# The Impact of Corrected and Uncorrected Refractive Error on Visual Functioning: The Singapore Malay Eye Study

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**PURPOSE.** To determine the impact of corrected and uncorrected myopia and hyperopia on visual functioning in an urban Malay population.

**METHODS.** The Singapore Malay Eye Study is a population-based, cross-sectional study of Singaporean Malays aged 40 to 80 years. Myopia was defined as spherical equivalence (SE) ≤ −0.50 D, hyperopia as SE > 1.0 D, and emmetropia as SE −0.5 to 1.0 D in the better eye. Uncorrected myopia and hyperopia were defined as at least a 2-line difference between habitual and best corrected VA in persons with myopia or hyperopia, respectively. Visual functioning was assessed with the VF-11 scale.

**RESULTS.** Of 2912 participants, 441 (15.1%) and 213 (7.3%) had corrected or uncorrected hyperopia and 333 (11.4%), and 131 (4.5%) had corrected or uncorrected myopia, respectively. Of those, 249 (8.6%) participants were considered emmetropic with a >2-line difference between habitual and best corrected vision, and 1543 (53.1%) participants had a ≤2-line difference. In linear regression models adjusted for age, sex, educational attainment, ocular conditions, and nonocular comorbidity, only uncorrected myopia was independently associated with poorer overall visual functioning ($\beta$ regression coefficient = −0.34; $P \leq 0.001$) and with activities such as reading street signs ($\beta = -0.47$; 95% CI: −0.62 to −0.33; $P < 0.001$), recognizing friends ($\beta = -0.52$; 95% CI: −0.67 to −0.37; $P < 0.001$), and watching television ($\beta = -0.33$; 95% CI: −0.44 to −0.22; $P < 0.001$). These findings were replicated in a healthy subsample with no other eye conditions and nonocular comorbidities ($n = 1112$).

**CONCLUSIONS.** Adequate myopia correction can improve participation in daily living and visual functioning in people with myopia. Correction of hyperopia does not have this effect.

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Refractive errors are common eye conditions affecting a large proportion of the adult population, particularly in Asian countries.[1–7] In the United States, the annual direct costs of correcting vision impairment associated with refractive error ranged from US$3.9 billion to US$7.2 billion in 2002.[8]

Myopia, a frequent type of refractive error, appears more prevalent in Asians than in Caucasians.[1–4] A prevalence of high myopia of 28% and 26.2%, has been recorded in Singaporeans of Chinese[6] and Malay origins,[7] respectively. Persons with myopia remain at risk for conditions caused by excessive axial elongation. Similarly, high myopia is a predisposing factor for retinal detachment, myopic retinopathy, myopic maculopathy, and glaucoma.[9]

Uncorrected refractive error is associated with decreased vision-related quality of life (QoL) and increasing difficulty in performing vision-related tasks.[10] In a recent Australian study, it was shown that myopia corrected with spectacles or contact lenses has a negative impact on some aspects of vision-dependent QoL.[11] This study was limited, however, by a relatively low prevalence of myopia and a small sample of subjects with myopia ($n = 66$). In Asian countries where the prevalence of myopia is high, improving our understanding of the impact of myopia on vision-specific QoL can contribute to more effective intervention trials, which can be of benefit to large sections of the population.[12] In addition, although hyperopia constitutes most of the refractive errors in older populations and a large proportion of people with hyperopia have uncorrected vision, there are no data on the impact of uncorrected hyperopia on vision-specific QoL.[12]

The Singapore Malay Eye Study was undertaken to determine the prevalence and impact of vision impairment and major eye diseases in urban Asian populations. Approximately one quarter of Singaporean Malays have myopia.[7] In this article, we report on the impact of corrected or uncorrected myopia and hyperopia on overall and specific aspects of visual functioning. This information is fundamental to improving our understanding of the impact of uncorrected refractive error on vision-dependent participation in daily living and to establish the need for and type of intervention programs for individuals with these refractive errors.

