Original Article

Relationship of lifestyle and body stature growth with the development of myopia and axial length elongation in Taiwanese elementary school children

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Context: The development of myopia and growth of the eye, occur at a time when body stature is increasing. **Aims:** To investigate the relationship of lifestyle and body growth with axial elongation and myopia development among schoolchildren aged 7 to 9 years. **Settings and Design:** Prospective study. **Materials and Methods:** Children in elementary schools without serious eye disorders were invited to participate. We measured cycloplegic refraction, corneal curvature, intraocular pressure, axial length, body height, and weight. Questionnaires about the children's daily lifestyles, family members' myopia and parents' socio-demographic status were completed. The children were followed up every 6 months in a 3-year period. **Statistical Analysis Used:** Bivariate correlations, simple and multiple regression. **Results:** Eighty-eight children participated in this study. Forty-eight were myopic at the beginning of the study, and their myopia correlated with longer axial length and parental myopia ($P = 0.015, 0.012$). Sixty-five children (74%) completed the study, and the rates of change per year were -0.43 ± 0.58 (mean + standard deviation) diopters in spherical equivalence, 0.32 ± 0.25 mm in axial length (AL), 5.73 ± 2.71 cm in body height, and 3.84 ± 2.23 kg in weight. The axial length change was positively correlated with the height change ($P < 0.001$). The myopia shift was correlated to axial length change ($P = 0.000$) but not correlated to height change. Using multiple regression test, near work was the only significant risk factor for myopia progression ($P = 0.022$). **Conclusions:** Our study showed that body height increment was correlated to axial length elongation but not to myopia shift in children aged 7-9 years. Genetic factors such as parental myopia and body height had a possible influence on myopia development, and the environment factor as near work intensity was related to myopia progression.

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Myopia has become a public health issue in Taiwan. Studies have shown that myopia usually starts between the ages of 6 and 14 years, and progresses until the general physical growth stage finishes at the end of adolescence.[1,2] The growth of the eye at a time when body stature is also increasing suggests the potential for a shared mechanism of action. In this study, we investigate the relationship of axial length change and body status change, as well as the possible effects of lifestyle (intensity of near work and outdoor activity) on the myopic shifts among elementary schoolchildren.

Materials and Methods

All children aged 7-9 years from two schools located in a semirural area of northern Taiwan were invited to join this study from 2010 to 2012. Children with any serious ophthalmic disorders, such as congenital cataracts, glaucoma, strabismus, anisometropia or amblyopia, were excluded from this study. The parents provided written informed consent. The study was approved by the ethics committee and the study's protocol adhered to the tenets of the Declaration of Helsinki.

The children were examined in the pediatric eye clinics by three ophthalmologists. A complete ocular examination and intraocular pressure measurement were obtained. After the instillation of 0.5% proparacaine, cycloplegia was induced in each eye by administering one drop of 1% cyclopentolate solution and 2 drops of 1% tropicamide solution at 10-minute intervals. Thirty minutes after the last drop was administered, the measurements of refraction and corneal curvature were taken with an auto-kerato-refractor (model RK-F1; Canon Inc, Ltd., Tochigiken, Japan). The average of six consecutive measures (all readings < 0.25 D apart) was taken. The average of two measurements of the corneal radii of curvature in the flatter and steeper meridians was also calculated. A biometry ultrasound unit (probe frequency of 10 MHz; model A-5500; Sonomed Co., Ltd, N.Y., USA) was used to measure the axial length (AL). The average of six measurements was taken, and the standard deviation (SD) of these six readings was less than 0.12 mm. Height was measured with students standing without shoes. Weight in kilograms was measured using one standard weighing machine calibrated before the beginning of the study. Parents completed a comprehensive questionnaire during the visit, which included the total family income per year, parental education, parental myopia, time and type of their children's near work, and time and type of their children's outdoor activities. The children were required to return to the clinics for examinations and to take a questionnaire every half-year.

Definition

The spherical equivalent (SE) of the eye was calculated as sphere power + (0.5 × cylinder power). Myopia was defined as an SE less than - 0.5 diopter (D). The rate of change in the SE, AL, height, and weight were determined by the total changes (data in the last visit - the first visit) divided by the duration of follow-up.

