.25) | **0.008** |
| Primary or below education | 1.38 (0.96 to 1.97) | 0.080 | | |
| Individual monthly income less than SGD $2000 | 1.37 (0.84 to 2.22) | 0.207 | | |
| Lives in a 1-2 room flat or smaller | 1.09 (0.63 to 1.91) | 0.754 | | |
| Low socioeconomic status[a] | 0.90 (0.50 to 1.60) | 0.710 | 0.70 (0.38 to 1.31) | 0.264 |
| Without private health insurance | 1.59 (1.05 to 2.40) | **0.029** | 1.22 (0.76 to 1.95) | 0.417 |

[a]Primary or lower education, individual monthly income less than SGD $2000, and 1-2 room flat.
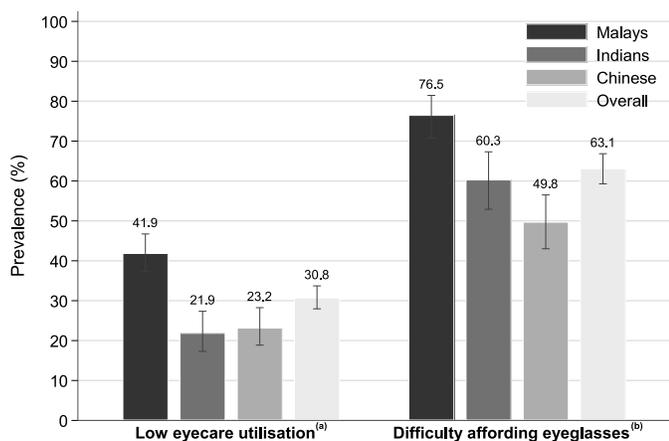


Significant **gaps in utilization of eyecare and affordability of eyeglasses** among individuals with visual impairment in multi-ethnic Singaporeans. Error bars represent 95% confidence intervals.

**Figure.** Eyecare utilization and eyeglass affordability stratified by ethnicity in the Singapore Epidemiology of Eye Disease Study.

are needed. Interestingly, two-thirds of our participants with good eyecare utilization were also visually impaired. The main reasons for VI in these individuals were undercorrected refractive error (50.1%), cataract (40%), DR (5%), and glaucoma (4.9%); suggesting that these individuals are less likely to adhere and comply with subsequent referrals to tertiary eyecare services.

A substantial proportion of our population with VI reported difficulty affording glasses (63%). This finding can result in un/undercorrected refractive error, which has several poor QOL outcomes.[3] Given that refractive error is largely amenable to simple correction with eyeglasses, the potential positive impact of spectacle correction is of appreciable public health importance. Our result highlights that eyeglass affordability may be a barrier in reducing the prevalence of un/undercorrected refractive error, therefore, suggesting the necessity for provision of subsidized glasses, which may mitigate some of the problems with refractive error and, in turn, reduce the prevalence of VI.

We found that Malays had the lowest rates of eyecare utilization and more likely to report difficulty affording glasses; independent of education level and income, both proxy indicators of SES. This result contrasts with some conceptual models, which suggest that the influence of ethnicity on health is mediated through SES.[34] Indeed, studies in the United States have found that apparent ethnic differences in eyecare utilization among black, white, and Hispanic American individuals are driven by socioeconomic and life-burden factors.[32,35–37] Several factors beyond SES may explain the ethnic disparity in utilizing eyecare services in our study, such as adaptation to vision loss, health beliefs, and behaviors, illness perceptions, use of alternative medicine, coping skills, social support, and minority status in Malays compared to Chinese and Indians, all of which vary according to religious and cultural backgrounds.[38–42]

In a previous report by our group, we found that a higher proportion of Malays compared to Chinese or Indians had undiagnosed eye diseases, such as glaucoma, DR, and vision-threatening DR,[19–21,25] suggesting that Malays take a more passive approach to disease management compared to their ethnic counterparts, consequently leading to low utilization of eyecare. More qualitative and quantitative research is needed to better understand why Malays have lower utilization of eyecare services and are more likely to find glasses less affordable. If modifiable factors, such as health beliefs or health-seeking behaviors are found,

they can be targeted for better outcomes in the different ethnic groups in Singapore.

Similar to other studies,[43–46] we observed that visually impaired individuals with low SES had lower eyecare utilization than their wealthier counterparts. This finding may be because of their inability to pay for the cost associated with preventative eyecare services, lack of vision and eyecare insurance coverage,[45,47] as well as their education, and beliefs about health.[48,49] Furthermore, our results demonstrate that persons without DM were more likely to have low eyecare utilization than those with DM. This is likely because patients with DM in Singapore attend an annual DR screening program in community clinics, which may serve to link up patients with eyecare services very early.

