Height, Stunting, and Refractive Error Among Rural Chinese Schoolchildren: The See Well to Learn Well Project

ABHISHEK SHARMA, NATHAN CONGDON, YANG GAO, YAOGUI LU, YANRU YE, JING WU, DENNIS S. C. LAM, LIPING LI, JIASI WU, YEE KIT TSE, MINGZHI ZHANG, YUE SONG, AND SIAN GRIFFITHS

- PURPOSE: To evaluate the hypothesis that changes in nutritional status could be partly responsible for observed increases in myopia prevalence among Chinese children.
- DESIGN: Cross-sectional cohort study.
- METHODS: Rural Chinese secondary school children participating in a study of interventions to promote spectacle use were randomly sampled (20% of children with uncorrected vision ≥6/12 bilaterally, and 100% of remaining children) and underwent cycloplegic refraction with subjective refinement and measurement of height and weight. Stunting was defined according to the World Health Organization standard population.
- RESULTS: Among 3226 children in the sample, 2905 (90.0%) took part. Among 1477 children undergoing refraction, 1371 (92.8%) had height and weight measurements. These children had a mean age of 14.5 ± 1.4 years, 59.8% were girls, and mean spherical equivalent refraction was −1.93 ± 1.82 diopters. Stunting was present in 87 children (6.4%). While height was inversely associated with refractive error (RE) (taller children were more myopic) among boys (r = −0.147, P = .001), this disappeared when adjusting for age, and no such association was observed among girls. Neither girls nor boys with stunting differed significantly in refraction from children without stunting, and neither stunting nor height was associated with RE when adjusting for age, height, and parental education. The power of this study to have detected a 0.75 diopters difference in RE between children with and without stunting was 0.96.
- CONCLUSION: Results from this cross-sectional study are not consistent with the hypothesis that nutritional status is a determinant of RE in this setting. 

Accepted for publication Aug 13, 2009.

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EVIDENCE FROM STUDIES IN CHINA,1–3 SINGAPORE,4 HONG KONG,5 TAIWAN,6 AND AUSTRALIA7 SUGGESTS THAT CHILDREN OF CHINESE DESCENT HAVE AMONG THE WORLD’S HIGHEST PREVALENCE OF MYOPIA. FURTHERMORE, THIS ALREADY-HIGH PREVALENCE OF MYOPIA AMONG CHINESE CHILDREN8,9 AND YOUNG ADULTS10 MAY BE RISING, THOUGH METHODOLOGICAL QUESTIONS REMAIN ABOUT SOME STUDIES OF THIS PHENOMENON.11

In order to explain the apparent rise in myopia prevalence among children of Chinese ethnicity, a number of potential environmental causative factors have been examined. These have included increased near-work activity,12,13 higher levels of education,14 decreased outdoor activity,15,16 and increasing population density.17

In China, improved nutrition in the two decades since the economic reforms of the early 1980s is believed to have resulted in increases in height among recent cohorts when compared to those born in previous years.18,19 It has been theorized that a larger body habitus might be associated with a greater axial length (AL) simply as a function of larger overall body size.20 This relationship between increased height and longer AL has been reported among Singaporean Chinese schoolchildren21 and in a Singaporean adult population.22

The association of height with refractive error (RE) is likely to be more complex than that with AL, because of the process of vision-driven emmetropization. In fact, studies of height and RE have reported mixed results, including the finding of greater stature among myopic children,21 of no association,22,23 and of shorter heights among myopic individuals.24 Nonetheless, some authors have proposed that nutritional differences might exist between myopic and nonmyopic individuals.25–27

We sought to examine the basic plausibility of the hypothesis that nutritional changes might underlie observed increases in the myopia prevalence among Chinese children. Height and weight among children during the teenage years, when childhood myopia is most prevalent, may be assumed to reflect a variety of factors, including the stage of puberty and genetic inheritance. In order to focus on those aspects of stature most directly responsive to nutritional intake, we chose to study stunting, which is defined with reference to a standard population assembled by the World Health Organization (WHO)28 as height ≥2 standard deviations (SD) below the mean for gender and age in months, that is, at the 2.5th percentile or below. Stunting in children and teens is...
generally held to reflect poor nutritional intake over a prolonged period of time. To the best of our knowledge, stunting has not previously been examined as an index of nutrition in myopic children.