## METHODS

### Study Population

The Singapore Malay Eye Study is a population-based cross-sectional study of Malay subjects residing in Singapore, and the study procedures are described elsewhere.[13–15] Briefly, an age-stratified random sampling procedure was used to select Malay people aged 40 to 80 years living in the South-Western part of Singapore.[8] Of the 4168 eligible participants from the sampling frame, 3280 (78.7%) participated. Sociodemographic and medical data were recorded by using a standard-

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**TABLE 1.** SE, PVA, CVA, and the Difference between PVA and CVA in the Better and Worse Eyes for the Whole Sample and the Study Groups

| | Corrected Hyperopia $n$ = 441 (15.1%) | Uncorrected Hyperopia $n$ = 213 (7.3%) | Corrected Myopia $n$ = 333 (11.4%) | Uncorrected Myopia $n$ = 131 (4.5%) | Uncorrected Emmetropia $n$ = 249 (8.6%) | Corrected Emmetropia $n$ = 1545 (53.1%) | Total $N$ = 2912 (100%) |
|---|---|---|---|---|---|---|---|
| SE (D) | | | | | | | |
| Better eye | 1.98 ± 0.72 | 1.86 ± 0.58 | −2.68 ± 2.11 | −2.22 ± 2.34 | 0.30 ± 0.52 | 0.25 ± 0.39 | 0.18 ± 1.69 |
| Worse eye | 2.23 ± 1.34 | 2.21 ± 1.05 | −3.10 ± 2.77 | −3.08 ± 3.07 | 0.18 ± 180 | 0.43 ± 0.81 | 0.25 ± 2.23 |
| PVA (logMAR) | | | | | | | |
| Better eye | 0.15 ± 0.15 | 0.45 ± 0.18 | 0.17 ± 0.23 | 0.65 ± 0.21 | 0.40 ± 0.19 | 0.11 ± 0.15 | 0.20 ± 0.23 |
| Worse eye | 0.28 ± 0.21 | 0.56 ± 0.20 | 0.31 ± 0.30 | 0.78 ± 0.20 | 0.53 ± 0.23 | 0.23 ± 0.23 | 0.32 ± 0.27 |
| CVA (logMAR) | | | | | | | |
| Better eye | 0.07 ± 0.13 | 0.07 ± 0.12 | 0.12 ± 0.21 | 0.18 ± 0.18 | 0.08 ± 0.15 | 0.04 ± 0.13 | 0.07 ± 0.15 |
| Worse eye | 0.14 ± 0.19 | 0.15 ± 0.19 | 0.19 ± 0.26 | 0.30 ± 0.28 | 0.19 ± 0.24 | 0.09 ± 0.17 | 0.13 ± 0.21 |
| Difference between PVA and CVA (logMAR) | | | | | | | |
| Better eye | 0.08 ± 0.07 | 0.39 ± 0.14 | 0.05 ± 0.06 | 0.47 ± 0.18 | 0.32 ± 0.10 | 0.06 ± 0.07 | 0.13 ± 0.15 |
| Worse eye | 0.15 ± 0.14 | 0.41 ± 0.18 | 0.13 ± 0.14 | 0.52 ± 0.24 | 0.34 ± 0.17 | 0.13 ± 0.14 | 0.19 ± 0.18 |

Data are the mean ± SD.

ized questionnaire that has been described elsewhere.[8] The study was conducted in accordance with the Declaration of Helsinki. Ethics approval was obtained from the Singapore Eye Research Institute Institutional Review Board.

## Vision Assessment

Participants underwent an extensive and standardized examination procedure that included visual acuity testing and a detailed clinical slit lamp examination. Each participant's presenting visual acuity was determined for each eye separately, with habitual optical correction (spectacles or contact lenses) in place. Visual acuity was measured with a logarithm of the minimum angle of resolution (logMAR) vision chart (Lighthouse International, New York, NY) read at a 4-m distance.[15]

Refraction and the corneal curvature radii in the horizontal and vertical meridian were measured with an autorefractor (Canon RK-5 Auto Ref-Keratometer; Canon Inc. Ltd., Tokyo, Japan). Final refraction was determined subjectively by trained and certified study optometrists.[7] A trial frame was placed and adjusted on the subject's face. Autorefraction readings were used as the starting point, and refinement of sphere, cylinder, and axis was performed until the best visual acuity was obtained. Subjective refraction could not be obtained in <1% ($n$ = 17) of the participants, and autorefractive measurements were used instead.

