Epidemiologic Study of the Prevalence and Severity of Myopia Among Schoolchildren in Taiwan in 2000

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Background and Purpose: A nationwide survey was performed in 2000 to determine the prevalence and severity of myopia among schoolchildren in Taiwan and to compare these findings with the results of the last survey performed in 1995.
Methods: We first divided the whole island into regions according to developmental grade scores and then sampled with the probability proportional to the size of the population within each stratum. A total of 10,889 students were enrolled, including 5,664 boys and 5,225 girls, with ages ranging from 7 to 18 years. The refractive status and corneal radius of each student were measured with an autorefractometer under cycloplegia and checked with retinoscopy. Axial length was measured using biometric ultrasound.
Results: The myopia rate increased from 20% at 7 years, to 61% at 12 years, and 81% at 15 years. A myopic rate of 84% was found for schoolchildren aged 16 years through 18 years. The mean refractive index reached myopic status at the age of 8, and increased to –4.12 D in girls and –3.15 D in boys at the age of 18 years. The prevalence of high myopia (> –6.0D) at the age of 18 years was 24% in girls and 18% in boys. The increase in axial length corresponded with the progression of myopia. The anterior chamber depth was slightly deeper from 7 years to 13 years and then remained stable. The lens thickness decreased from 7 years to 11 years. After age 15, further thickening of the lens was correlated with both age and severity of myopia. However, the corneal curvature was not related to age or severity of myopia. Girls had a higher prevalence and more severe degree of myopia than boys. Children in urban areas had a higher prevalence and more severe degree of myopia than children in rural areas.
Conclusion: The prevalence and severity of myopia in schoolchildren in Taiwan in 2000 increased compared to 1995, with the most severe increases occurring in younger age groups. Thus, preventing schoolchildren developing myopia at a young age may slow down the increase in severity of myopia in Taiwan.

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Key words:
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prevalence
axial length
corneal curvature

Taiwan has developed rapidly within the past two decades, not only economically but also in educational standards. Goldschmidt studied the prevalence of myopia among individuals in different occupational categories grouped according to the expected level of close-work performed, and found that college students had a higher prevalence of myopia [1]. During their school years, more than 70% of children in Taiwan become myopic [2]. Our previous study showed that the prevalence of myopia among children of purely aboriginal ancestry was lower than that among children of Chinese ancestry, and rural children had a lower prevalence than urban children [3]. Rapid economic development in Taiwan may have impacted the prevalence of myopia. This study aimed to determine the prevalence of myopia among schoolchildren in Taiwan in 2000. Nationwide surveys of myopia in schoolchildren have been performed every 5 years since 1983. The last survey was performed in 1995, and found that the preva-

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lence of myopia ranged from 12% at 7 years old to 56% at 12 years old, and more than 76% at 15 years old[4]. In senior high and vocational schools (16–18 yr old), the prevalence reached a striking 84%. The myopia rates approached 50% among rural children compared to 70% among children in urban areas.

Most investigations have used cross-sectional methods to determine the refraction of large samples. Large sample studies have used different definitions of myopia [5, 6]. To facilitate appropriate comparisons of the prevalence of myopia as well as secondary trends across different populations, studies should have similar definitions of myopia, refract children under cycloplegia, and report findings by age. Nationwide surveys of the prevalence of myopia in schoolchildren in Taiwan have been performed four times since 1983, using the same sampling scheme with probability proportional to population size. All schools were stratified first based on the developmental grade of the areas where the school is located. Cycloplegic refractions and ocular components were measured and analyzed. The techniques used for refraction and the definition of myopia were the same as in our previous surveys.

Materials and Methods

Sampling methods

In Taiwan, students attend primary school (age 7–12 yr), then junior high school (age 13–15 yr), and senior high school (age 16–18 yr) before entering university. In addition, Taiwan has many vocational schools for students aged 15 years to 18 years. After completion of elementary education, about 80% of children enter either senior high school or vocational schools.