People who were older, female, and of Malay ethnicity were more likely to report difficulty affording glasses. We speculate that older individuals may be retired and, thus, have less available income, and may also have several comorbid conditions meaning they are less likely to prioritize purchase of eyeglasses.[50,51] The sex disparity may be due to complex behavioral, social, and economic decision making differences between men and women regarding health-related necessities.[52] Future studies are needed to better understand the reasons behind these observed association.

Strengths of our study include its population-based study design, which is generalizable to the Singaporean population; the use of standardized interview-based assessment and clinical testing protocols, and the ability to control for a range of known risk factors. However, our results must be interpreted within the context of certain limitations. Eyecare utilization and eyeglass affordability rating was self-reported and, as a result, our outcomes may be subjected to recall and other biases. The study design is cross-sectional, which precludes us from examining trends in eyecare utilization over time and from examining the temporality of our associations. Eyecare affordability was assessed in terms of spectacle affordability, whereas other costs, such as examination fees, prescription medications, etc., were not evaluated. Our study was not adequately powered to determine interactions aong covariates, such as ethnicity, sex, and SES, and, therefore, we did not conduct separate analyses among different ethnic groups and men and women for spectacle affordability. Future studies with adequate sample sizes to allow separate analyses among ethnic groups and between men and women stratified by SES for spectacle affordability are warranted. Furthermore, as only participants who wore eyeglasses were queried about difficulty affording eyeglasses, we might have potentially missed those who did not wear glasses because they cannot afford to have them. Indeed, upon studying baseline participant characteristics by presence or absence of eyeglasses, we found that, compared to individuals who had eyeglasses, those who did not have eyeglasses had poor presenting VA ($0.60 \pm 0.35$ vs. $0.49 \pm 0.19$ in the better eye), poorer BCVA (0.35 vs. 0.24 in the better eye), and low SES. These results indicate that there was a need for correction among those without eyeglasses and, as such, suggest that our rates for spectacle affordability are likely to be underestimated.

In summary, the rates of low eyecare utilization and difficulty affording eyeglasses were 31% and 63%, respectively, in our population-based study of Asian adults with VI. There were ethnic and age-related disparities in eyecare utilization and eyeglass affordability. Further qualitative work to understand the barriers associated with using eyecare services and spectacle affordability in different ethnic groups to better understand the ethnic differences are warranted. This will inform strategies to improve eyecare utilization and eyeglass affordability, such as tailored eyecare utilization awareness campaigns and awareness of available subsidy schemes for at-risk Singaporeans, such as Malays.

## Acknowledgments

Disclosure: **P. Gupta**, None; **S. Majithia**, None; **E.K. Fenwick**, None; **A.T.L. Gan**, None; **Y.-C. Tham**, None; **S. Poh**, None; **S. Thakur**, None; **C. Sabanayagam**,

None; **T.Y. Wong**, None; **C.-Y. Cheng**, None; **E.L. Lamoureux**, None

*PG and ELL had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

# References

1. Bourne RRA, Flaxman SR, Braithwaite T, et al. Magnitude, temporal trends, and projections of the global prevalence of blindness and distance and near vision impairment: a systematic review and meta-analysis. *Lancet Glob Health*. 2017;5:e888–e897.

2. Chiang PP, Zheng Y, Wong TY, Lamoureux EL. Vision impairment and major causes of vision loss impacts on vision-specific functioning independent of socioeconomic factors. *Ophthalmology*. 2013;120:415–422.

3. Lamoureux EL, Saw SM, Thumboo J, et al. The impact of corrected and uncorrected refractive error on visual functioning: the Singapore Malay Eye Study. *Invest Ophthalmol Vis Sci*. 2009;50:2614–2620.

4. Lamoureux EL, Chong EW, Thumboo J, et al. Vision impairment, ocular conditions, and vision-specific function: the Singapore Malay Eye Study. *Ophthalmology*. 2008;115:1973–1981.

5. West SK, Munoz B, Rubin GS, et al. Function and visual impairment in a population-based study of older adults. The SEE project. Salisbury Eye Evaluation. *Invest Ophthalmol Vis Sci*. 1997;38:72–82.

6. Wang X, Lamoureux E, Zheng Y, Ang M, Wong TY, Luo N. Health burden associated with visual impairment in Singapore: the Singapore epidemiology of eye disease study. *Ophthalmology*. 2014;121:1837–1842.

7. Crews JE, Chou CF, Sekar S, Saaddine JB. The Prevalence of chronic conditions and poor health among people with and without vision impairment, aged >/=65 years, 2010-2014. *Am J Ophthalmol*. 2017;182:18–30.