## Definitions and Diagnosis

The refractive error was estimated using standardized subjective refraction techniques and if unavailable, autorefraction measurements were used instead.[7] Myopia was defined as spherical equivalence (SE) < −0.50 D, hyperopia was defined as SE > +1.0 D and emmetropia as SE −0.5 to +1.0 D. We used the SE for the better eye for our analyses (Table 1). Uncorrected myopia and uncorrected hyperopia were defined as at least a 2-line difference between presenting and corrected logMAR in the better spherical eye and the presence of myopia or hyperopia, respectively.[16]

## Visual Functioning

Visual functioning was assessed with the VF-11 (a modified version of VF-14), which had been changed to suit the local cultural context—namely Chinese Singaporean.[17] The administration and validation of the VF-11 has been described elsewhere.[18] Briefly, 11 visual functioning questions were used to assess the level of difficulty in performing the following activities: seeing stairs, seeing street or shop signs, recognizing people, watching television, cooking, playing cards (or mahjong), reading newspapers, completing lottery forms, reading small print, driving in the day, and driving at night. The VF-11 scale, a numeric scale ranging from 0 (no difficulty) to 4 (unable to perform activity) was chosen, as it assesses participation in some daily activities important in the local context (i.e., playing cards and the lottery).

## Rasch Analyses

Rasch analysis was undertaken to determine the validity and measurement characteristics of the VF-11, as described previously.[18] In the Rasch analysis, the probability of an individual's choosing a particular item response depends on both the person's ability and the difficulty of the item. It is taken as a criterion for the structure of responses that the person should be satisfied with, rather than a simple statistical description of the responses. Both person ability and item difficulty must refer to a trait being measured (i.e., visual functioning), hence the Rasch model is unidimensional. Once data fit the Rasch model, estimates of measures on an interval scale are provided, which improves scoring accuracy and tends to remove measurement noise.[19–22] The unit of measurement in Rasch analysis is logits, which is the natural logarithm of the odds of success in choosing a response. Tasks of average difficulty are assigned 0 logits. Tasks with above-average difficulty get a positive logit score, and tasks with below-average difficulty get a negative logit score. Person ability is defined as 0 logits when the respondent has a 50% chance of endorsing an item of average difficulty. A person with a logit score of 2.0 has a 50% chance of selecting an item with a difficulty level of 2.0 logits.

We used the Andrich rating scale to determine whether the VF-11 data fitted the Rasch model.[23] Content validity was evaluated using person and item fit residual statistics, where it is expected that the mean and SD values approximate 0 and 1, respectively. An overall item–trait interaction score ($\chi^2$) with a statistically nonsignificant probability ($P > 0.05$) indicates fit to the model and that hierarchical ordering of the items (i.e., from difficult to easy) is consistent across all levels of vision function. An estimate of the internal reliability of the scale based on the person separation reliability (PSR) was also reported.[24] A PSR (similar to Cronbach's $\alpha$) ≥ 0.7 is suitable for group use.[25] This reliability measure is closely linked to the targeting of the scale as it differentiates the number of statistically distinct groups of respondents that can be identified on the trait.[26]

Disordered thresholds were also assessed, as participants often have difficulty discriminating between the response options. Category collapsing is often the solution to disordered thresholds. DIF (differential item functioning) testing was undertaken to determine whether different groups within the sample (e.g., sex, eye diseases), despite equal levels of functioning, respond differently to individual items. The unidimensionality of the scale was determined by using principal

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components analysis (PCA) of the residuals. Unidimensionality took the form of an independent *t*-test technique that tests for deviations between two sets of person locations, on a person-by-person basis.[27,28] The two location sets were derived from two subsets of items (positive and negative loading subsets) from the final scale and identified by the loadings of item residuals in a PCA. The overall proportion of *t* results falling outside a ±1.96 range should be ≤5% to confirm unidimensionality. Most of the Rasch analyses were performed with Rasch item analysis software (RUMM2020, 2003; RUMM Laboratory, Perth, Australia).[29] The Winsteps software (version 3.61)[30] was used to generate transformed individual person scores for all items, as this feature is not currently available in RUMM.

## Statistical Analyses

Descriptive statistical analyses were performed to characterize the participants' sociodemographic and clinical data using statistical software (SPSS ver. 15.0; SPSS Science, Chicago, IL). The overall and individual item scores linearly estimated after Rasch analysis were fitted to linear regression models and used *t*-based 95% confidence intervals (CIs) for the regression coefficients. The association between overall and specific aspects of visual functioning and refractive error was analyzed (linear regression analyses), with adjustment for age, sex, nonocular comorbidity, ocular conditions, and educational attainment. In linear regression models, independent significant predictors were considered to be clinically meaningful if their $\beta$ coefficients were approximately one half the SD of the mean, which is generally considered a useful estimate of a clinically meaningful difference.[31–33]