This study used a survey method based on a grading of the developmental status of cities. Areas were first stratified based on the developmental grade and then sampled with a probability proportional to their population size. The total population for the regions surveyed in this study included nearly 4 million schoolchildren in elementary, junior high, senior high, and vocational schools in Taiwan. The multistage stratified sampling method was used to select random samples of schoolchildren for this national survey. In the sampling of schoolchildren, the 361 administrative areas in Taiwan were first grouped into 10 strata according to their urbanization status. They included Taipei City, Kaohsiung City, and eight strata of other areas. Various numbers of townships were further selected from each stratum based on the sampling probabilities proportional to their population sizes. A total of 18 administrative areas were selected for inclusion in this study. Elementary, junior high, senior high, and vocational schools within these areas were next selected with a probability proportional to the student size. A total of 41 primary schools, 39 junior high schools, 13 senior high schools, nine vocational schools, and four colleges were selected from these 18 administrative areas. Students in these schools were then randomly selected based on their grade and sex. A total of 11,995 students were selected and 10,889 (91%) participated in the study, including 5,664 boys and 5,225 girls with ages ranging from 7 to 18 years.

Examination

Corneal radius and refractive status were measured with an autorefractor (RK-3000, Topcon, Tokyo, Japan). Cycloplegic refraction was measured 30 minutes after the last instillation of three drops of 1% tropicamide at 5-minute intervals. All values of refractive status were rechecked with a retinoscope by one of two senior ophthalmologists. The biometric axial length (including anterior chamber depth [ACD], lens thickness, and total axial length) was measured by A-scan ultrasonography (A-1500, Sonomed, Lake Success, NY, USA). Three measurements were recorded for each procedure, and mean and standard deviations (SDs) were calculated from these measurements.

Calculation and statistics

Data from the right eye only were used to determine the prevalence of myopia and the distribution of refractive errors and ocular components in the population. Mean values of spherical equivalents of refractive status and corneal radii from the autorefractometer were used for calculation. Emmetropia was defined as a mean spherical equivalent of between –0.25 D and +0.5 D. Myopia was defined as a mean spherical equivalent of –0.25 D or more. Astigmatism was not assessed in this study.

Data were entered into the computer of the central office in the Department of Epidemiology of National Taiwan University. Due to the omission of some unclear data, the total numbers for each measurement showed some difference. To avoid data entry errors, double-entry of data was performed by two independent groups plus a third person for adjudication. Results for ocular components are given as mean ± SD. Regression analysis was used to test for trends with respect to age. Analysis of variance and multiple comparisons were performed to evaluate the differences within groups or between boys and girls.

Results

Prevalence

The prevalence of myopia increased from 20% at 7 years old to 61% at 12 years old, and 81% at 15years old.

The increasing trend was statistically significant ($p < 0.01$). The prevalence of myopia was approximately 84% among schoolchildren aged 16 to 18 years (Fig. 1). The overall prevalence of myopia in this sample was around 64% for girls and 59% for boys.

The prevalence of high myopia (> –6.0D) was around 8.2% in girls and 6% in boys among all students surveyed. It increased with age in girls from 0.2% at 7 years old to 3.4% at 12 years old, and 13.0% at 15 years old. It also increased with age in boys from 0.2% at 7 years old to 1.5% at 12 years old, and 13.0% at 15 years old. Between the ages of 16 and 18 years old, it increased from 19% to 24% in girls and from 13 to 18% in boys (Fig. 2). Both increases were significant ($p < 0.001$) with respect to age.

The overall prevalence of anisometropia (> –2.0D) was approximately 2.8% in girls and 2.6% in boys. It increased with age from 0.2% at 7 years old to 2.3% at 12 years old in girls, and from 0.6% to 2.7% in boys. At the age of 15 years old, the prevalence of anisometropia was 5.5% in girls and 2.9% in boys ($p < 0.001$). The prevalence of anisometropia was even higher at the age of 18 years (6.6% in girls and 5.3% in boys; Fig. 3).