Our hypothesis is that, if improved nutrition could plausibly explain recent increases in myopia prevalence, then children identified on a cross-sectional basis with very low height attributable to poor nutrition (stunting) ought to have significantly less myopia than children with normal or above-normal (overweight or obese) nutritional status.

**METHODS**

THE “SEE WELL TO LEARN WELL” PROJECT IS AN ON-GOING randomized trial of interventions to promote spectacle wear among 10 000 secondary school children in 3 towns in the rural Chaoshan region of Southern China. Participants are selected at random from Year 1 and Year 2 classes at all junior and senior high schools in the area.

- **SUBJECTS:** All Year 1 and Year 2 classes (average size approximately 60 children) in all 5 junior high schools and the 1 senior high school of Fuyang Township, Guangdong Province, were enumerated and classes were selected at random from a list of all eligible classes at each school until a total of 600 children (usually 8 to 10 classes) had been identified in the sampling frame. Our pilot testing in the area had demonstrated that participation rates were on the order of 80% to 85%, meaning that 600 children in the sampling frame would be sufficient to guarantee a target figure of 500 children examined at each school.

Fuyang is located in the east of Guangdong province, and has a size of 38.5 square kilometers and a population of 97 000 in 2004. It is located within 90 minutes' drive of the city of Shantou (population 4.97 million at the end of 2006). The large majority of adults in Fuyang work in farming or agriculture.

- **MEASUREMENT OF VISUAL ACUITY AND REFRACTION:** Visual acuity (VA) with and without habitual refraction (if available) was measured by trained study personnel in well-lighted areas of the school during daylight hours, at a distance of 5 meters, separately for each eye of each child. Children who did not have their spectacles at school were asked to bring them for vision assessment on a separate day. Identical illuminated Snellen tumbling E vision charts (Shantou City Medical Equipment Ltd, Shantou, China) were employed for all testing. The nontested eye was covered by the subject using a hand-held occluder, with proper occlusion and neutral head position monitored by the examiner. The right eye was tested first. A single optotype of each size was presented first, starting at 6/30. If a letter was failed, testing began 2 lines above, with the child being asked to read all optotypes on the line sequentially. A subject had to identify correctly more than half of the letters on a given line (eg, 3 out of 5, 4 out of 6) in order to be considered to have achieved that level of acuity.

All subjects with vision of ≤6/12 in either eye, and a 20% sample of children with vision >6/12 in both eyes,
underwent cycloplegic autorefraction (Potec PRK-5000; Potec Co Ltd, Seoul, Korea) with subjective refinement by an ophthalmologist in each eye, at least 30 minutes after receiving cyclopentolate 1% (Cyclogyl; Alcon Laboratories, Fort Worth, Texas, USA) 1 drop to both eyes every 5 minutes, for a total of 2 drops in each eye. (Figure 1) The results of subjective refraction are utilized throughout.

### MEASUREMENT OF HEIGHT AND WEIGHT:
The height in centimeters and weight in kilograms of all subjects were measured (RGZ-120 analog height measurement unit and scale, Jiangsu Suhong Medical Instruments Co Ltd, Changzhou, Jiangsu, People’s Republic of China) and recorded by trained study personnel (physicians), with the children dressed in stocking feet and their usual school clothing. The scale was zeroed at the beginning and end of each morning’s and afternoon’s testing session. Height and weight were used to calculate the body mass index (BMI) of each subject according to the following formula: (weight in kg)/(height in m)². The following terms were defined for subjects by gender and age in months with regard to a (non-Chinese) standard WHO reference population: 28 stunting (height ≥2 SDs below the mean of the reference population for gender and age in months, ie, at the 2.5th percentile or below); overweight (≥1 SD above the mean BMI by age and gender); and obese (≥2 SD above the mean BMI by age and gender). The latter 2 definitions approach the standard adult cut-offs of BMI ≥25 kg/m² and BMI ≥30 kg/m² respectively as the age of the child approaches 19 years. 30

