WORLD VIEW

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

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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 Opacity 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 (–1.50 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.[1] 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.[2–18] Less consistent associations between myopia and occupations associated with near work activities (for example, professionals)[5 7 15 19] and higher income levels[2 8 9] 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.[20 21] For example, the onset and progression of myopia among medical students[22] and clinical microscopists[23] 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.[24] 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.[24–26] 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

Abbreviations: ACD, anterior chamber depth; AL, axial length; CR, curvature radius; LOCS, Lens Opacities Classification System; LT, lens thickness; NO, nuclear opacity; VCD, vitreous chamber depth

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

	Spearman rank correlation coefficient			
	Education (years)	Occupation (others, near work)	Income, category	Housing type, category
Age (years)	−0.44***	−0.17***	−0.47***	−0.08**
Sex (men, women)	−0.26***	−0.14***	−0.33***	0.05
Axial length (mm)	0.35***	0.25***	0.31***	0.07*
Anterior chamber (mm)	0.34***	0.19***	0.35***	0.09**
Lens thickness (mm)	−0.28***	−0.14***	−0.34***	−0.08*
Vitreous chamber (mm)	0.35***	0.24***	0.33***	0.06
Corneal curvature radius (mm)	0.07*	0.06*	0.13***	0.01
Nuclear opacity, LOCS III	−0.34***	−0.16***	−0.36***	−0.08*
Refraction (dioptres)	−0.30***	−0.23***	−0.25***	−0.04

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

included (n = 951) and excluded (n = 281) from the ocular biometric analyses in this study has been previously presented.[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]

Ocular biometry and refraction

The biometry and refraction examination procedures followed standardised protocols described elsewhere.[24 26 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).[26] The hard tipped, corneal contact ultrasound probe was mounted on a tonometer set to the individual's intraocular pressure. The mean of 16 separate readings was recorded, together with standard deviation of each parameter. Corneal curvature radius (CR) was assessed using a hand held autorefractor/keratometer (Retinomax, Nikon, Tokyo, Japan).[26] The device recorded eight separate estimates of corneal curvature along two meridians each 90 degrees apart. A mean value along each meridian was recorded, and the mean CR was calculated as the average of the greater and lesser radius of the curvature. Non-cycloplegic objective refraction was assessed with the same hand held autorefractor used to measure CR, following which a single optometrist performed a subjective refinement of the refraction with a phoropter, using the results of the objective refraction.[24] Data on refraction were analysed in spherical equivalents dioptres, and were based on subjective refraction when participants had both subjective and objective refraction, and on objective refraction when only this information was available.[24] Lens nuclear opacity (NO) was graded at a slit