Severity

Table 1 shows the mean refractive status within each age group for boys and girls. The mean ocular refraction was nearly emmetropic at 7 years old. It became myopic at 8 years old, with –0.2 D for girls and -0.1 D for boys. The severity of myopia gradually increased with age and educational level. Students in high schools had a higher degree of myopia than younger students ($p < 0.001$). The mean spherical equivalent at the age of 12 years was –1.64 D in girls and –1.26 D in boys, then progressed to –2.99 D in girls and –2.79 D in boys at the age of 15 years, and further progressed to –4.12 D in girls and –3.15 D in boys at the age of 18 years. There was a significant trend between the mean refractive status and age for both boys and girls (both $p = 0.0001$).

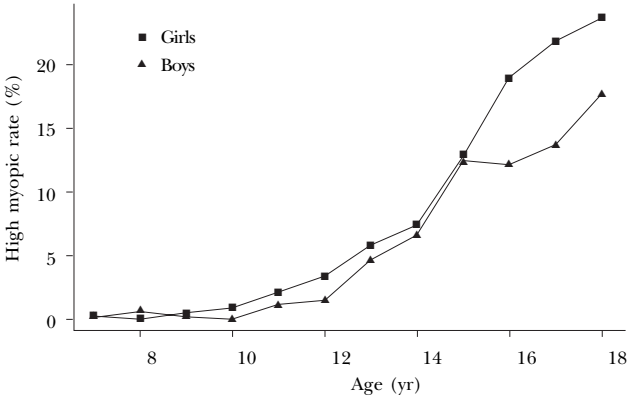

Fig. 2. *Prevalence of high myopia (> –6.0 D) among schoolchildren.*

For all students, mean deviation in refractive status in girls (–2.0 D ± 2.61) was significantly greater than that in boys (–1.57 D ± 2.36; $p < 0.0001$).

Corneal curvature

The corneal radius remained almost unchanged with increasing age and was not significantly different for girls and boys ($p > 0.05$; Table 2). Corneal curvature in boys (7.85 ± 0.26 mm) was significantly flatter than that in girls (7.72 ± 0.25 mm; $p < 0.0001$).

Axial length

Axial length gradually increased with age and, thus, the severity of myopia increased with age for both boys and girls (both $p = 0.0001$). At 7 years old, the mean axial length was 22.55 mm in girls and 23.02 mm in boys. At 8 years old, when the mean refractive index started to become myopic, it was 22.86 mm in girls and 23.38 mm in boys. At 9 years old, the mean axial length was 23.12 mm in girls and 23.68 mm in boys, and increased to 23.79 mm in girls and 24.17 mm in boys at the age of

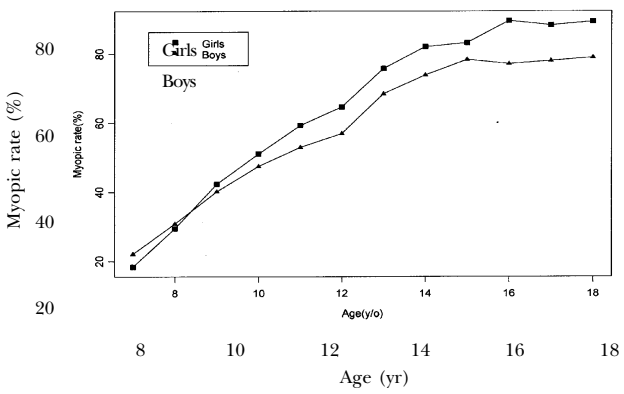

Fig. 1. *Prevalence of myopia among schoolchildren in Taiwan.*

Fig. 3. *Prevalence of anisometropia (> –2.0 D) among schoolchildren.*

Table 1. Refractive status (D) among male and female schoolchildren in each age group (right eye only)