### INTERVIEW DATA:
All study subjects were administered a Chinese-language questionnaire prior to being told the results of their vision assessment. The basic questionnaire included questions on age, gender, highest educational attainment by either parent, child’s history of glasses wear, and reasons for glasses nonwear. The questionnaire included a Chinese translation of an instrument developed originally by Fletcher and associates, to assess self-reported visual function (VF) in rural Asia. 31 This instrument has previously been validated for use in Chinese subjects, 32 and is described elsewhere in detail. 31

### STATISTICAL METHODS:
A two-tailed Student t test was applied for group comparison if the data were normally distributed. For skewed data, the Mann–Whitney U test was used. The χ² test was employed to compare group differences for categorical variables. The Pearson correlation was used to evaluate the association between spherical equivalent (SE) and height by gender. Moreover, multiple linear regression analysis was performed to examine the association between SE and height and nutritional indicators, adjusting for age and parental education and stratifying by gender. Quantitative data were summarized either in mean (SD) or median (interquartile range).

### TABLE 1. Demographic Characteristics, Vision, and Visual Function for 1371 Rural Chinese Schoolchildren With Complete Data on Refraction, Height, and Weight

<table>
<thead>
<tr>
<th>Age (years), mean (SD)</th>
<th>Gender, n (%)</th>
<th>Parents’ highest education, n (%)</th>
<th>Uncorrected vision in the better eye, n (%)</th>
<th>Presenting vision in the better eye, n (%)</th>
<th>Refractive error in the better eye, mean (SD)</th>
<th>Visual function score, mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Data Complete (n = 1371)</td>
<td>Normal Vision (VA 6/12 Both Eyes) (n = 355, 25.9%)</td>
<td>Low Vision (Uncorrected VA 6/12 Either Eye) (n = 1016, 74.1%)</td>
<td>P value*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years), mean (SD)</td>
<td>14.5 (1.4)</td>
<td>14.1 (1.1)</td>
<td>14.6 (1.4)</td>
<td>&lt;.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>551 (40.2%)</td>
<td>184 (51.8%)</td>
<td>367 (36.1%)</td>
<td>&lt;.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>820 (59.8%)</td>
<td>171 (48.2%)</td>
<td>649 (63.9%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary or below</td>
<td>266 (19.4%)</td>
<td>68 (19.2%)</td>
<td>198 (19.5%)</td>
<td>.707</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Junior school</td>
<td>708 (51.6%)</td>
<td>179 (50.4%)</td>
<td>529 (52.1%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High school</td>
<td>272 (19.8%)</td>
<td>77 (21.7%)</td>
<td>195 (19.2%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>College or above</td>
<td>46 (3.4%)</td>
<td>10 (2.8%)</td>
<td>36 (3.5%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>79 (5.8%)</td>
<td>21 (5.9%)</td>
<td>58 (5.7%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤6/12</td>
<td>753 (54.9%)</td>
<td>0 (0.0%)</td>
<td>753 (74.1%)</td>
<td>&lt;.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;6/12</td>
<td>618 (45.1%)</td>
<td>355 (100.0%)</td>
<td>263 (25.9%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤6/12</td>
<td>388 (28.3%)</td>
<td>1 (0.3%)</td>
<td>387 (38.1%)</td>
<td>&lt;.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;6/12</td>
<td>983 (71.7%)</td>
<td>354 (99.7%)</td>
<td>629 (61.9%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refractive error in the better eye, mean (SD)</td>
<td>−1.93 (1.82)</td>
<td>−0.48 (0.82)</td>
<td>−2.44 (1.80)</td>
<td>&lt;.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual function score, mean (SD)</td>
<td>76.1 (16.0)</td>
<td>86.1 (13.0)</td>
<td>72.8 (15.5)</td>
<td>&lt;.001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SD = standard deviation; VA = visual acuity.

