Height and Its Relationship to Refraction and Biometry Parameters in Singapore Chinese Children

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Abstract

Purpose. To examine the association between the anthropometric measurements of height, weight, body mass index (BMI) and refraction and other ocular parameters in Singapore Chinese children.

Methods. In a cross-sectional study of 1449 Chinese schoolchildren, aged 7 to 9 years, from three Singapore schools, height and weight were measured according to standard protocol, and BMI was calculated. Refractive error and corneal curvature measures were determined by autorefration in eyes under cycloplegia. Axial length, vitreous chamber depth, lens thickness, and anterior chamber depth were measured using A-scan biometry ultrasonography.

Results. In comparison with the children with height in the first quartile for a given age and gender, the eyeball length in children in the fourth quartile was 0.46 mm longer, the vitreous chamber depth 0.46 mm deeper, the corneal radius of curvature 0.10 mm greater (i.e., flatter), refraction more negative by 0.47 D (−0.76 D versus −0.29 D), and axial length-to-corneal curvature radius (AL-CR) ratio higher, after analyses controlling for age, gender, parental...
myopia, reading, school, and weight. The associations of height with refractive error and AL-CR ratio were significant in girls but not in boys. Heavier and more obese children had refractions that were more hyperopic \( (P = 0.01, P = 0.08) \), after analyses controlling for age, gender, parental myopia, reading, and school (height was also controlled for if weight was evaluated). This association was present in boys but not in girls.

Conclusions. Controlling for age, gender, parental myopia, reading, school, and weight showed that taller Singapore Chinese children had eyes with longer axial lengths, deeper vitreous chambers, flatter corneas, and refractions that tended toward myopia. In multivariate analysis, eyes in children who were heavier or who had a higher BMI tended to have refractions that were more hyperopic, and eyes in heavier children had shorter vitreous chambers. Differences between the present results and a recent report in Singapore adults suggest either a cohort effect or a potential influence of systemic endocrine or metabolic factors during childhood on refractive development.

Myopia has reached almost epidemic proportions in certain Asian cities such as Singapore. In considering other factors, we noted that height and obesity have been linked to several eye conditions. Higher intraocular pressure and cataract were found to be more common in taller individuals. Cataract occurs either in underweight or overweight individuals, whereas elevated intraocular pressure is associated with obesity. Eyeball length or myopia may be influenced by height or BMI. In previous studies, no relationship between anthropometric measurements and myopia was detected in Israeli military recruits, whereas myopic Finnish males were taller than their nonmyopic counterparts. These studies were limited because there was no control for possible confounders such as nearwork and parental myopia. Often, ocular biometry was not performed, and height and weight were self-reported, rather than measured.

In a recent study by Wong et al. in Singapore Chinese adults, taller persons were found to have eyes with longer eyeballs, deeper anterior chambers, thinner lenses, and flatter corneas, although no increase in myopia. In their study, ocular measurements did not vary with weight or BMI. Because myopia most commonly starts in young children and the period of critical body and eye growth occurs in early childhood, the effects of dynamic changes in body growth on the emmetropization process would be best studied in young growing children. Because few studies have been conducted in children, we investigated the variation in ocular biometry and refraction with anthropometric determinants, such as height, weight, and BMI, in Singapore Chinese children.

Methods

The methodology of the initial cross-sectional part of a cohort study in children aged 7 to 9 years in Singapore has been reported. The Ethics Committee of the Singapore Eye Research Institute approved the study, and the conduct of the study followed the tenets of the Declaration of Helsinki. Written informed consent was obtained from all parents after the nature of the study was explained. Children from grades 1 and 2 from an eastern school (\( n = 660 \)) and children from grades 1, 2, and 3 from a northern school (\( n = 1023 \)) were invited to participate in November 1999, and children from grades 1, 2, and 3 from a western school (\( n = 1230 \)) were enrolled in May 2001. Children with serious medical conditions (\( n = 94 \)), such as heart disorders, syndrome-associated myopia, or serious eye disorders, such as cataract, were excluded from the study. Only Chinese children with biometry measurements were included (\( n = 1453 \)) to examine the effects of anthropometric measures in an ethnically homogenous population and to facilitate direct comparison to the recent report in Chinese adults in Singapore. The overall participation rate was 66.3%. The proportion of children who reported nearsightedness before the school eye examination did not differ in participants (44.3%) and nonparticipants (37.6%; \( P = 0.30 \)).