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Data analysis

Data analysis was conducted using computer software, statistical package for the social sciences (SPSS, ver. 13.0). As the biometric data for the right and left eye were highly correlated, analyses were performed using data for the right eye only. Bivariate correlations between the AL and height were calculated. The relationship between the analyzed variables and myopia was assessed by logistic regression. Simple linear regression and multiple linear regression analyses were conducted to investigate the association of the factors with myopic progression. All probabilities quoted are two-sided and were considered statistically significant when they were less than 0.05. The correlation coefficients are presented as R (95% confidence interval [CI]).

Results

There were 88 children (47 boys and 41 girls) who participated in the study. The data on ocular biometric and body stature are shown in Table 1, and the distributions of daily activities are shown in Table 2. Forty-eight of the children were myopic. Using logistic regression to determine the possible relationships with myopia, only the AL and parental myopia were significant [Table 3]. Twenty-three children were excluded from the following analysis for irregular follow-up or incomplete data. They were found to be similar in age, sex, refractive error, ocular biometric parameters, body stature, sociodemographic status, near work, and outdoor activity when compared with the 65 children who were included [Table 1].

At the final visit, there were significant differences in the SE, AL, body height, and body weight compared to the first visit (paired *t* test, $P < 0.001$ for each parameter). The changes of the corneal curvature were not significant. After adjusting for gender and age, the correlations between the AL and height were statistically significant at the first ($r = 0.30$, $P = 0.038$, 95% CI, -0.021 to 0.540) and at the final visits ($r = 0.39$, $P = 0.003$, 95% CI, 0.141 to 0.598). The correlation between the AL change (AL in final visit – AL in the beginning) and the height change was also statistically significant ($r = 0.55$, $P < 0.001$, 95% CI, 0.246 to 0.793) [Fig. 1]. The change rates were - 0.43 ± 0.58 D (mean + standard deviation) per year in SE, 0.32 ± 0.25 mm per year in AL, 5.73 ± 2.71 cm per year in body height, and 3.84 ± 2.23 kg per year in body weight. The myopia progression rate was correlated to the AL elongation rate ($r = -0.64$, $P = 0.000$, 95% CI, −0.889 to −0.376). The correlation between myopia progression rate and the rate of height change or weight change was not significant. Using multiple linear regression, to determine the possible factors affecting the rate of SE change (myopic shift), only total near work was significant [Table 4]. These data showed that children who do more total near work are predisposed to developing a greater myopic shift.

Discussion

The rate of myopia progression is fastest from ages 6 to 9 years, and an early onset of myopia is associated with high myopia in adult life.[2] Environmental factors, especially such near work as reading, writing, and watching TV, and educational level have been associated with myopia.[3-5] A history of myopia in one's parents or siblings also predisposes a subject to myopia.[6,7] Several pieces of evidence have suggested that increased outdoor activities may help to prevent myopia.[8-10] The major structural cause of myopia is an excessive axial elongation of the eye; on average, each diopter (D) of myopia in young adults is associated with an axial length (AL) increase of approximately 0.3 to 0.5 mm.[11,12]

Table 1: Baseline demographic characteristics, ocular biometry and body stature in different groups

	Mean±SD			*P* value*
	Total (*N*=88)	Included (*N*=65)	Excluded (*N*=23)	
Age (years)	8.05±0.82	8.06±0.80	8.04±0.82	0.989
Gender (boys, %)	53.4%	50.5%	60.9%	0.404
SE	−1.08±1.50	−0.96±1.47	−1.40±1.60	0.251
Axial length (mm)	23.70±1.08	23.63+1.06	24.01±1.18	0.188
CR (mm)	43.53±1.89	43.70±1.83	43.31±2.17	0.611
Height (cm)	129.10±7.65	129.39±7.91	130.61±6.80	0.339
Weight (kg)	27.66±6.69	27.71±6.734	29.81±7.70	0.106
BMI	16.30±2.45	16.38±2.65	16.85±2.71	0.278

SE=Spherical equivalent, CR=Cornea radius of curvature; *P* value* for comparing the difference of the mean between included and excluded children, based on the Chi-squared test and independent *t* test

