Education, socioeconomic status, and ocular dimensions in Chinese adults: the Tanjong Pagar Survey

T Y Wong, P J Foster, G J Johnson, S K L Seah

Aim: To relate indices of education, occupation, and socioeconomic status to ocular dimensions and refraction in an adult population.

Methods: A population based, cross sectional survey of adult Chinese aged 40–81 years residing in the Tanjong Pagar district in Singapore. Ocular dimensions, including axial length, anterior chamber depth, lens thickness, and vitreous chamber depth, were measured using an A-mode ultrasound device. Corneal radius of curvature and refraction were determined with an autorefractor, with refraction further refined subjectively, and lens nuclear opacity was graded clinically using the modified Lens Opacities Classification System III score. Data on education, occupation, income, and housing type were obtained from a standardised interview.

Results: Biometric data were available on 951 phakic subjects. After controlling for age, sex, occupation, income and housing type, higher education was associated with longer axial lengths (0.60 mm; 95% confidence interval [CI]: 0.34, 0.85, for every 10 years of education), longer vitreous chambers (0.53 mm; 95% CI: 0.30, 0.77), and more myopic refractions (1.14 dioptres, 95% CI: –2.08, –0.92). Adjustment for axial length attenuated the refractive association of education (–0.68 dioptre, 95% CI: –1.14, –0.21). Similarly, near work related occupations (managers, professionals, and office workers) and higher income were independently associated with longer axial lengths, longer vitreous chambers, and more myopic refractions, and adjustment for axial length attenuated the refractive associations.

Conclusions: Adults with greater education, near work related occupations, and higher income are more likely to have longer axial lengths and vitreous chambers, and more myopic refractions. The refractive associations of education, occupation, and income are largely explained by variations in axial length.

The aetiology of myopia is not fully understood, but is believed to be the result of a combination of genetic and environmental factors. Among the myriad risk factors described, most studies, including several population based surveys, have demonstrated a strong and consistent association between higher education levels and myopia, as determined from refraction. Less consistent associations between myopia and occupations associated with near work activities (for example, professionals) and higher income levels have also been described.

However, the final refractive state of an eye is dependent on the interaction between specific ocular components (that is, axial length, corneal curvature, and lenticular power). Thus, data on ocular dimensions (for example, axial length) may be useful for further understanding of the anatomical mechanisms of myopia associated with higher education, near work occupation, and higher socioeconomic status. For example, the onset and progression of myopia among medical students and clinical microscopists have been shown to be related to changes in axial lengths and vitreous chamber depths, suggesting possible associations between higher education and near work occupation with axial myopia. Whether these associations are similar in the general adult population are uncertain.

In our previous study among adult Chinese living in Singapore, we reported that people with higher education, near work occupations (for example managers, professionals, and office workers) and higher incomes, and who lived in better housing were more likely to have a myopic refraction. The purpose of this present analysis is to describe the associations between these factors (education, occupation, income, and housing) and specific ocular biometric components.

METHODS

Study population

The Tanjong Pagar Survey was a population based, cross sectional survey of ocular disorders among adult Chinese living in Singapore between October 1997 and August 1998. Detailed population selection and methodology have been previously reported. In brief, the 1996 Singapore electoral register of the Tanjong Pagar district was used as the sampling frame in this study. The electoral register listed 15 082 Chinese names aged between 40–79 years residing in the district. Two thousand (13.3%) names were initially selected using a stratified, clustered, random sampling method (with more weights given to the older age groups). Among the 2000 names selected, 46 had died and 235 had moved to addresses outside the district before the study period and two people were excluded on grounds of ill health, leaving 1717 subjects considered eligible to participate in this study. These people were invited for a comprehensive eye examination at the study clinic, following which an abbreviated home examination on non-respondents was conducted. The total number of subjects examined in either setting was 1232 (71.8%), but only the 1090 (63.5%) subjects examined at the study clinic setting had biometric examination. Of these, 80 (4.7%) had previous cataract extraction in their right eyes, and data on biometry were unavailable in a further 59 (3.4%), leaving 951 participants (55.4% of the 1717) for this analysis. Comparison of people...
included (n = 951) and excluded (n = 281) from the ocular biometric analyses in this study has been previously presented. In general, people included were younger, had higher education levels, were more likely to be professionals, managers and office workers, had higher incomes and lived in better housing.