Refractive Error Measurements

The children were examined on the school premises by a team of ophthalmologists, optometrists, and research assistants. Measurements of distance-corrected and -uncorrected log minimum angle of resolution (logMAR) visual acuity in each eye were conducted according to a standard protocol. After instillation of 0.5% proparacaine, cycloplegia was induced in each eye by administering three drops of 1% cyclopentolate solution at 5-minute intervals. Thirty minutes after the last drop of cyclopentolate solution was instilled, one of two autokeratorefractometers (model; RK5; Canon Inc, Ltd., Tochigiken, Japan) was used to obtain the average of five consecutive measurements. Five consecutive keratometry measurements were
obtained in each of the flatter and steeper meridians. The average of the keratometry readings in the flatter and steeper meridians was obtained. The machines were calibrated at the beginning of the study.

Axial length, anterior chamber depth, lens thickness, and vitreous chamber depth measurements were obtained using a biometry ultrasound unit (probe frequency of 10 mHz; Echoscan US-800; Nidek Co. Ltd., Tokyo). One drop of 0.5% proparacaine was instilled into each eye before ultrasound biometry measurements were made. The average of six values was taken with the SD of the six measurements less than 0.12 mm.

Anthropometric and Questionnaire Measurements

Both height and weight were measured on the school premises in adherence to a standard protocol. Height was measured with students standing and without shoes. Weight in kilograms was measured using one standard portable weighing machine calibrated before the beginning of the study. BMI (in kilograms per square meters) was computed as the product of the weight divided by the square of the height. The parents completed a questionnaire, written in English or Chinese, before the school examination visit. Sociodemographic information; indicators of socioeconomic status, such as total family income per month; father's education; mother's education; housing; nearwork activity (number of books read per week); and use of a night light before 2 years were collected. To evaluate whether the parents had myopia, questions about whether the parents were wearing spectacles or contact lenses for nearsightedness were included.

Data Analysis

Axial length, vitreous chamber depth, anterior chamber depth, lens thickness, corneal curvature radius, and spherical equivalent (SE; sphere power +0.5 negative cylinder power) were normally distributed. Data from the right and left eye were similar (Pearson correlation coefficient for refractive error was 0.96 and 0.95 for axial length, respectively), and thus only the right eye results are presented. Height, weight, and BMI were expressed as quartiles for each gender and age stratum: 7-, 8-, and 9-year-old boys and 7-, 8-, and 9-year-old girls (Table 1). There were no height or weight data available for four children, and they were excluded from all analyses. Statistical analyses were therefore performed on data from 1449 children. The linear trend tests were performed by assigning consecutive integers to each quartile and then regressing the dependent variables on this new score, testing for the zero slope of the score variable. Outcome variables including biometry measurements, corneal curvature radius, refractive error, and AL-CR ratio were assessed with multivariate linear regression models, with the three anthropometric variables in quartiles as the major explanatory factors, adjusting for characteristics of the study population. Subjects were divided into four refractive error groups, based on their spherical equivalent (refractions: higher myopes (SE $\leq$ −3.0 D), lower myopes (−3.0 < SE $\leq$ −0.5 D), nonmyopes (−0.5 < SE $\leq$ +1.0 D), and hyperopes (SE > +1.0 D). Multinomial regression models were constructed to estimate the prediction of refractive error groups by the various anthropometric variables, controlling for other confounders. A separate analysis of data was performed for each school. All probabilities quoted are two-sided and were considered statistically significant when less than 0.05. Data analysis was conducted by computer (Stata, ver.7.0).

Results

There were 628 7-year-olds, 469 8-year-olds, and 352 9-year-olds; 51.5% were boys and 48.5% were girls. The prevalence rate of myopia (at least −0.5 D) was 36.7% (95% confidence interval [CI] 34.2–39.2), and the mean right eye SE was −0.52 D (range, −5.8 to +4.9 D). The mean right eye axial length was 23.1 ± 0.9 mm (SD) in 7-year-olds, 23.4 ± 0.9 mm in 8-year-olds, and 23.8 ± 1.0 mm in 9-year-olds. The mean vitreous chamber depth was 16.0 ± 0.9 mm (SD) in 7-year-olds, 16.3 ± 0.8 mm in 8-year-olds, and 16.8 ± 1.0 mm in 9-year-olds. There was good correlation between height and weight (Pearson's correlation coefficient = 0.74). The age- and gender-specific quartiles of height, weight, and BMI are shown in Table 1. As expected, boys were taller and heavier (denoted by both weight and BMI; $P < 0.001$) and older children were taller and heavier ($P < 0.001$).