Age (yr)	Boys			Girls		
	n	Mean (± SD)	95% CI	n	Mean (± SD)	95% CI
7	494	+0.11 ± 1.01	+0.02 to +0.20	430	+0.22 ± 1.12	+0.11 to +0.32
8	455	–0.19 ± 1.40	–0.32 to –0.06	460	–0.10 ± 1.19	–0.21 to +0.01
9	486	–0.52 ± 1.37	–0.64 to –0.40	404	–0.65 ± 1.57	–0.80 to –0.49
10	518	–0.67 ± 1.57	–0.81 to –0.54	427	–0.87 ± 1.94	–1.05 to –0.68
11	478	–1.05 ± 1.82	–1.22 to –0.89	466	–1.35 ± 2.04	–1.54 to –1.17
12	480	–1.26 ± 1.93	–1.44 to –1.09	440	–1.64 ± 2.11	–1.84 to –1.44
13	528	–1.91 ± 2.26	–2.10 to –1.71	441	–2.31 ± 2.32	–2.53 to –2.10
14	543	–2.33 ± 2.36	–2.53 to –2.14	417	–2.55 ± 2.39	–2.78 to –2.32
15	480	–2.79 ± 2.63	–3.03 to –2.55	457	–2.99 ± 2.63	–3.23 to –2.75
16	420	–2.76 ± 2.71	–3.04 to –2.52	462	–3.83 ± 2.64	–4.07 to –3.59
17	382	–2.91 ± 2.59	–3.17 to –2.65	420	–3.89 ± 2.73	–4.15 to –3.63
18	394	–3.15 ± 2.83	–3.43 to –2.87	396	–4.12 ± 2.77	–4.39 to –3.84
Total	5658	–1.57 ± 2.36	–1.63 to –1.51	5220	–2.00 ± 2.61	–2.07 to –1.92
p-value		0.0001			0.0001	

p-value based on test of age trend.

12 years. At 15 years old, the mean axial length further increased to 24.42 mm in girls and 24.96 mm in boys, and at the age of 18 years was 24.97 mm in girls and 25. 26 mm in boys (Table 3). Axial length in boys (24.26 ± 1.30 mm) was significantly greater than that in girls (23.91 ± 1.35 mm; $p < 0.0001$).

Anterior chamber depth

The ACD increased slightly with age and severity of myopia for both boys and girls (both $p = 0.0001$). At 7 years old, the ACD was 3.45 mm in girls and 3.54 mm in boys, and increased to 3.51 mm in girls and 3.59 mm in boys at 8 years old, when the mean refractive status became myopic. At 9 years old, the ACD was 3.57 mm in girls and 3.66 mm in boys. It increased continuously with age and the progression of myopia. At 13 years old, the ACD was 3.68 mm in girls and 3.78 mm in boys. It remained stable from the age of 13 to 18 years, around 3.69 mm in girls and 3.78 mm in boys (Table 4). ACD in boys (3.71 ± 0.28 mm) was slightly greater than that in girls (3.63 ± 0.27 mm; $p < 0.0001$).

Lens thickness

The mean lens thickness decreased between 7 and 11 years old. At 7 years old, it was 3.57 mm in girls and 3.55 mm in boys. At 8 years old, it was 3.5 mm in both

Table 2. Corneal curvature radius (mm) among male and female schoolchildren in each age group (right eye only)

Age (yr)	Boys			Girls		
	n	Mean (± SD)	95% CI	n	Mean (± SD)	95% CI
7	469	7.82 ± 0.26	7.80 to 7.84	408	7.70 ± 0.26	7.68 to 7.73
8	442	7.86 ± 0.26	7.83 to 7.88	440	7.71 ± 0.25	7.69 to 7.74
9	473	7.87 ± 0.26	7.84 to 7.89	389	7.70 ± 0.25	7.68 to 7.72
10	505	7.83 ± 0.26	7.81 to 7.86	414	7.74 ± 0.25	7.72 to 7.77
11	464	7.82 ± 0.26	7.80 to 7.85	455	7.71 ± 0.26	7.69 to 7.74
12	464	7.85 ± 0.25	7.82 to 7.87	425	7.69 ± 0.24	7.67 to 7.72
13	480	7.86 ± 0.24	7.84 to 7.88	403	7.73 ± 0.24	7.70 to 7.75
14	497	7.85 ± 0.26	7.82 to 7.87	384	7.73 ± 0.25	7.71 to 7.76
15	438	7.86 ± 0.25	7.84 to 7.88	421	7.73 ± 0.24	7.71 to 7.76
16	346	7.86 ± 0.23	7.83 to 7.88	435	7.73 ± 0.25	7.70 to 7.75
17	319	7.85 ± 0.25	7.82 to 7.87	405	7.72 ± 0.25	7.69 to 7.74
18	309	7.88 ± 0.29	7.85 to 7.91	375	7.71 ± 0.23	7.68 to 7.73
Total	5206	7.85 ± 0.26	7.84 to 7.86	4954	7.72 ± 0.25	7.71 to 7.72
p-value		0.0237			0.1985	

p-value based on test of age trend.