Table 2: The distribution of daily activities

	Mean±SD (per day) (hours)
TV	1.09±0.82
Internet	0.56±0.67
Video game	0.38±0.61
Outdoor	1.10±0.86
Homework	1.43±0.80
Book reading	0.93±0.71
Instrument	0.21±0.37
After-school program	1.70±1.41

SD=Standard deviation

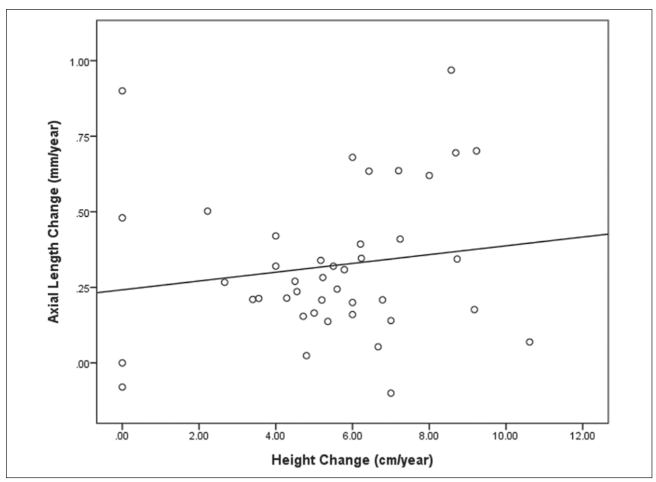

Figure 1: The correlation between the axial length change per year and the height change per year 1.Axial length data with good reliability (The average of six measurements was taken, and the SD of these six readings was less than 0.12 mm) was used for analysis ($n = 42$). 2.Correlation $r = 0.55$, $P < 0.001$

Table 3: Logistic regression analysis of factors associated with myopia in all children at the beginning of the study (*N*=88)

	Myopia			
	Simple logistic regression		Multiple logistic regression	
	Odds ratio	*P* value	Odds ratio	*P* value
Gender	1.865 (0.797~4.365)	0.151	0.670 (0.145~3.106)	0.609
Age	1.623 (0.953~2.764)	0.075	1.974 (0.767~5.080)	0.158
AL	3.329 (1.663~6.661)	0.001*	3.335 (1.260~8.826)	0.015*
CR	1.142 (0.879~1.484)	0.320		
Height	1.000 (0.941~1.062)	0.999		
Weight	1.010 (0.943~1.082)	0.776		
Myopic parents	2.252 (1.138~4.454)	0.020*	3.903 (1.345~11.325)	0.012*
Total near work	0.890 (0.741~1.068)	0.209		
Outdoor activity	0.882 (0.510~1.525)	0.652		

Myopia was defined as SE < −0.5 diopter; the values in parentheses are 95% confidence intervals. AL=Axial length, CR=Corneal radius of curvature. *Indicates statistical significance

Table 4: Linear regression analysis of factors associated with myopic progression rate (*N*=65)

	Myopic shift (D/year)			
	Simple linear regression		Multiple linear regression	
	Adjusted estimate	*P* value	Adjusted estimate	*P* value
Gender	0.014 (−0.010~0.037)	0.264	0.015 (−0.010~0.041)	0.227
Age	−0.005 (−0.020~0.010)	0.545	0.002 (−0.014~0.018)	0.796
Baseline AL	0.003 (−0.012~0.017)	0.714		
Baseline CR	−0.005 (−0.013~0.003)	0.244		
Baseline SE	0.009 (0.001~0.017)	0.025*	0.008 (−0.001~0.017)	0.092
Baseline height	0.000 (−0.001~0.002)	0.640		
Baseline weight	0.001 (−0.001~0.003)	0.216		
Myopic parents	−0.016 (−0.032~0.001)	0.060		
Total near work	−0.008 (−0.014~−0.003)	0.004*	−0.007 (−0.013~−0.001)	0.022*
Outdoor activity	0.002 (−0.012~0.017)	0.755		

Myopia was defined as SE < −0.5 diopter; the values in parentheses are 95% confidence intervals. AL=Axial length, CR=Corneal radius of curvature, *indicates statistical significance