Height, weight, and BMI did not vary with measures of socioeconomic status—specifically, total monthly income, father's education, and mother's education—after we adjusted for age, gender, parental myopia, and school. The nearwork activities (books read per week) of taller children were similar in shorter children ($P = 0.72$) and did not vary with weight ($P = 0.72$) or BMI ($P = 0.86$), after we controlled for the same factors. Controlling for age, gender, books read per week, and school showed no association between weight ($P = 0.45$) or BMI ($P = 0.68$) and the number of myopic parents, but children with a parental
In general, taller children had eyes with longer eyeballs, deeper vitreous chambers, thinner lenses, deeper anterior chambers, flatter corneas, more negative refraction, and higher AL-CR ratios than did shorter children (Table 2). Controlling for age, gender, parental myopia, books read per week, school, and weight showed that children with heights in the fourth quartile for a given gender and age stratum had eyes with axial lengths that were 0.46 mm longer, vitreous chambers 0.46 mm deeper, flatter corneas (7.80 vs 7.70 mm), more negative refractions (−0.47 D more), and AL-CR ratios that were 0.02 higher. Several multivariate linear regression models revealed that these differences were statistically significant. Children with higher myopia (at least −3.0 D) had a mean height of 130.6 ± 7.2 cm (SD), those with lower myopia (−3.0 < SE ≤ −0.5 D), 127.6 ± 7.6 cm; those with emmetropia, 126.5 ± 7.1 cm; and those with hyperopia (>1.0 D), 124.4 ± 7.2 cm. These results are consistent with the findings for the association between height and refractive error as a linear variable. Controlling for the same factors showed that children with higher myopia were more likely to be taller than emmetropes (P = 0.042), and children with hyperopia were more likely to be shorter than emmetropes (P = 0.078). Stratifying the population by sex revealed gender-based differences between refraction, biometry components, and anthropometric measures (Table 3). In multiple linear regression models, taller boys and girls had eyes with longer eyeballs, deeper vitreous chambers, and flatter corneas; taller girls but not boys had more negative refractions and higher AL-CR ratios.

Adjustment for age, gender, parental myopia, books read per week, school, and height showed that eyes in children with weight in the fourth quartile had vitreous chambers that were 0.06 mm shorter than those in children in the first quartile (P = 0.04), and heavier children were also more likely to have eyes with more hyperopic refractions (P = 0.01; Tables 2). Controlling for the same factors showed that lower myopes were more likely to weigh less (P = 0.008) than emmetropes, but higher myopes and hyperopes did not differ in weight from emmetropes (P = 0.94, P = 0.13, respectively). A model that adjusted for age, gender, parental myopia, books read per week, and school did not alter the noncorrelation of BMI with the various ocular dimensions, but the more obese children were more likely to have refractions that were more hyperopic (P = 0.08). The average BMI was 16.3 ± 2.4 kg/m² in children with higher myopia, 16.0 ± 2.6 kg/m² in children with lower myopia, 16.2 ± 2.5 kg/m² in children with emmetropia, and 16.2 ± 2.5 kg/m² for hyperopic children. Controlling for the same factors showed that the BMIs of higher myopes, lower myopes, and hyperopes did not differ from those of emmetropes (P = 0.48, 0.10, and 0.22, respectively). In multiple linear regression models, heavier boys but not heavier girls had eyes with shorter axial lengths and vitreous chambers and refractions that tended toward hyperopia (Table 3). In addition, obese girls had eyes with significantly longer axial lengths (P = 0.02), longer vitreous chambers (P = 0.03), thinner lenses (P = 0.04), and flatter corneas (P = 0.012). Results were similar among subgroups defined according to type of school or myopia (presence or absence).

Discussion

Besides providing the only comparison of anthropometric measures to refraction in a large sample of Asian children, our study included biometry and detailed information on various potential confounders, such as nearwork and parental myopia. In our study, taller children had eyes with longer eyeballs, deeper vitreous chambers, flatter corneas, and more negative refractions, when we controlled for confounders such as age, gender, parental myopia, books read per week, school, and weight. Thus, none of these factors accounted for the association between height and myopia in our population sample. Adjustment for age, gender, parental myopia, books read per week, and height showed that heavier children tended to have refractions that were more hyperopic, and shorter vitreous chambers. Eyes in obese children were more likely to have more hyperopic refractions, when we controlled for age, gender, parental myopia, and books read per week. Gender differences were found between the various anthropometric measures with refraction and biometry. Eyes in taller girls, but not boys, had refractions that tended toward myopia. In addition, eyes in heavier boys and not girls had shorter vitreous chambers and refractions that tended toward hyperopia. In this unique study of Singapore Chinese children, comprehensive risk factor information, biometry, and refraction measures were available. However, the response rate (66%) was only fair, and because nonresponders may be different from responders, the mean measures of ocular biometry and refraction may not be truly representative of all Singapore children of similar ages.
Prior associations of height with refractive status have been primarily investigated in adult populations. Myopic males were 1.9 cm taller than nonmyopic males in a population-based Finnish study. Among Danish draftees, myopes were 0.8 cm taller than emmetropes, and hypermetropes were 0.2 cm shorter. In a population-based survey of a Labrador community, axial length correlated positively with adult stature. In a study of British children of unspecified age attending a school clinic, children with progressive myopia grew in both height and weight more quickly than children with stationary myopia. However, a study of 106,926 Israeli military recruits found that myopia was not associated with height. The discrepancies between the results of these studies could be due to varying sample sizes, different age ranges and refractive error measurement techniques, or the lack of control for confounding variables.