*P value for the comparison between children with normal vision and low vision.
TABLE 2. Analysis of Demographic Characteristics, Vision, Visual Function, and Refractive Error According to Nutritional Status

<table>
<thead>
<tr>
<th></th>
<th>Total Children (n = 1364)</th>
<th>Stunted Children&lt;sup&gt;a&lt;/sup&gt; (n = 87)</th>
<th>Overweight/Obese Children&lt;sup&gt;b&lt;/sup&gt; (n = 79)</th>
<th>Normal Children (n = 1,198)</th>
<th>P value&lt;sup&gt;c&lt;/sup&gt;</th>
<th>P value&lt;sup&gt;d&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years), mean (SD)</td>
<td>14.5 (1.4)</td>
<td>14.7 (1.4)</td>
<td>14.0 (1.30)</td>
<td>14.5 (1.3)</td>
<td>.002</td>
<td>.260</td>
</tr>
<tr>
<td>Gender, n (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>549 (40.2%)</td>
<td>45 (51.7%)</td>
<td>39 (49.4%)</td>
<td>465 (38.8%)</td>
<td>.762</td>
<td>.017</td>
</tr>
<tr>
<td>Female</td>
<td>815 (59.8%)</td>
<td>42 (48.3%)</td>
<td>46 (50.6%)</td>
<td>733 (61.2%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height (cm), mean (SD)</td>
<td>155.7 (7.4)</td>
<td>144.4 (5.8)</td>
<td>158.0 (6.4)</td>
<td>156.4 (6.8)</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>BMI (kg/m&lt;sup&gt;2&lt;/sup&gt;), median (interquartile range)</td>
<td>18.0 (16.8 to 19.6)</td>
<td>17.0 (15.6 to 18.6)</td>
<td>24.1 (23.2 to 25.9)</td>
<td>18.0 (16.8 to 19.3)</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Primary or below</td>
<td>263 (19.3%)</td>
<td>23 (26.4%)</td>
<td>14 (17.7%)</td>
<td>226 (18.9%)</td>
<td>.106</td>
<td>.170</td>
</tr>
<tr>
<td>Junior school</td>
<td>705 (51.7%)</td>
<td>46 (52.9%)</td>
<td>44 (55.7%)</td>
<td>615 (51.3%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High school</td>
<td>271 (19.9%)</td>
<td>11 (12.6%)</td>
<td>15 (19.0%)</td>
<td>245 (20.5%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>College or above</td>
<td>46 (3.4%)</td>
<td>4 (4.6%)</td>
<td>0 (0.0%)</td>
<td>42 (3.5%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missing</td>
<td>79 (5.8%)</td>
<td>3 (3.4%)</td>
<td>6 (7.6%)</td>
<td>70 (5.8%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presenting vision in the better eye, n (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤6/12</td>
<td>386 (28.3%)</td>
<td>21 (24.1%)</td>
<td>20 (25.3%)</td>
<td>345 (28.8%)</td>
<td>.860</td>
<td>.352</td>
</tr>
<tr>
<td>&gt;6/12</td>
<td>978 (71.7%)</td>
<td>66 (75.9%)</td>
<td>59 (74.7%)</td>
<td>853 (71.2%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Child’s spherical equivalent in the better, mean (SD)</td>
<td>−1.93 (1.82)</td>
<td>−1.91 (1.81)</td>
<td>−1.72 (1.88)</td>
<td>−1.94 (1.82)</td>
<td>.506</td>
<td>.883</td>
</tr>
<tr>
<td>Visual function score, mean (SD)</td>
<td>76.1 (16.0)</td>
<td>76.9 (15.5)</td>
<td>75.6 (13.7)</td>
<td>76.0 (16.2)</td>
<td>.590</td>
<td>.659</td>
</tr>
</tbody>
</table>