# Results

In this study, 2912 participants with sociodemographic, clinical, and visual functioning data were included in the analyses. Overall, the participants' mean ± SD age was 57.5 (±10.7) years and there were marginally more men (1511; 51.9%) than women. Of the participants, 373 (12.8%) had cataract, 122 (4.2%) had diabetic retinopathy, and 26 (0.9%) age-related macular degeneration; 441 (15.1%), 213 (7.3%), 333 (11.4%), and 131 (4.5%); had corrected and uncorrected hyperopia and corrected and uncorrected myopia, respectively. There were 1792 participants considered to be emmetropic, of which 249 (8.6%) had more than a 2-line difference between presenting and corrected vision in the better eye. We labeled this group uncorrected emmetropia. The remaining 1543 (53.1%) participants had a 2-line or less difference and were labeled corrected emmetropia (Table 1). The mean (±SD) for spherical equivalence (SE), presenting visual acuity (PVA), corrected visual acuity (CVA), and the difference between PVA and CVA (logMAR) in the better and worse eyes are presented in Table 1. Those with uncorrected myopia had significantly poorer presenting and corrected VA in the better and worse eyes than participants with corrected myopia ($P < 0.001$, Table 1). A similar difference was found between corrected and uncorrected hyperopia, although it was only statistically significant for presenting VA ($P < 0.001$).

Validation of the VF-11 in this population by Rasch analysis has been described previously.[18,34] There was evidence of disordered thresholds, which necessitated that categories 2, moderate difficulty, and 3, a little difficulty, be collapsed, and that resulted in ordered thresholds for all items. Two items—Do you have difficulty in driving during the day because of vision? and Do you have difficulty in driving at night time because of vision?—showed misfit and had to be removed. The fit statistics of the remaining nine items were found to be consistent with the Rasch model requirements. The PSR was 0.82, which indicates that the VF-11 can distinguish between several levels of person ability and has good internal reliability. There was no evidence of multidimensionality that supports the validity of the VF-11 being able to assess one underlying trait (visual functioning) that it purports to measure. Overall, the three most difficult items in the VF-9 were difficulty reading small print (1.34 logits), difficulty in filling out lottery forms (0.76 logits), and difficulty reading newspaper (0.65 logits). Conversely, the three least difficult items were associated with difficulty cooking, difficulty playing games, and difficulty seeing stairs, with logit scores of −1.56, −1.26, and −0.71, respectively. Fit of the VF-11 data to the Rasch model implies that the overall score has interval properties. Collectively, these results show that the VF-11 is a unidimensional, reliable, and valid scale to assess visual functioning in this sample.

The mean overall participants' score on the VF-11 was 3.65 ± 0.87 logits (Table 2). The positive score suggests that the participants' level of functioning was higher than the mean required level of difficulty for the items. One-way ANOVA found significant between-group effects on the overall and five individual items related to difficulty with seeing stairs, reading street signs, recognizing faces, watching TV, and filling lottery tickets (Table 2). Multiple comparisons showed that participants with uncorrected myopia recorded significantly worse visual functioning scores on these parameters than did those in the other five categories of refractive error ($P < 0.05$).

For the overall visual functioning score, a clinically important difference was estimated at ±0.43 logit, which is approximately half the SD of the mean overall score (0.87 logit). We controlled for age, sex, educational attainment, ocular conditions, and nonocular comorbidity (stroke, heart attack, diabetes, high cholesterol, and hypertension). Considering that 8.6% of participants with emmetropia had more than a 2-line difference between presenting and corrected vision in the better eye, we considered six categories of refractive error for the regression models: 441 (15.1%), 213 (7.3%), 333 (11.4%), 131 (4.5%) 249 (8.6%), and 1545 (53.1%) for corrected hyperopia, uncorrected hyperopia, corrected myopia, uncorrected myopia, uncorrected emmetropia (>2 lines), and corrected emmetropia (≤2 lines, reference), respectively.

Only uncorrected myopia was independently associated with the overall functioning score. Compared with participants with corrected emmetropia, those with uncorrected myopia recorded significantly worse visual functioning scores overall ($\beta$ regression coefficient = −0.34, $P \leq 0.001$; Table 3). This result suggests that compared with persons with corrected emmetropia, those with uncorrected myopia, on average, have poorer overall QoL by 0.34 logit, and the deterioration in functioning was close to being considered clinically meaningful. Self-reported heart attack, being female, having an ocular condition, and less education were independently associated with poorer visual functioning ($P < 0.05$, Table 3). A similar independent association with uncorrected myopia was found for three individual items—reading street signs ($\beta = -0.47$; 95% CI: −0.62 to −0.33; $P < 0.001$), recognizing friends ($\beta = -0.52$; 95% CI: −0.67 to −0.37; $P < 0.001$), and watching television ($\beta = -0.33$; 95% CI: −0.44 to −0.22; $P < 0.001$). These associations were all considered to be clinically meaningful. When presenting visual acuity in the better eye was introduced in the linear regression models, no category of refractive error was found to be independently associated with any aspect of visual functioning.