An implication of our findings in young children is that emmetropization mechanisms may relate to body growth. In models that adjusted for putative myopia risk factors, taller children in our study still had eyes with longer eyeballs, deeper vitreous chamber depths, and flatter corneas. Because eyes in taller children had similar lens thickness and anterior chamber depths, vitreous chamber elongation is the main mechanism by which longer eyes developed in taller children. As traditionally hypothesized, flatter corneas among subjects with longer eyes constitute a compensatory optical power reduction, to maintain distant images on the retina. Because of the excess myopia in taller children, this compensation or emmetropization is incomplete, but it is related to body height. The higher AL-CR ratio in taller children confirms an incomplete emmetropization that contrasts with the findings in shorter children.

The adult study most relevant to the present report in children is a recent comparison of anthropometric and refractive data in Singapore Chinese adults. In contrast to children, there are no differences in refraction for Singapore Chinese adults of different final heights, although taller adults had eyes with longer eyeballs, deeper vitreous chambers, and flatter corneas. Because myopia is becoming more prevalent among young Singaporeans, a cohort effect may account for these differences between adults and children in Singapore. That is, whatever mechanism is causing the recent increase in myopia's prevalence may also contribute to the association of height with myopia. A more interesting possible explanation, however, is that the difference in the height–myopia association between young children and adults may be physiologic. In other words, developmental mechanisms in young children that influence early childhood body growth may interact with mechanisms that influence refractive development at this age. Environmental influences (e.g., increased nearwork) and/or altered systemic physiology (e.g., the hormonal alterations with puberty) may sufficiently shift the mechanisms governing refractive development in later childhood years that the association with height and myopia becomes obscured or lost. The latter hypothesis, if valid, suggests that endocrine and/or metabolic features of childhood and adolescence may provide important leads for the study of mechanisms regulating refractive development.

One explanation proposed for the association of height with refractive status is that height is a marker of socioeconomic status, itself a risk factor for myopia, and that both taller children and more myopic children are independent consequences of higher socioeconomic status. The height–refractive error relationship remained after adjusting for socioeconomic status, although we acknowledge that income or education may not completely control for differences in socioeconomic status. Height may be a marker of other unmeasured factors, such as nutritional status. However, because weight and BMI were associated with refractions that tended toward hyperopia rather than myopia, identifying any possible role for nutrition per se in refractive development would require comprehensive dietary methods, not included in the current study.

The relationship of obesity to refractive status and biometry measurements has not been as well studied as other anthropometric parameters. In a Finnish twin study, myopic individuals were not heavier, whereas Gardiner found that the rate of growth in body weight of school children was faster for children with myopia. In adult Singapore Chinese subjects, obese adults were noted to have more hyperopic vision. In our study, eyes in heavier children had refractions that tended toward hyperopia rather than myopia, identifying any possible role for nutrition per se in refractive development would require comprehensive dietary methods, not included in the current study.

Several associations between the various anthropometric indices and specific biometry parameters or refraction were different in boys and girls. The excess myopia and higher AL-CR ratio in taller children were statistically significant in girls, but...
not in boys, suggesting possible gender differences in the emmetropization mechanism in young children. Girls reach puberty at earlier ages than do boys, and perhaps the pubertal growth spurt may contribute to excess myopia in girls. Heavier boys, but not girls, had eyes with refractions that tended toward hyperopia and shorter vitreous chambers. Perhaps girls may experience a pubertal growth spurt, even at this early age, resulting in eyes with refractions that are more myopic and vitreous chambers that are longer than the more hyperopic refractions and shorter vitreous chambers in boys.

In conclusion, controlling for other variables showed that height is associated with eyes with longer eyeballs, deeper vitreous chambers, corneal flattening, and more “negative” refractions in Singapore Chinese children. Eyes in heavier and more obese children had refractions that tend toward hyperopia and heavier children had eyes with shorter vitreous chambers. These relationships varied with gender. The associations differed from recent findings among Singapore adults and suggest that more directed analysis of the relationships between anthropometric dimensions, gender, eye growth, and refraction may provide a novel approach to the study of the mechanisms underlying refractive development in young children.

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Table 1.

| Quartiles and Means of Height, Weight, and BMI by Age and Gender |

Table 2.

| Unadjusted and Adjusted Mean Ocular Biometry Measurements and Refraction by Quartiles of Height, Weight and BMI |

Table 3.

| View Table |
Linear Regression Models of Ocular Biometry Measurements and Refraction by Height, Weight, and BMI for Boys and Girls Separately

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Population Density and Refractive Error among Chinese Children

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