8. Koberlein J, Beifus K, Schaffert C, Finger RP. The economic burden of visual impairment and blindness: a systematic review. *BMJ Open*. 2013;3:e003471.

9. Varadaraj V, Frick KD, Saaddine JB, Friedman DS, Swenor BK. Trends in eye care use and eyeglasses affordability: the US National Health Interview Survey, 2008–2016. *JAMA Ophthalmol*. 2019;137:391–398.

10. Jin YP, Trope GE. Eye care utilization in Canada: disparity in the publicly funded health care system. *Can J Ophthalmol*. 2011;46:133–138.

11. McGwin G, Khoury R, Cross J, Owsley C. Vision impairment and eye care utilization among Americans 50 and older. *Curr Eye Res*. 2010;35:451–458.

12. Wang JJ, Mitchell P, Smith W. Use of eye care services by older Australians: the Blue Mountains Eye Study. *Aust N Z J Ophthalmol*. 1999;27:294–300.

13. Nirmalan PK, Katz J, Robin AL, et al. Utilisation of eye care services in rural south India: the Aravind Comprehensive Eye Survey. *Br J Ophthalmol*. 2004;88:1237–1241.

14. Fotouhi A, Hashemi H, Mohammad K. Eye care utilization patterns in Tehran population: a population based cross-sectional study. *BMC Ophthalmol*. 2006;6:4.

15. Wang D, Ding X, He M, et al. Use of eye care services among diabetic patients in urban and rural China. *Ophthalmology*. 2010;117:1755–1762.

16. Department of Statistics Singapore. Singapore in Figures. Singapore. Available at: https://www.singstat.gov.sg/publications/singapore-in-figures. (2015).

17. Pan CW, Chiang PP, Wong TY, et al. Ethnic differences in undercorrected refractive error in Asians. *Optom Vis Sci*. 2014;91:212–220.

18. Tan GS, Gan A, Sabanayagam C, et al. Ethnic differences in the prevalence and risk factors of diabetic retinopathy: the Singapore Epidemiology of Eye Diseases Study. *Ophthalmology*. 2018;125:529–536.

19. Chua J, Baskaran M, Ong PG, et al. Prevalence, risk factors, and visual features of undiagnosed glaucoma: the Singapore Epidemiology of Eye Diseases Study. *JAMA Ophthalmol*. 2015;133:938–946.

20. Chua J, Lim B, Fenwick EK, et al. Prevalence, risk factors, and impact of undiagnosed visually significant cataract: the Singapore Epidemiology of Eye Diseases Study. *PLoS One*. 2017;12:e0170804.

21. Chua J, Tham YC, Liao J, et al. Ethnic differences of intraocular pressure and central corneal thickness: the Singapore Epidemiology of Eye Diseases study. *Ophthalmology*. 2014;121:2013–2022.

22. Wong TY, Chong EW, Wong WL, et al. Prevalence and causes of low vision and blindness in an urban Malay population: the Singapore Malay Eye Study. *Arch Ophthalmol*. 2008;126:1091–1099.

23. Zheng Y, Lavanya R, Wu R, et al. Prevalence and causes of visual impairment and blindness in an urban Indian population: the Singapore Indian Eye Study. *Ophthalmology*. 2011;118:1798–1804.

translational vision science & technology

24. Tham YC, Lim SH, Shi Y, et al. Trends of visual impairment and blindness in the Singapore Chinese population over a decade. *Sci Rep*. 2018;8:12224.

25. Huang OS, Tay WT, Ong PG, et al. Prevalence and determinants of undiagnosed diabetic retinopathy and vision-threatening retinopathy in a multiethnic Asian cohort: the Singapore Epidemiology of Eye Diseases (SEED) study. *Br J Ophthalmol*. 2015;99:1614–1621.

26. Pan CW, Zheng YF, Anuar AR, et al. Prevalence of refractive errors in a multiethnic Asian population: the Singapore Epidemiology of Eye Disease study. *Invest Ophthalmol Vis Sci*. 2013;54:2590–2598.

27. Foong AW, Saw SM, Loo JL, et al. Rationale and methodology for a population-based study of eye diseases in Malay people: the Singapore Malay eye study (SiMES). *Ophthalmic Epidemiol*. 2007;14:25–35.

28. Lavanya R, Jeganathan VS, Zheng Y, et al. Methodology of the Singapore Indian Chinese Cohort (SICC) eye study: quantifying ethnic variations in the epidemiology of eye diseases in Asians. *Ophthalmic Epidemiol*. 2009;16:325–336.