### Ocular biometry and refraction

The biometry and refraction examination procedures followed standardised protocols described elsewhere.\(^{24-27}\) Measurements of axial length (AL), anterior chamber depth (ACD), lens thickness (LT) and vitreous chamber depth (VCD) were obtained using a 10 MHz A-mode ultrasound device (Storz Compuscan, Storz, St Louis, MO, USA). Measurements of axial length (AL), anterior chamber depth (ACD), lens thickness (LT) and vitreous chamber depth (VCD) were obtained using a 10 MHz A-mode ultrasound device (Storz Compuscan, Storz, St Louis, MO, USA).\(^{24-27}\) The hard tipped, corneal contact ultrasound probe was mounted on a tonometer better housing.

### Table 1: Correlations between education, occupation, income, and housing type with ocular biometry and refraction

<table>
<thead>
<tr>
<th>Ocular parameter</th>
<th>Education (years)</th>
<th>Occupation (others, near work)</th>
<th>Income, category</th>
<th>Housing type, category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>-0.44***</td>
<td>-0.17***</td>
<td>-0.47**</td>
<td>-0.08**</td>
</tr>
<tr>
<td>Sex (men, women)</td>
<td>-0.26***</td>
<td>-0.14***</td>
<td>-0.33**</td>
<td>0.05</td>
</tr>
<tr>
<td>Axial length (mm)</td>
<td>0.33***</td>
<td>0.25***</td>
<td>0.31***</td>
<td>0.07**</td>
</tr>
<tr>
<td>Anterior chamber (mm)</td>
<td>0.34***</td>
<td>0.19***</td>
<td>0.35***</td>
<td>0.09**</td>
</tr>
<tr>
<td>Lens thickness (mm)</td>
<td>-0.28***</td>
<td>-0.14***</td>
<td>-0.34**</td>
<td>-0.08*</td>
</tr>
<tr>
<td>Vitreous chamber (mm)</td>
<td>0.35***</td>
<td>0.24***</td>
<td>0.33**</td>
<td>0.06</td>
</tr>
<tr>
<td>Corneal curvature radius (mm)</td>
<td>0.07**</td>
<td>0.06**</td>
<td>0.13***</td>
<td>0.01</td>
</tr>
<tr>
<td>Nuclear opacity, LOCS III</td>
<td>-0.34***</td>
<td>-0.16***</td>
<td>-0.36**</td>
<td>-0.08*</td>
</tr>
<tr>
<td>Refraction (dioptres)</td>
<td>-0.23***</td>
<td>-0.23***</td>
<td>-0.25***</td>
<td>-0.04</td>
</tr>
</tbody>
</table>

*Significant at p<0.05, **significant at p<0.01, ***significant at p<0.001.

LOCS III: Lens Opacity Classification System III score (from 1 to 6).

Education categories: no formal education, primary, secondary, tertiary.

Occupation categories: near work occupations, others (refer to text for details of occupation categories).

Income categories: $1000 or less, $1001–2000, $2001–3000, more than $3000.

Housing type categories: 1 or 2 room government flats, 3 room government flats, 4 or 5 room government flats and private housing.

There were 29 people with missing data on housing type (unclassifiable occupation), 104 with missing data on income (including 95 who had retired) and 5 with missing data on occupation.