To validate our findings, all participants with a documented nonrefractive cause of vision impairment and nonocular comorbidities were excluded, to minimize the confounding effect of visual disability and morbidity on visual functioning. After the removal of these participants, 1112 participants remained. Overall, the participants' mean age was 52.8 (±9.6) years, and there were marginally more women (600, 54%) than men. Of these, 119 (10.7%), 56 (5.0%), 125 (11.2%), 85 (7.8%),

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**Table 2.** Participants with Myopia, Hyperopia, and Emmetropia (Corrected and Uncorrected), Stratified for the Parameters Shown

| | Corrected Hyperopia *n* = 441 (15.1%) | Uncorrected Hyperopia *n* = 213 (7.3%) | Corrected Myopia *n* = 333 (11.4%) | Uncorrected Myopia *n* = 131 (4.5%) | Uncorrected Emmetropia *n* = 249 (8.6%) | Corrected Emmetropia *n* = 1545 (53.1%) | Total *N* = 2912 (100%) | *P* |
|---|---|---|---|---|---|---|---|---|
| Sex | | | | | | | | |
| Male | 220 (14.6%) | 133 (8.8%) | 192 (12.7%) | 75 (5.0%) | 133 (8.8%) | 758 (50.2%) | 1511 | 0.001 |
| Female | 221 (15.8%) | 80 (5.7%) | 141 (10.1%) | 56 (4.0%) | 116 (8.3%) | 787 (56.2%) | 1401 | |
| Age range (y) | | | | | | | | |
| 40–49 | 15 (1.9%) | 14 (1.7%) | 129 (16.1%) | 49 (6.1%) | 47 (5.9%) | 548 (68.3%) | 802 | <0.001 |
| 50–59 | 135 (14.7%) | 77 (8.4%) | 97 (10.6%) | 24 (2.6%) | 90 (9.8%) | 495 (53.9%) | 918 | |
| 60–69 | 184 (27.4%) | 77 (11.5%) | 41 (6.1%) | 24 (3.6%) | 55 (8.2%) | 290 (43.2%) | 671 | |
| 70–80 | 107 (20.5%) | 45 (8.6%) | 66 (12.7%) | 34 (6.5%) | 57 (10.9%) | 212 (40.7%) | 521 | |
| Education | | | | | | | | |
| No formal education | 100 (18.9%) | 55 (10.4%) | 43 (8.1%) | 25 (4.7%) | 63 (11.9%) | 244 (46.0%) | 530 | <0.001 |
| Less than elementary | 47 (19.6%) | 16 (6.7%) | 13 (5.4%) | 16 (6.7%) | 26 (10.8%) | 122 (50.8%) | 240 | |
| Elementary | 209 (15.4%) | 106 (7.8%) | 116 (8.6%) | 65 (4.8%) | 111 (8.2%) | 747 (55.2%) | 1354 | |
| High school | 64 (11.0%) | 32 (5.5%) | 109 (18.8%) | 21 (3.6%) | 41 (7.1%) | 313 (54.0%) | 580 | |
| College/university | 19 (9.3%) | 4 (2.0%) | 51 (25.0%) | 4 (2.0%) | 8 (3.9%) | 118 (57.8%) | 204 | |
| Hypertension | | | | | | | | |
| Yes | 203 (19.3%) | 89 (8.5%) | 104 (9.9%) | 41 (3.9%) | 90 (8.5%) | 526 (50.0%) | 1053 | <0.001 |
| No | 236 (12.9%) | 123 (6.7%) | 225 (12.3%) | 89 (4.9%) | 155 (8.5%) | 998 (54.7%) | 1826 | |
| Stroke | | | | | | | | |
| Yes | 10 (14.7%) | 9 (13.2%) | 8 (11.8%) | 3 (4.4%) | 8 (11.8%) | 30 (44.1%) | 68 | 0.388 |