Table 3. Axial length (mm) among male and female schoolchildren in each age group (right eye only)

Age (yr)	Boys			Girls		
	n	Mean (± SD)	95% CI	n	Mean (± SD)	95% CI
7	470	23.02 ± 0.72	22.95 to 23.08	412	22.55 ± 0.73	22.48 to 22.62
8	441	23.38 ± 0.85	23.30 to 23.46	441	22.86 ± 0.80	22.78 to 22.93
9	473	23.68 ± 0.89	23.60 to 23.76	389	23.12 ± 0.94	23.03 to 23.21
10	504	23.75 ± 0.98	23.67 to 23.84	414	23.42 ± 1.04	23.32 to 23.52
11	466	23.99 ± 1.03	23.91 to 24.09	457	23.65 ± 1.07	23.55 to 23.74
12	464	24.17 ± 1.07	24.08 to 24.27	426	23.79 ± 1.20	23.67 to 23.90
13	496	24.56 ± 1.17	24.46 to 24.66	428	24.16 ± 1.29	24.03 to 24.28
14	519	24.68 ± 1.20	24.58 to 24.79	406	24.21 ± 1.15	24.10 to 24.33
15	453	24.96 ± 1.26	24.84 to 25.08	442	24.42 ± 1.27	24.31 to 24.55
16	420	24.95 ± 1.30	24.82 to 25.07	459	24.86 ± 1.12	24.76 to 24.97
17	383	25.01 ± 1.34	24.88 to 25.15	419	24.92 ± 1.26	24.80 to 25.04
18	394	25.26 ± 1.41	25.12 to 25.40	394	24.97 ± 1.21	24.85 to 25.08
Total	5483	24.26 ± 1.30	24.22 to 24.29	5087	23.91 ± 1.35	23.88 to 24.23
p-value		0.0001			0.0001	

p-value based on test of age trend.

Table 4. Anterior chamber depth (mm) among male and female schoolchildren in each age group (right eye only)

Age (yr)	Boys			Girls		
	n	Mean (± SD)	95% CI	n	Mean (± SD)	95% CI
7	470	3.54 ± 0.25	3.51 to 3.56	412	3.45 ± 0.25	3.43 to 3.48
8	441	3.59 ± 0.27	3.56 to 3.62	441	3.51 ± 0.25	3.49 to 3.53
9	473	3.66 ± 0.27	3.63 to 3.68	389	3.57 ± 0.27	3.55 to 3.60
10	504	3.67 ± 0.27	3.64 to 3.69	414	3.59 ± 0.27	3.57 to 3.62
11	466	3.71 ± 0.28	3.69 to 3.74	457	3.65 ± 0.25	3.63 to 3.67
12	464	3.72 ± 0.28	3.70 to 3.75	425	3.66 ± 0.26	3.63 to 3.68
13	496	3.78 ± 0.28	3.75 to 3.81	428	3.68 ± 0.28	3.66 to 3.71
14	518	3.78 ± 0.26	3.75 to 3.80	406	3.67 ± 0.27	3.64 to 3.69
15	453	3.81 ± 0.28	3.78 to 3.83	442	3.67 ± 0.26	3.64 to 3.69
16	420	3.75 ± 0.28	3.73 to 3.78	459	3.70 ± 0.24	3.68 to 3.73
17	382	3.76 ± 0.28	3.73 to 3.79	419	3.69 ± 0.26	3.67 to 3.72
18	394	3.77 ± 0.28	3.74 to 3.79	394	3.69 ± 0.28	3.66 to 3.72
Total	5481	3.71 ± 0.28	3.70 to 3.72	5086	3.63 ± 0.27	3.62 to 3.64
p-value		0.0001			0.0001	

p-value: based on test of age trend.