### Table 2: Unadjusted mean ocular biometry and refraction, by education, occupation, income, and housing type

<table>
<thead>
<tr>
<th>Housing type</th>
<th>No</th>
<th>Axial length (mm)</th>
<th>Anterior chamber (mm)</th>
<th>Lens thickness (mm)</th>
<th>Vitreous chamber (mm)</th>
<th>Nuclear opacity, LOCS III</th>
<th>Corneal curvature radius (mm)</th>
<th>Refraction (dioptres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1–2 room flats</td>
<td>163</td>
<td>22.72 (0.9)</td>
<td>2.69 (0.4)</td>
<td>4.93 (0.4)</td>
<td>15.11 (0.9)</td>
<td>3.6 (0.9)</td>
<td>7.63 (0.3)</td>
<td>0.38 (2.0)</td>
</tr>
<tr>
<td>3 room flats</td>
<td>515</td>
<td>23.07 (1.1)</td>
<td>2.87 (0.4)</td>
<td>4.77 (0.5)</td>
<td>15.42 (1.0)</td>
<td>3.2 (0.9)</td>
<td>7.66 (0.3)</td>
<td>-0.08 (2.2)</td>
</tr>
<tr>
<td>4–5 room/execute/private</td>
<td>268</td>
<td>23.20 (1.1)</td>
<td>2.87 (0.4)</td>
<td>4.77 (0.5)</td>
<td>15.42 (1.0)</td>
<td>3.2 (0.9)</td>
<td>7.66 (0.3)</td>
<td>-0.08 (2.2)</td>
</tr>
</tbody>
</table>

Data are expressed as means (SD). Probabilities are based on test of trend, except for occupation, based on χ² test. There were 29 people with missing data on occupation (unclassifiable occupation), 104 with missing data on income (including 95 who had retired) and 5 with missing data on housing type.

LOCS III: Lens Opacity Classification System III score (from 1 to 6).

*Significant at p<0.05, **significant at p<0.01, ***significant at p<0.001.

<table>
<thead>
<tr>
<th>Occupation*</th>
<th>No</th>
<th>Axial length (mm)</th>
<th>Anterior chamber (mm)</th>
<th>Lens thickness (mm)</th>
<th>Vitreous chamber (mm)</th>
<th>Nuclear opacity, LOCS III</th>
<th>Corneal curvature radius (mm)</th>
<th>Refraction (dioptres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No work</td>
<td>229</td>
<td>22.72 (0.9)</td>
<td>2.69 (0.4)</td>
<td>4.93 (0.4)</td>
<td>15.11 (0.9)</td>
<td>3.6 (0.9)</td>
<td>7.63 (0.3)</td>
<td>0.38 (2.0)</td>
</tr>
<tr>
<td>Near work</td>
<td>191</td>
<td>23.07 (1.1)</td>
<td>2.87 (0.4)</td>
<td>4.77 (0.5)</td>
<td>15.42 (1.0)</td>
<td>3.2 (0.9)</td>
<td>7.66 (0.3)</td>
<td>-0.08 (2.2)</td>
</tr>
</tbody>
</table>

Data on refraction were analysed in spherical equivalents dioptries, and were based on subjective refraction when participants had both subjective and objective refraction, and on objective refraction when only this information was available. Lens nuclear opacity (NO) was graded at a slit

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27 In general, people included were younger, had higher education levels, were more likely to be professionals, managers and office workers, had higher incomes and lived in better housing.\(^{27}\)
Table 3  Linear regression models of ocular biometry and refraction by education, occupation, income, and housing type