| No | 431 (15.2%) | 204 (7.2%) | 324 (11.4%) | 127 (4.5%) | 241 (8.5%) | 1514 (53.3%) | 2841 | |
| Heart attack | | | | | | | | |
| Yes | 36 (20.6%) | 12 (6.9%) | 22 (12.6%) | 7 (4.0%) | 26 (14.9%) | 72 (41.1%) | 175 | 0.004 |
| No | 405 (14.8%) | 200 (7.3%) | 311 (11.4%) | 124 (4.5%) | 223 (8.2%) | 1470 (53.8%) | 2733 | |
| Cholesterol | | | | | | | | |
| Yes | 178 (21.0%) | 67 (7.9%) | 83 (9.8%) | 24 (2.8%) | 65 (7.7%) | 429 (50.7%) | 846 | <0.001 |
| No | 242 (12.5%) | 135 (7.0%) | 231 (12.0%) | 100 (5.2%) | 173 (9.0%) | 1048 (54.3%) | 1929 | |
| Diabetes | | | | | | | | |
| Yes | 95 (18.3%) | 52 (10.0%) | 46 (8.8%) | 11 (2.1%) | 36 (6.9%) | 280 (53.8%) | 520 | <0.001 |
| No | 343 (14.5%) | 160 (6.8%) | 284 (12.0%) | 120 (5.1%) | 213 (9.0%) | 1246 (52.7%) | 2366 | |
| Visual function scores (logit) | | | | | | | | |
| Overall | 3.67 ± 0.95 | 3.55 ± 1.13 | 3.79 ± 0.97 | 3.22 ± 1.21 | 3.52 ± 1.08 | 3.68 ± 0.99 | 3.65 ± 0.87 | <0.001 |
| Seeing stairs | 2.96 ± 0.52 | 2.96 ± 0.53 | 2.93 ± 0.58 | 2.88 ± 0.73 | 2.94 ± 0.58 | 3.01 ± 0.41 | 2.98 ± 0.50 | 0.002 |
| Reading street signs | 2.94 ± 0.55 | 2.74 ± 0.88 | 2.86 ± 0.69 | 2.32 ± 1.25 | 2.78 ± 0.89 | 2.85 ± 0.72 | 2.83 ± 0.77 | <0.001 |
| Recognizing faces | 2.85 ± 0.70 | 2.72 ± 0.94 | 2.83 ± 0.76 | 2.35 ± 1.21 | 2.77 ± 0.91 | 2.89 ± 0.72 | 2.83 ± 0.79 | <0.001 |
| Watching TV | 2.94 ± 0.56 | 2.90 ± 0.67 | 2.98 ± 0.51 | 2.67 ± 0.94 | 2.91 ± 0.65 | 2.95 ± 0.55 | 2.96 ± 0.55 | <0.001 |
| Cooking | 3.03 ± 0.33 | 3.03 ± 0.33 | 3.04 ± 0.30 | 2.98 ± 0.54 | 2.99 ± 0.47 | 3.03 ± 0.34 | 3.03 ± 0.36 | 0.500 |
| Playing games | 2.98 ± 0.48 | 3.02 ± 0.37 | 3.03 ± 0.33 | 2.89 ± 0.80 | 3.08 ± 0.00 | 3.03 ± 0.41 | 3.02 ± 0.41 | 0.291 |
| Reading newspapers | 2.73 ± 0.88 | 2.58 ± 1.13 | 2.75 ± 0.89 | 2.69 ± 1.00 | 2.63 ± 1.03 | 2.62 ± 1.02 | 2.65 ± 0.99 | 0.135 |
| Filling in lottery tickets | 2.79 ± 0.80 | 2.65 ± 1.03 | 2.82 ± 0.83 | 2.69 ± 1.00 | 2.61 ± 1.14 | 2.67 ± 0.98 | 2.70 ± 0.97 | 0.039 |
| Reading phonebooks | 2.38 ± 1.33 | 2.40 ± 1.27 | 2.59 ± 1.15 | 2.19 ± 1.53 | 2.28 ± 1.43 | 2.34 ± 1.31 | 2.37 ± 1.32 | 0.056 |

641 (57.6%), and 84 (7.6%) had corrected and uncorrected myopia, corrected and uncorrected hyperopia, and corrected and uncorrected emmetropia, respectively. The independent associations found in the main sample were replicated in this subsample and were clinically meaningful for reading street signs, recognizing friends, and watching television (Table 4). It approached clinical significance for the overall score.