BMI = body mass index; SD = standard deviation.
<sup>a</sup>Of the total 1371 subjects for whom height and weight measurements were available, 7 children who are both stunted and overweight/obese were dropped from the analysis.
<sup>b</sup>Definition of stunting: height 2 SDs below the mean for age and gender according to the World Health Organization reference population.28
<sup>c</sup>Definition of overweight: ≥1 SD above the mean BMI by age and gender. Definition of obese: ≥2 SD above the mean BMI by age and gender.
<sup>d</sup>P value for the comparison between stunted children and overweight/obese children.
<sup>e</sup>P value for the comparison between stunted children and normal children.

Statistical analyses were done using SPSS 14.0 (SPSS Inc, Chicago, Illinois, USA). All statistical tests were two-sided, and a P value < .05 was considered statistically significant.

RESULTS

AMONG 3,226 CHILDREN IN THE SAMPLE FRAME IN FUYANG secondary schools, 2905 (90.0%) took part in the survey; among those not taking part, 264 (8.2%) failed to obtain parental consent and 57 (1.8%) were absent from school during the survey period (Figure 1). Vision examinations were completed on all but 0.2% of participants, while refraction was carried out on a random 20% sample of children with normal vision (n = 366) and 97% of those with uncorrected VA ≤6/12 in either eye (n = 1,111). Among these 1477 children with refraction data, height and weight were measured for 1371 (92.8%) (Figure 1). These 1371 children form the basis for the remaining analyses.

The mean age of children with complete data was 14.5 ± 1.4 years (range, 12 to 17 years), and 59.8% were girls. The mean SE RE in the better-seeing eye was −1.93 ± 1.82 diopters (D) (Table 1). Children with low vision (VA ≤6/12 in either eye) were older, were significantly more likely to be girls, and had worse RE and self-reported visual function than children with normal vision (Table 1).

The mean height and BMI for children with complete data were 156 ± 7 cm and 18.0 kg/m<sup>2</sup> (interquartile range, 16.8 to 19.6 kg/m<sup>2</sup>) (Table 2). Height and RE were inversely associated (that is, taller children were more myopic) among boys (<i>P</i> = .001) but not girls (<i>P</i> = .46) or boys (<i>P</i> = .193) (Figure 2). Height and RE were not significantly associated among boys (<i>P</i> = .46) or girls (<i>P</i> = .85) when adjusting for age.

The RE and presenting vision of stunted children did not differ significantly from those of either normal or obese/overweight children (Table 2). The lack of significant difference between stunted and normal or obese/overweight children persisted when data were stratified by gender (data not shown).

In multivariate models predicting SE-RE in the better-seeing eye, when adjusting for age and parental education, neither stunting nor height was significantly associated with RE for the group of children as a whole, or for boys or girls considered separately (Table 3).
The power of the study to have detected a difference of 0.50 D in RE between stunted and normal children was 0.77, while the power to detect a difference of 0.75 D was 0.96.

**DISCUSSION**

DATA FROM THIS COHORT OF RURAL SECONDARY SCHOOL children suggests that stunting is unassociated with RE for either girls or boys. We chose to examine the plausibility of a link between nutrition and RE by investigating a population with a high prevalence of both myopia and poor nutrition, while focusing on children among whom the influence of nutrition on height is expected to be most salient: children with stunting. Although some children are naturally of short stature attributable to their genetic endowment, when this prevalence exceeds 2.5% (2 SDs below the mean), as in this cohort where 87 of 1364 (6.4%) subjects were stunted, it is expected that many children have short stature as a result of poor nutrition.
Our failure to detect a difference in myopia prevalence between stunted children and those with normal stature, or children with overweight/obesity (thus eliminating subjects with borderline nutritional status), is not consistent with a causative role for nutrition in the development of myopia in this population. This lack of an association persisted when adjusting for age and parental education and stratifying by gender.