<table>
<thead>
<tr>
<th>Education, per 10 years</th>
<th>Crude data</th>
<th>p Value</th>
<th>Age and sex adjusted</th>
<th>p Value</th>
<th>Multivariate adjusted</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial length (mm)</td>
<td>-0.04 (-0.07 to -0.01)</td>
<td>&lt;0.001</td>
<td>-0.04 (-0.07 to -0.01)</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior chamber depth (mm)</td>
<td>-0.04 (-0.07 to -0.01)</td>
<td>&lt;0.001</td>
<td>-0.04 (-0.07 to -0.01)</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lens thickness (mm)</td>
<td>-0.04 (-0.07 to -0.01)</td>
<td>&lt;0.001</td>
<td>-0.04 (-0.07 to -0.01)</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitreous chamber depth (mm)</td>
<td>-0.04 (-0.07 to -0.01)</td>
<td>&lt;0.001</td>
<td>-0.04 (-0.07 to -0.01)</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuclear opacity, LOCS III</td>
<td>-0.04 (-0.07 to -0.01)</td>
<td>&lt;0.001</td>
<td>-0.04 (-0.07 to -0.01)</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corneal curvature radius (mm)</td>
<td>-0.04 (-0.07 to -0.01)</td>
<td>&lt;0.001</td>
<td>-0.04 (-0.07 to -0.01)</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refraction (dioptres)</td>
<td>-0.04 (-0.07 to -0.01)</td>
<td>&lt;0.001</td>
<td>-0.04 (-0.07 to -0.01)</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data are linear regression coefficients (95% confidence intervals) of ocular biometric components or refraction, with education occupation, income, and housing type as independent variables. There were 29 people with missing data on occupation (unclassifiable occupation), 104 with missing data on income (including 95 who had retired) and 5 with missing data on housing type.

LOCS III: Lens Opacity Classification System III score from 1 to 6.

*All models include the following independent variables: age, sex, education, occupation, income, and housing. Linear regression coefficients for a particular variable (eg, education) are adjusted for other independent variables (ie, age, sex, occupation, income, and housing). For example, a 10 year difference in education is associated with a 0.60 mm (95% CI: 0.34 to 0.85) difference in axial length, adjusted for age, sex, occupation, income, and housing.

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Definitions of education, income, housing type, and occupation

Education, occupation, income, and housing type were ascertained from a structured interview. Education was ascertained by the question, “What was your highest education level?” and recorded in years of education, but was categorised into four groups for analysis: (1) no formal education (0 years), (2) primary (1–6 years), (3) secondary (7–10 years), and (4) tertiary (11 years or more). Occupation was ascertained with the question, “What group of occupations do you feel best categorises your job?” with the response recorded into one of 12 groups, but recategorised into two groups for analysis: (1) near work related occupations: managers and executives, professionals and office workers, and (2) other occupations: sales people, machine operators, production workers, labourers and agricultural workers, homemakers, and unemployed people. This dichotomy was based on our previous study that showed a higher prevalence of myopia among those categorised as having near work related occupations compared to others (mean refraction was –1.69 dioptres for near work related occupations versus –0.18 dioptres for other occupations). People with unclassifiable occupations were not categorised into either group (n = 29). Individual monthly income was ascertained in Singapore dollars (approximate exchange rate of Sing$1.7 = US$1) and categorised into four groups for analysis: (1) $1000 or less, (2) $1001–2000, (3) $2001–3000, and (4) more than $3000. Retired people were excluded from these categories (n = 95). Housing type was initially recorded into one of five groups, and recategorised into three for analysis: (1) one or two room government flats, (3) three room government flats, and (3) four to five room government flats, “executive” government flats, and private housing.

Statistical analysis

We analysed data from both eyes separately, but present only the results using data from the right eye, since the results were similar between the two eyes and the correlation between eyes for ocular biometry and refraction was high (Pearson’s correlation coefficients between right and left eyes for axial length = 0.85, vitreous chamber depth = 0.86, and spherical equivalent refraction = 0.85). Biometric components and refraction were treated as continuous variables.