## Discussion

Although it is well recognized that uncorrected refractive error affects a substantial proportion of the population, there are currently limited data on the impact of uncorrected refractive error on overall visual functioning and specific activities of daily living. Our population-based study among Malay persons demonstrates that corrected myopia, corrected and uncorrected hyperopia, and uncorrected emmetropia do not significantly affect general and specific aspects of vision function. Second, we show that persons with uncorrected myopia recorded significantly worse participation scores than those in other categories of refractive error on several aspects of functioning. Finally, we provide evidence that uncorrected myopia was not independently associated with poorer functioning when presenting visual acuity was introduced in the regression models. This finding suggests that myopia alone does not have an effect on daily activities, but myopia that remains uncorrected affects visual functioning. These findings were replicated after we included only those with refractive error, and no other eye condition and nonocular comorbidities. These are important findings considering that the prevalence and severity of myopia are increasing in different parts of the world, particularly in Asian cities such as Singapore.[4,6,35]

Because of the lack of published data in this area, it is difficult to compare our findings with those in previous work. In Singapore teenagers, utility values in myopic students were found to be higher for those with better presenting visual acuity and for those who wore spectacles or contact lenses, had a higher total family income, had more "academic" schooling, and were non-Muslim.[12] In adult patients with myopia in hospital in the UK, it was shown that higher levels of myopia have an adverse effect on QoL scores (measured using the VF-14 and VCM1) comparable to that of patients with such eye diseases as keratoconus, which is widely accepted to be visually disabling.[36] Although the study by Rose et al.[36] had a low

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**Table 3.** Differences in the Overall Visual Functioning Score in the Linear Regression Model

| Socioeconomic and Clinical Characteristics | Adjusted Mean (SE) | β (95% CI) |
|---|---|---|
| Age (y) | | |
| 1-Year increment | — | 0.05 (−0.11 to 0.11) |
| Sex | | |
| Female (Ref) | 3.36 (0.07) | — |
| Male | | **−0.14 (−0.22 to −0.07)** |
| Education | | |
| College/university (Ref) | 3.58 (0.10) | — |
| No formal education | — | **−0.68 (−0.87 to −0.50)** |
| Less than elementary | — | **−0.53 (−0.72 to −0.33)** |
| Elementary | — | **−0.20 (−0.35 to −0.05)** |
| High school | — | −0.03 (−0.19 to 0.13) |
| Hypertension | | |
| No (Ref) | 3.29 (0.08) | — |
| Yes | — | −0.001 (−0.09 to 0.09) |
| Stroke | | |
| No (Ref) | 3.63 (0.05) | — |
| Yes | — | −0.15 (−0.39 to 0.09) |
| Heart attack | | |
| No (Ref) | 3.41 (0.07) | — |
| Yes | — | **−0.23 (−0.39 to −0.07)** |
| Cholesterol | | |
| No (Ref) | 3.27 (0.08) | — |
| Yes | — | 0.05 (−0.04 to 0.14) |
| Diabetes | | |
| No (Ref) | 3.28 (0.08) | — |
| Yes | — | 0.02 (−0.08 to 0.13) |
| Refractive error | | |
| Corrected emmetropia (Ref) | 33.4 (0.07) | |
| Corrected myopia | — | 0.09 (−0.03 to 0.21) |
| Uncorrected myopia | — | **−0.34 (−0.53 to −0.15)** |
| Corrected hyperopia | — | −0.05 (−0.16 to 0.06) |
| Uncorrected hyperopia | — | 0.04 (−0.12 to 0.19) |
| Uncorrected emmetropia | — | −0.04 (−0.16 to 0.08) |

The adjusted mean (SE [standard error]) is given for the reference categories (Ref). Bold coefficients represent independent variables significantly associated with vision-specific function ($P < 0.05$).

response among patients with myopia invited to participate in the study (28%) and did not stratify for correction of refractive error, their findings suggest that irrespective of cultural differences, myopia has an adverse effect on subjective visual functioning.

To the authors' knowledge, this is also the first study to show the impact of uncorrected myopia on specific aspects of visual functioning. As well as the overall functioning score, our findings showed that three items of the VF-11 requiring distance vision were also independently associated with uncorrected myopia: reading street signs, recognizing friends, and watching television. Considering that participants were asked to consider the difficulty that they had in undertaking these activities, even when wearing their glasses, these findings suggest that persons with uncorrected myopia tend to experience difficulty in certain activities requiring distance vision. As expected, myopia was not an independent predictor of activities requiring near vision, such as completing lottery tickets or reading and playing games. Considering that people with myopia see nearby objects clearly but distant objects less distinctly, our findings are valid and not unexpected.