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

	No	Axial length (mm)	Anterior chamber (mm)	Lens thickness (mm)	Vitreous chamber (mm)	Nuclear opacity, LOCS III	Corneal curvature radius (mm)	Refraction (dioptres)
Education								
No education	229	22.72 (0.9)	2.68 (0.4)	4.93 (0.4)	15.11 (0.9)	3.6 (0.9)	7.63 (0.3)	0.38 (2.0)
Primary (1–6 years)	382	23.07 (1.1)	2.87 (0.4)	4.79 (0.5)	15.42 (1.0)	3.2 (0.9)	7.65 (0.3)	−0.08 (2.2)
Secondary (7–10 years)	266	23.67 (1.1)	3.06 (0.4)	4.62 (0.4)	15.98 (1.1)	2.9 (0.7)	7.67 (0.3)	−1.31 (2.8)
Tertiary (11 or more years)	74	24.06 (1.5)	3.06 (0.4)	4.59 (0.4)	16.42 (1.4)	2.7 (0.7)	7.69 (0.3)	−2.35 (3.3)
		p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p=0.03	p<0.001
Occupation*								
Others	731	23.06 (1.1)	2.85 (0.4)	4.79 (0.5)	15.43 (1.0)	3.2 (0.9)	7.64 (0.3)	−0.18 (2.4)
Near work	191	23.86 (1.3)	3.05 (0.4)	4.64 (0.5)	16.17 (1.3)	2.9 (0.8)	7.68 (0.2)	−1.69 (3.0)
		p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p=0.05	p<0.001
Income, per month								
$1000 or less	565	22.99 (1.1)	2.81 (0.4)	4.83 (0.5)	15.37 (1.0)	3.3 (0.9)	7.63 (0.3)	−0.16 (2.4)
$1001–2000	173	23.58 (1.2)	3.07 (0.4)	4.56 (0.5)	15.95 (1.1)	2.7 (0.7)	7.68 (0.3)	−1.05 (2.9)
$2001–3000	62	23.64 (1.0)	3.13 (0.4)	4.50 (0.5)	16.01 (1.0)	2.6 (0.5)	7.70 (0.3)	−1.50 (2.4)
More than $3000	47	24.37 (1.4)	3.22 (0.4)	4.50 (0.5)	16.64 (1.3)	2.5 (0.7)	7.74 (0.3)	−2.55 (3.3)
		p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001
Housing type								
1–2 room flats	163	23.08 (1.1)	2.85 (0.4)	4.80 (0.5)	15.43 (1.0)	3.3 (0.9)	7.64 (0.3)	−0.34 (2.4)
3 room flats	515	23.20 (1.1)	2.87 (0.4)	4.77 (0.5)	15.57 (1.1)	3.2 (0.9)	7.66 (0.3)	−0.43 (2.6)
4–5 room/executive/private	268	23.38 (1.3)	2.97 (0.5)	4.70 (0.5)	15.71 (1.2)	3.1 (0.8)	7.66 (0.2)	−0.67 (2.7)
		p=0.008	p=0.003	p=0.02	p=0.01	p=0.01	p=0.72	p=0.17

Data are expressed as means (SD). Probabilities are based on test of trend, except for occupation, based on χ^2 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).
*Refer to text for definition of occupation categories.

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Table 3 Linear regression models of ocular biometry and refraction, by education, occupation, income, and housing type