We initially examined the crude association between education, occupation, income and housing type with specific biometric components and refraction using the Spearman rank correlation coefficient. We calculated the mean values of specific biometric components and refraction by categories of education, occupation, income, and housing. We used linear regression models to assess the effect of education, occupation, income, and housing (independent variables) on specific components and refraction.
biometric components and refraction (dependent variables). Initial models were adjusted for age and sex. The multivariate models include all variables (education, income, occupation, and housing) entered simultaneously to evaluate their independent effects. Finally, to examine if a particular biometric component (for example, axial length) explained the refractive associations of education, occupation, income, and housing, this component was entered as an additional covariate in the multivariate models for refraction. The adequacy of all linear regression models was assessed by plotting the residuals of the regression model against the covariate in the multivariate models for refraction. The model included the following independent variables: age, sex, education, occupation, income, and housing. Linear regression coefficients for a particular variable (e.g., education) are adjusted for other independent variables (i.e., age, sex, occupation, income, and housing). For example, a 10-year difference in education is associated with 1.50 dioptres difference in refraction, adjusted for age, sex, occupation, income, and housing. Model 2–5 includes specific biometric components added as additional independent variables to Model 1.

### RESULTS

The crude correlation coefficients among education, occupation, income, and housing type with ocular biometric variables and refraction are shown in Table 1. The correlations between higher education, near work occupations and higher income were similar: positively with AL, ACD, VCD, and CR; and negatively with age, female sex, LT, NO, and refraction. Housing type showed a weak positive correlation with AL and ACD, and a negative correlation with age, LT, NO, and refraction. Table 2 shows the mean values of ocular biometry and refraction, by categories of education, occupation, income and housing type. In general, higher education, near work occupations, and higher income were associated with longer ALs, longer ACDs, thinner lenses, longer VCDs, longer CRs (flatter corneas), less severe NOs, and more negative refractions (myopic refractions). Housing type was not significantly associated with AL and NO or VCD and refraction, controlling for age, sex, education, income, and housing type. To determine the extent a particular biometric component (for example, AL) explained the refractive associations for education, occupation, income, and housing, AL was entered into multivariate models for refraction (Table 4). Adjustment for AL and VCD attenuated the refractive associations for education and occupation and income. AL was added into multivariate models for refraction (Table 4). Adjustment for AL and VCD attenuated the refractive associations for education and occupation and income. 

### DISCUSSION

Our population-based study documents the relations of education, occupation, and indices of socioeconomic status to ocular dimensions and refraction in adult Chinese people living in Singapore. Firstly, we showed that higher education was associated with longer ALs and VCDs, and more myopic refractions, independent of age, sex, occupation, and indices of socioeconomic status. We found that near work occupations and higher income were similarly associated with longer axial dimensions and more myopic refractions, independent of education. Secondly, we demonstrated that adjusting for AL or VCD substantially attenuated the refractive associations of education, occupation, and income, suggesting that their refractive associations were largely explained by variations in AL and VCD. Although numerous studies have previously shown that higher education, near work related occupation, and higher income are associated with a myopic refraction, it has been hypothesised

| Table 4 Linear regression models of refraction, by education, occupation, and income, adjusted for ocular biometric components
| Linear regression coefficients of refraction (dioptres) |
| Model 1 | Model 2 (+ anterior chamber) | Model 3 (+ anterior chamber) | Model 4 (+ lens thickness) | Model 5 (+ vitreous chamber) |
| Education, per 10 years | −1.50 (−2.08 to −0.92) | −0.68 (−1.14 to −0.21) | −1.42 (−2.00 to −0.85) | −1.49 (−2.07 to −0.91) | −0.71 (−1.19 to −0.24) |
| Occupation, near work or others* | −0.71 (−1.24 to −0.17) | −0.32 (−0.75 to 0.11) | −0.68 (−1.21 to −0.15) | −0.71 (−1.25 to −0.17) | −0.35 (−0.78 to 0.09) |
| Income, per category* | −0.23 (−0.52 to 0.03) | −0.35 (−0.78 to 0.02) | −0.22 (−0.69 to 0.05) | −0.25 (−0.53 to 0.02) | −0.08 (−0.29 to 0.15) |

Data are linear regression coefficients (95% confidence intervals) of refraction, with education, occupation, and income as independent variables. There were 292 people with missing data on occupation (unclassifiable occupation), 104 with missing data on income (including 95 who had retired) and 5 with missing data on housing type.