Our study is also one of the few in which uncorrected hyperopia was evaluated. It was surprising that there was no significant association between uncorrected hyperopia and visual functioning on any of the near-vision activities. It is possible that the magnitude of refractive error in those with uncorrected hyperopia (0.39 ± 0.14 logMAR) was not enough to significantly affect daily living activities. A similar finding was observed in those considered emmetropic but with a more than 2-line difference between presenting and corrected vision in the better eye. Although the mean refractive error was 0.32 ± 0.10 logMAR, we found no significant difference between the corrected and uncorrected emmetropic groups on all aspects of visual functioning investigated in this study. Further work is needed to confirm our findings.

We have pointed out some limitations of the VF-11 as an adequate tool for assessing visual functioning in this sample and the need for a refractive-error–specific questionnaire when assessing impact on visual functioning. Considering the documented psychological impact of myopia, vision-specific QoL questionnaires are needed to determine the impact of myopia and refractive error on several aspects of daily living. Several scales have been developed in Western countries such as the Refractive Status and Vision Profile,[37] the National Eye Institute Refractive Quality of Life,[38] and the Quality of Life Impact of Refractive Correction.[22] These scales either should be validated in non-Western countries such as Singapore or a new scale, specific to East Asian countries, should be developed and validated. Adults with eye disease, who were excluded from our study, may differ, so that the effect of myopia on visual functioning may be different in our population.

One of the strengths of this study is the use of the Rasch analysis to produce an estimated interval overall measure of vision-dependent function. To our knowledge, this is the first time this technique has been used in a population-based survey of eye diseases to determine the impact of corrected and uncorrected refractive error on visual functioning. A major limitation common to most studies on visual functioning or QoL has been the use of a mean or summary score. Summary scoring, termed Likert scoring, allocates an ordinal assignment

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**Table 4.** Linear Regression Models Showing $\beta$ Coefficients in the Study Groups for Overall Functioning and Three Specific Items, after Adjustment for Age, Sex, Education

| | Corrected Emmetropia Adjusted Mean (SE) | Corrected Hyperopia $\beta$ (95% CI) | Uncorrected Hyperopia $\beta$ (95% CI) | Corrected Myopia $\beta$ (95% CI) | Uncorrected Myopia $\beta$ (95% CI) | Uncorrected Emmetropia $\beta$ (95% CI) |
|---|---|---|---|---|---|---|
| Overall QoL | 3.70 (0.04) | −0.15 (−0.35 to 0.05) | −0.02 (−0.23 to 0.20) | 0.18 (−0.01 to 0.37) | **−0.34 (−0.60 to −0.08)** | −0.01 (−0.23 to 0.20) |
| Difficulty reading street signs | 2.88 (0.04) | −0.03 (−0.18 to 0.12) | −0.12 (−0.28 to 0.05) | 0.07 (−0.08 to 0.21) | **−0.53 (−0.73 to −0.33)** | −0.14 (−0.30 to 0.03) |
| Difficulty recognizing friends | 2.95 (0.03) | −011 (−0.25 to 0.02) | −0.16 (−0.32 to −0.01) | 0.01 (−0.12 to 0.15) | **−0.48 (−0.66 to −0.30)** | −0.08 (−0.23 to 0.08) |
| Difficulty watching television | 3.00 (0.02) | −0.09 (−0.19 to 0.01) | −0.04 (−0.15 to 0.07) | 0.02 (−0.08 to 0.12) | **−0.30 (−0.43 to −0.16)** | −0.02 (−0.13 to 0.09) |

The adjusted mean scores (SE [standard error]) are given for the reference category (corrected emmetropia). Bold coefficients represent independent variables significantly associated with vision-specific function ($P < 0.05$).

of a numerical value to a participant's response and assumes a score based on an interval scale. In Rasch analysis this assumption is formally tested, and once the data fit the Rasch model, estimates of measures on a interval scale are provided that improve the accuracy of scoring and remove measurement noise.[19–22] The transformed overall score can then be used in analysis of variance and regression more readily than the raw total score, which has floor and ceiling effects.[39–41] Another potential strength of our study is that our findings can be generalized to Singaporean Malays, as our initial analyses included the whole sample, which was subsequently replicated in a healthy subsample.

In conclusion, our study shows that although corrected myopia and hyperopia do not affect visual functioning, uncorrected myopia is associated with decreased visual function. As myopia has a negative impact on self esteem, career choice, and ocular health, interventions that correct myopia could improve participation in daily living and other aspects of QoL in people with uncorrected myopia. Myopia is potentially fully correctable by spectacles or contact lenses. Strategies that inform people of the benefits of proper correction are needed. The long-term benefits of full correction of myopia may include improved visual functioning and QoL for community-living individuals.

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