This study showed that AL was positively correlated to body height in children aged 7 to 9 years upon both cross-sectional and longitudinal analysis and after adjusting for age and gender. These results are consistent with previous cross-sectional studies on either children or adult populations.[13-16] In the study by Wong *et al*.[16] on Singaporean Chinese adults, taller persons were more likely to have longer axial lengths (+0.23 mm longer axial length for every 0.10 m difference in height). The data from Saw *et al*.[13] showed that in Singaporean children a +0.29 mm longer axial length in boys and a +0.32 mm longer axial length in girls for every 0.10 m difference in height. In the study by Ojaimi *et al*,[15] of 1765 year-1 Sydney school students, children in the 1st quintile for height had an average AL of 22.39 ± 0.04 mm, compared with 22.76 ± 0.04 mm in children in the 5th quintile. In the study by Wang *et al* [14]. the longitudinal changes of AL and height were concluded to occur concomitantly in children. Our study also showed that the rates of AL and height changes were related; thereby, indicating that the children aged 7-9 years who experienced greater height changes might also experience greater AL elongation at the same time. Zhang *et al*.[17] recruited 565 pairs of twins and revealed that 89% of the phenotypic correlation between AL and height was due to shared genetic factors.

Given that AL is a key determinant of myopia, the relationship between myopia and height should be confirmed. However, consistent results have not yet been achieved in cross-sectional studies. Saw *et al*. concluded that taller Singaporean Chinese children had eyes with longer ALs, deeper vitreous chambers, flatter corneas, and refractions that tended toward myopic.[13] In the study by Wong *et al*.[16], taller Singaporean adults were found to have eyes with longer eyeballs, deeper anterior chambers, thinner lenses, and flatter corneas, although they lacked any increased prevalence of myopia. Ojami *et al*.[15] found a strong association between height and AL, but not SE. Similarly, our results showed that myopia was associated with AL but not with height, although AL and height were correlated. One possible explanation involves the roles played by the other ocular components, such as the cornea or lens. Blanco *et al*. studied 583 university students and found that in emmetropes or subjects with low myopia, the corneal curvature was directly correlated with AL. When the increase in AL is excessive, this compensatory effect of cornea tends to disappear.[18] Longitudinal studies have reported that lens thinning occurs throughout childhood (a reduction of 0.2 mm between 6 and 14 years of age).[19,20] Some studies proposed that myopia may occur when AL elongation continues in the absence of compensatory lens changes.[21,22]

Our results revealed that the rate of SE change is related to the rate of AL elongation, while the rate of SE change is not related to the rate of height change. In the recent study by Yip *et al.*, [23] 1779 schoolchildren (aged ages 6 to 14 years) were assessed, and the mean age at the peak height velocity was found to be 11.47 years. The mean age of the peak AL velocity was 10.64 years, and the mean age of the peak SE velocity was 10.31 years. Children with earlier peak height velocities experienced earlier peak SE and AL velocities. Thus, variations in the onset and peak progression of myopia may be associated with height spurts. The study by Northstone *et al*.[24] compared the growth trajectories (between birth and 10 years), refractive errors (aged 11 to 15 years) and AL (aged 15 years) in a U.K. cohort. They concluded that up to the age of 10 years, shared growth mechanisms contribute to the scaling of the eye and body size but minimally to the development of myopia. All of these studies noted that there are some factors that are superior to the body/AL growth harmony that may interfere with the development of refractive power. Our result found that total near work was the most important factors to intensify the process of myopization, while outdoor activity was not associated. Near work plays a recognized role in myopia,[5,25,26] and evidence also indicated that outdoor activity may be a protective factor.[27] A threshold of 10-14 hours spent outdoors per week seems to protect against myopia.[8,28] In the study by Lu *et al*., no protective effect was observed in a rural population of Chinese children, who averaged 6 hours of outdoor activity per week.[29] Our children spent fewer than 10 hours per week in outdoor activities, and this might explain the similarity of our results with those of Lu *et al*.

In summary, our data showed that body height changes are associated with AL elongation in children aged 7-9 years but show no association with SE changes. Parental myopia is a risk factor for myopia, while near work is a risk factor for myopic progression. To the best of our knowledge, this is the first study comparing the possible effects of genetic and environmental factors and body growth on myopia from both cross-sectional and longitudinal views. However, the results are limited due to the small sample size of the study. Further large scale cohort studies are necessary to confirm these results.

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