*Refer to Table 1 for definitions of occupation, income, and housing type categories.
that these associations reflect "axial myopia." 9, 10 Our study now provides population based data to support this hypothesis by showing a direct association between increasing years of education, near work related occupations, and higher income with increasing AL and VCD, and by demonstrating that variations in AL and VCD explain more than 50% of the education, occupation, and income myopia relation observed. However, variations in either CR or lens NO (both important determinants of refraction) do not appear to account for the relation between these risk factors and myopia. In our study, lens NO was graded clinically according to LOCS III criteria, and it is possible that more precise measurements of this variable will offer further insights into the contribution of lens power in these associations. 11

In our study, the association between near work related occupations and higher income with increasing AL and VCD was independent of education. Other population based studies have also shown that near work occupations are associated with myopia, even after controlling for education. 12, 13 However, it is difficult to determine which of these (that is, education, occupation, and income) are relatively more important as possible risk factors for axial myopia. Education appeared to have the strongest associations with AL and VCD, as evident by the fact that adjustment for occupation and income resulted in only a slight attenuation of the strength of the associations (see changes in regression coefficients in Table 3).

Regardless, our study does not provide a biological explanation for these observed associations. Education, occupation, and income have been hypothesised to be crude markers of the amount of near work activity (for example, reading) in early life. 14, 15 It is further suggested that education is an indicator of near work activities in childhood, whereas occupation is a surrogate for these activities in early adult life, such that cumulative lifetime exposure to near work predisposes a person to axial myopia. 16, 17 We did not find evidence that education modified the biometric and refractive associations of occupation, which would have supported such a hypothesis. In addition to being markers for near work activities, education, occupation, and income may also reflect the effects of greater intelligence, 9, 10 genetic and hereditary factors, 12, 13, 18, 19 and better socioeconomic environment. 14, 15, 18, 19 Further investigations with quantitative measures of near work activities and more specific risk factors may provide greater insights into these associations.

As expected, we did not find an association between education, occupation, income, and nearness to CR, NO, and CR, after we adjusted for age and sex, which provided some assurance that the data were reliable.

A strength of our study was that the population was randomly selected from the community, which avoided possible bias seen in studies of refraction and biometry in specific, highly selected patient groups, such as military personnel, 14, 15 schoolchildren, 14, 15, 16, 17, 18, and clinical microscopists. 19 In addition, as the prevalence of myopia in our population was high, any variation in the biometric components with education, occupation, and socioeconomic indicators were potentially accentuated. Nevertheless, there were important limitations. Firstly, we had biometric data on only 55% of the eligible sample, and selection biases could have accentuated some associations and masked others. For example, our observations could be explained if less educated and less myopic people were excluded from our study population, due perhaps to a higher cataract extraction rates among these people (aphakic and pseudophakic data were not analysed), higher mortality or other unknown reasons for non-participation. However, we have no reason to believe this is likely to be substantial. Secondly, since these associations were cross sectional, we were unable to determine if they represented causal relations (for example, education causes longer AL and VCD). Thirdly, as already noted, we did not have data on specific risk factors (for example, amount of reading and other near work activities) to examine more precisely the associations observed. Finally, it is unclear how applicable our data are to other populations and racial groups with lower rates of myopia. 3, 19

In summary, we demonstrated that higher educational levels, near work occupations, and higher income were independently associated with longer ALs, deeper VCDs, and more myopic refractions in adults aged 40–81 years. These population based data provide an anatomical explanation for the previously observed associations between these factors and myopia.

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Authors’ affiliations

T Y Wong, S K L Seah, Department of Ophthalmology, National University of Singapore, Singapore

T Y Wong, P J Foster, S K L Seah, Singapore National Eye Center and Singapore Eye Research Institute, Singapore

P J Foster, G J Johnson, Department of Epidemiology and International Eye Health, Institute of Ophthalmology, University College London, UK

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