	Linear regression coefficients of ocular biometry and refraction					
	Crude data	p Value	Age and sex adjusted	p Value	Multivariate adjusted†	p Value
Education, per 10 years						
Axial length (mm)	1.03 (0.85 to 1.22)	<0.001	0.85 (0.63 to 1.06)	<0.001	0.60 (0.34 to 0.85)	<0.001
Anterior chamber depth (mm)	0.35 (0.28 to 0.42)	<0.001	0.12 (0.05 to 0.20)	<0.001	0.07 (−0.02 to 0.16)	0.13
Lens thickness (mm)	−0.31 (−0.39 to −0.24)	<0.001	−0.02 (−0.01 to 0.01)	0.55	0.00 (−0.01 to 0.01)	0.99
Vitreous chamber depth (mm)	0.99 (0.82 to 1.16)	<0.001	0.75 (0.55 to 0.94)	<0.001	0.53 (0.30 to 0.77)	<0.001
Nuclear opacity, LOCS III	−0.78 (−0.91 to −0.65)	<0.001	−0.09 (−0.21 to 0.02)	0.12	−0.08 (−0.22 to 0.06)	0.25
Corneal curvature radius (mm)	0.06 (0.02 to 0.11)	0.005	0.03 (−0.02 to 0.08)	0.26	0.01 (−0.05 to 0.07)	0.81
Refraction (dioptres)	−2.06 (−2.47 to −1.64)	<0.001	−1.89 (−2.37 to −1.41)	<0.001	−1.50 (−2.08 to −0.92)	<0.001
Occupation, near work *v* others*						
Axial length (mm)	0.84 (0.64 to 1.04)	<0.001	0.66 (0.47 to 0.86)	<0.001	0.28 (0.04 to 0.52)	0.02
Anterior chamber depth (mm)	0.22 (0.14 to 0.29)	<0.001	0.09 (0.02 to 0.16)	0.009	0.03 (−0.06 to 0.11)	0.54
Lens thickness (mm)	−0.17 (−0.25 to −0.09)	<0.001	−0.02 (−0.09 to 0.05)	0.54	−0.01 (−0.09 to 0.08)	0.91
Vitreous chamber depth (mm)	0.78 (0.59 to 0.96)	<0.001	0.58 (0.40 to 0.77)	<0.001	0.25 (0.03 to 0.47)	0.03
Nuclear opacity, LOCS III	−0.40 (−0.55 to −0.26)	<0.001	−0.05 (−0.16 to 0.05)	0.32	−0.02 (−0.15 to 0.11)	0.74
Corneal curvature radius (mm)	0.02 (0.02 to 0.09)	0.04	0.03 (−0.02 to 0.07)	0.28	0.00 (−0.05 to 0.06)	0.96
Refraction (dioptres)	−1.71 (−2.15 to −1.27)	<0.001	−1.48 (−1.93 to −1.03)	<0.001	−0.71 (−1.24 to −0.17)	0.01
Income, per category*						
Axial length (mm)	0.45 (0.36 to 0.54)	<0.001	0.33 (0.22 to 0.43)	<0.001	0.15 (0.03 to 0.27)	0.02
Anterior chamber depth (mm)	0.22 (0.14 to 0.29)	<0.001	−0.02 (−0.05 to 0.02)	0.003	0.03 (−0.02 to 0.07)	0.21
Lens thickness (mm)	−0.15 (−0.18 to −0.11)	<0.001	0.28 (0.19 to 0.38)	0.37	−0.01 (−0.06 to 0.03)	0.62
Vitreous chamber depth (mm)	0.43 (0.34 to 0.51)	<0.001	−0.01 (−0.07 to 0.04)	<0.001	0.12 (0.01 to 0.24)	0.03
Nuclear opacity, LOCS III	−0.33 (−0.39 to −0.27)	<0.001	−0.02 (−0.06 to 0.20)	0.60	0.01 (−0.06 to 0.07)	0.75
Corneal curvature radius (mm)	0.04 (0.02 to 0.06)	<0.001	0.02 (0.00 to 0.05)	0.05	0.02 (−0.01 to 0.05)	0.13
Refraction (dioptres)	−0.78 (−0.99 to −0.58)	<0.001	−0.65 (−0.89 to −0.41)	<0.001	−0.25 (−0.52 to 0.03)	0.07
Housing type, per category*						
Axial length (mm)	0.18 (0.06 to 0.30)	0.004	0.16 (0.05 to 0.28)	0.006	−0.04 (−0.16 to 0.09)	0.56
Anterior chamber depth (mm)	0.07 (0.02 to 0.11)	0.002	0.05 (0.01 to 0.09)	0.02	0.02 (−0.02 to 0.07)	0.29
Lens thickness (mm)	−0.05 (−0.10 to −0.01)	0.03	−0.02 (−0.06 to 0.20)	0.32	−0.02 (−0.06 to 0.03)	0.47
Vitreous chamber depth (mm)	0.16 (0.05 to 0.27)	0.006	0.14 (0.03 to 0.24)	0.01	−0.04 (−0.16 to 0.07)	0.47
Nuclear opacity, LOCS III	−0.11 (−0.20 to −0.02)	0.01	−0.03 (−0.09 to 0.03)	0.39	−0.01 (−0.08 to 0.06)	0.72
Corneal curvature radius (mm)	0.01 (−0.02 to 0.03)	0.68	0.01 (−0.02 to 0.04)	0.44	0.00 (−0.03 to 0.03)	0.91
Refraction (dioptres)	−0.27 (−0.54 to 0.01)	0.05	−0.18 (−0.45 to 0.08)	0.17	0.28 (0.01 to 0.56)	0.05

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).
*Refer to Table 1 for definitions of occupation, income, and housing type categories.
†All multivariate 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.