29. Sabanayagam C, Yip W, Gupta P, et al. Singapore Indian Eye Study-2: methodology and impact of migration on systemic and eye outcomes. *Clin Exp Ophthalmol*. 2017;45:779–789.

30. Rosman M, Zheng Y, Wong W, et al. Singapore Malay Eye Study: rationale and methodology of 6-year follow-up study (SiMES-2). *Clin Exp Ophthalmol*. 2012;40:557–568.

31. American Diabetes Association. Standards of medical care in diabetes–2015: summary of revisions. *Diabetes Care*. 2015;38(Suppl. 1):S4.

32. Chou CF, Barker LE, Crews JE, et al. Disparities in eye care utilization among the United States adults with visual impairment: findings from the behavioral risk factor surveillance system 2006-2009. *Am J Ophthalmol*. 2012;154:S45–S52.e41.

33. Hill L, Makaroff LE, Early detection and timely treatment can prevent or delay diabetic retinopathy. *Diabetes Res Clin Pract*. 2016;120:241–243.

34. Schulman KA, Rubenstein LE, Chesley FD, Eisenberg JM. The roles of race and socioeconomic factors in health services research. *Health Serv Res*. 1995;30:179–195.

35. Baker RS, Bazargan M, Bazargan-Hejazi S, Calderon JL. Access to vision care in an urban low-income multiethnic population. *Ophthalmic Epidemiol*. 2005;12:1–12.

36. Lee DJ, Lam BL, Arora S, et al. Reported eye care utilization and health insurance status among US adults. *Arch Ophthalmol*. 2009;127:303–310.

37. Wagner LD, Rein DB. Attributes associated with eye care use in the United States: a meta-analysis. *Ophthalmology*. 2013;120:1497–1501.

38. Lim WY, Ma S, Heng D, Bhalla V, Chew SK. Gender, ethnicity, health behaviour & self-rated health in Singapore. *BMC Public Health*. 2007;7:184.

39. Quah SH, Bishop GD. Seeking help for illness: the roles of cultural orientation and illness cognition. *J Health Psychol*. 1996;1:209–222.

40. Lim AS, Bishop GD. The role of attitudes and beliefs in differential health care utilisation among Chinese in Singapore. *Psychol Health*. 2000;14:965–977.

41. Chan CQH, Lee KH, Low LL. A systematic review of health status, health seeking behaviour and healthcare utilisation of low socioeconomic status populations in urban Singapore. *Int J Equity Health*. 2018;17:39.

42. Caldwell EM, Baxter J, Mitchell CM, Shetterly SM, Hamman RF. The association of non-insulin-dependent diabetes mellitus with perceived quality of life in a biethnic population: the San Luis Valley Diabetes Study. *Am J Public Health*. 1998;88:1225–1229.

43. Schaumberg DA, Christen WG, Glynn RJ, Buring JE. Demographic predictors of eye care utilization among women. *Med Care*. 2000;38:638–646.

44. Robin AL, Nirmalan PK, Krishnadas R, et al. The utilization of eye care services by persons with glaucoma in rural south India. *Trans Am Ophthalmol Soc*. 2004;102:47–54; discussion 54–45.

45. Zhang X, Lee PP, Thompson TJ, et al. Health insurance coverage and use of eye care services. *Arch Ophthalmol*. 2008;126:1121–1126.

46. Zhang X, Beckles GL, Chou CF, et al. Socioeconomic disparity in use of eye care services among US adults with age-related eye diseases: National Health Interview Survey, 2002 and 2008. *JAMA Ophthalmol*. 2013;131:1198–1206.

47. Zhang X, Saaddine JB, Lee PP, et al. Eye care in the United States: do we deliver to high-risk people who can benefit most from it? *Arch Ophthalmol*. 2007;125:411–418.

48. Zhang X, Andersen R, Saaddine JB, Beckles GL, Duenas MR, Lee PP. Measuring access to eye care: a public health perspective. *Ophthalmic Epidemiol*. 2008;15:418–425.

49. Wong HZ, Lim WY, Ma SS, Chua LA, Heng DM. Health screening behaviour among Singaporeans. *Ann Acad Med Singapore*. 2015;44:326–334.

translational vision science & technology

50. Park S, Kim B, Kim S. Poverty and working status in changes of unmet health care need in old age. *Health Policy*. 2016;120:638–645.

51. Kwon E, Park S, McBride TD. Health insurance and poverty in trajectories of out-of-pocket expenditure among low-income middle-aged adults. *Health Serv Res*. 2018;53:4332–4352.

52. Doyal L, Das-Bhaumik RG, Sex, gender and blindness: a new framework for equity. *BMJ Open Ophthalmol*. 2018;3:e000135.

translational vision science & technology