We considered the possibility that children of Chinese descent might naturally be of shorter stature than the children making up the WHO reference population. However, when similar standard populations have been used to measure ethnically Chinese children in economically less disadvantaged areas, the prevalence of stunting has been very low (for example, 0.2% in Singapore in 2000). Thus, it would appear unlikely that a large proportion of the ethnically Chinese children classified as stunted according to the current study are in fact of shorter stature solely for genetic reasons.

Given the large number of children included in our sample and the relatively high prevalence of RE and poor nutrition, the power to have detected visually significant differences in RE between stunted and normal children was adequate.

The results of this study must be understood within the context of its limitations. Though a high prevalence of stunting as observed in this setting provides strong evidence of nutritional insufficiency among affected individuals, we did not attempt to validate this with other nutritional indicators such as dietary recall or a record of actual calories consumed. Height and weight measures as assessed by WHO cut-offs against the WHO standard population have been validated as robust indicators of nutritional status.

Secondly, our study was cross-sectional, which meant that the hypothesis that change in myopia status over time is linked to longitudinal variations in nutrition could not be directly examined. However, for this hypothesis to be valid, a minimum condition is that myopia and nutritional status should be causally linked. Our cross-sectional data on stunting and myopia are not consistent with such linkage.

Our sampling strategy over-sampled for children with myopia. Thus, it is possible that we failed to detect an association between myopia and stunting because of the large number of myopic children included relative to those without myopia. In order to reduce the chances of this, however, we did include a 20% random sample of children with normal (>6/12) uncorrected vision in both eyes, and ultimately obtained complete data on 355 such subjects, some 26% of our total cohort.

Finally, our study design did not include an exhaustive survey of all potential environmental associations with myopia, potentially including near work, outdoor activity, and population density. The possibility must be considered that an association might have been observed between stunting and RE if these potential confounding factors had been measured and adjusted for. Presumably, a strong association between stunting and RE would have been detected with the current study design. Despite its limitations, this is one of the first studies to directly examine the association between stunting and RE in a population at high-risk for both RE and poor nutrition. Our results do not appear consistent with a strong causative role for nutrition in determining the observed changes in RE occurring among Chinese children in recent years.

THIS STUDY WAS SUPPORTED BY A GRANT TO OXFORD UNIVERSITY FROM THE LI KA SHING FOUNDATION, HONG KONG, China (the See Well to Learn Well Project). The authors indicate no financial conflict of interest. Involved in design and conduct of study (N.C., Y.G., Y.L., Y.Y., Jin.W., Jia.W., Y.K.T., M.Z., Y.S., S.G.); collection, management, analysis, and interpretation of data (A.S., N.C., Y.G., Y.L., Y.Y., Jin.W., Jia.W., Y.K.T., M.Z., Y.S., S.G.); and preparation, review, or approval of the manuscript (N.C., Y.G., Y.L., Y.Y., Jin.W., D.S.C.L., L.L., Jia.W., Y.K.T., M.Z., Y.S., S.G.). The protocol has been approved in full by the Ethics Committees at the Chinese University of Hong Kong and the Joint Shantou International Eye Center, Guangdong Province, China, and by the tenets of the Declaration of Helsinki.

REFERENCES


Abhishek Sharma, MBBS, is a medical doctor from Australia, graduating from University of Tasmania in 2004, and completed a Masters in Medicine from University of Sydney in 2008. He is currently completing a DPhil in Public Health from the University of Oxford as a Rhodes Scholar, working on the Xichang Pediatric Refractive Error Study in conjunction with Chinese University of Hong Kong. He is interested in clinical science and public health research in myopia.