lamp using the modified Lens Opacities Classification System (LOCS) III score.[28]

Definitions of education, income, housing type, and occupation

Education, occupation, income, and housing type were ascertained from a structured interview.[24] 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 cleaners, 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).[24] 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 (for example, 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.[26 27] We initially examined the crude association between education, occupation, income and housing type with specific biometric component 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

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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 (+ axial length)	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 *v* 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*	−0.25 (−0.52 to 0.03)	−0.05 (−0.27 to 0.17)	−0.22 (−0.49 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 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.
Model 1 includes 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 −1.50 dioptres (95% CI: −2.08 to −0.92) 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.
*Refer to Table 1 for definitions of occupation, income, and housing type categories.

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 determine 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 independent variables, and also against the predicted values of the dependent variable (predicted fit). Statistical analyses were carried out using SPSS (SPSS Inc, Chicago, IL, USA).

This study was approved by the ethics committee of Singapore National Eye Centre and carried out in accordance with the tenets of the World Medical Association's declaration of Helsinki.

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 CR ($p = 0.72$) and refraction ($p = 0.17$).

Linear regression models, as described in the Methods section, are presented in Table 3. After adjustment for age and sex, education, occupation, income, and housing were not associated with LT, NO, and CR. Increasing years of education, near work occupations, higher incomes, and better housing were associated with longer ALs, longer ACDs, longer VCDs, and more myopic refractions. When age, sex, education, occupation, income, and housing were entered simultaneously in the multivariate models, associations for housing type were attenuated and no longer statistically significant, except for a weak association with refraction ($p = 0.05$). Associations for education, occupation, and income persisted with regard to AL, VCD, and refraction. In general, people with 10 years or more of education could be expected to have 0.60 mm longer ALs, 0.53 mm longer VCDs, and 1.50 dioptres more myopic refractions, controlling for age, sex, occupation, income, and housing type. Similarly, people with near work occupations could be expected to have 0.28 mm longer ALs, 0.25 mm longer VCDs, and 0.71 dioptre more myopic refractions, 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, and income, AL was entered into multivariate models for refraction (Table 4). Adjustment for AL and VCD attenuated the refractive associations for education and occupation by approximately 50% (for example, for education, the regression coefficient of refraction decreased from −1.50 dioptres in model 1 to −0.68 dioptres in model 2, after adjustment for axial length). The attenuation was even more marked for income (regression coefficient for income decreased from −0.25 dioptres in model 1 to −0.05 dioptres in model 2). In contrast, adjustment for ACD and LT had no substantial effect on the refractive associations of education, occupation, and income. Adjustment for NO and CR, and combinations of AL and NO or VCD and NO had no substantial effect (data not shown).

Finally, we tested for interactions among education, occupation, and income on their associations with AL, VCD, and refraction, by repeating these analyses separately in subgroups stratified by education, occupation, and income and by adding appropriate interaction terms (for example, education and occupation categories) in regression models. We found no substantial or statistically significant interactions (data not shown).

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,[2–18] the anatomical basis of these associations has remained unclear.[20] Since longer AL and VCD appear to be the main causes of both early and late onset myopia,[1 22 23 29–32] it has been hypothesised

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that these associations reflect "axial myopia."[5 9 20] 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.[33]

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.[5 7] 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.[1 9 10 15 19 20 23] This is supported by other studies that show association between more direct measures of near work activity in childhood and myopia.[34 35] It has further been suggested that education is an indicator of near work activities in childhood, whereas occupation is a surrogate of these activities in early adult life, such that cumulative lifetime exposure to near work predisposes a person to axial myopia.[20] 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,[11–13] genetic and hereditary factors,[1 9 12] and better socioeconomic environment.[1 8 20 36 37] 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 housing with LT, 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,[11 12 16] schoolchildren,[17 18 22 34] and clinical microscopists.[23] In addition, as the prevalence of myopia in our population was high, any variations 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.[2–8]

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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