girls and boys. Thereafter, the lens thickness continuously decreased with increasing age and severity of myopia to 11 years old, and then remained unchanged until age 15 years. However, lens thickness increased after age 15 years. It was 3.52 mm in girls and 3.51 mm in boys at the age of 18 years. Lens thickness at each age was not signi-ficantly different between boys and girls (boys, 3.46 ± 0.21 mm; girls, 3.47 ± 0.20 mm; $p > 0.05$; Table 5).

Differences between cities and villages

There were significant differences in the prevalence and severity of myopia between students in cities and villages. Boys (Taipei City, 49.2%) and girls (provincial cities, 52.1%) in metropolitan primary schools had a higher prevalence of myopia than children in remote (boys, 22.1%) and aboriginal (girls, 27.8%) areas. The prevalences of myopia in junior high schools of aboriginal and remote areas were 31.8% and 44.4% for boys, and 61.9% and 73.3% for girls, respectively. The highest prevalence of myopia was among schoolchildren aged from 13 to 15 years old in Kaohsiung City (boys, 81.1%) and provincial cities (girls, 88.3%). Table 6 shows the mean ocular refraction in schoolchildren aged 7 through 15 years old with respect to the 10 developmental gradings of urbanization. The ANOVA

Table 5. Lens thickness (mm) among male and female schoolchildren in each age group (right eye only)

Age (yr)	Boys			Girls		
	n	Mean (± SD)	95% CI	n	Mean (± SD)	95% CI
7	470	3.55 ± 0.22	3.53 to 3.57	412	3.57 ± 0.19	3.55 to 3.59
8	441	3.50 ± 0.20	3.48 to 3.52	441	3.49 ± 0.22	3.47 to 3.51
9	473	3.47 ± 0.20	3.45 to 3.49	389	3.47 ± 0.21	3.45 to 3.49
10	504	3.43 ± 0.19	3.41 to 3.45	414	3.44 ± 0.20	3.42 to 3.46
11	466	3.43 ± 0.20	3.41 to 3.44	457	3.42 ± 0.18	3.40 to 3.43
12	464	3.44 ± 0.18	3.42 to 3.45	425	3.44 ± 0.20	3.42 to 3.46
13	496	3.41 ± 0.20	3.40 to 3.43	428	3.44 ± 0.21	3.42 to 3.46
14	519	3.43 ± 0.19	3.41 to 3.45	406	3.47 ± 0.20	3.45 to 3.49
15	453	3.42 ± 0.20	3.40 to 3.44	442	3.45 ± 0.20	3.43 to 3.47
16	420	3.49 ± 0.21	3.47 to 3.51	459	3.46 ± 0.19	3.45 to 3.48
17	382	3.51 ± 0.21	3.49 to 3.53	419	3.48 ± 0.19	3.47 to 3.50
18	394	3.51 ± 0.21	3.49 to 3.53	394	3.52 ± 0.19	3.50 to 3.54
Total	5482	3.46 ± 0.21	3.46 to 3.47	5086	3.47 ± 0.20	3.46 to 3.47
p-value		0.0950			0.0535	

p-value: based on test of age trend.

Table 6. Refractive status (D) of schoolchildren in developmental strata (right eye only)

	Boys		Girls	
	Primary school Mean ± SD (n)	Junior high school Mean ± SD (n)	Primary school Mean ± SD (n)	Junior high school Mean ± SD (n)
Developing area	–0.52 ± 1.58 (694)	–2.44 ± 2.41 (307)	–0.62 ± 1.77 (618)	–2.53 ± 2.65 (246)
Aboriginal area	0.02 ± 1.75 (24)	–0.22 ± 1.52 (22)	–0.41 ± 1.35 (18)	–1.36 ± 1.87 (21)
Industrial area	–0.64 ± 1.73 (566)	–2.13 ± 2.35 (177)	–0.76 ± 2.10 (510)	–2.29 ± 2.34 (185)
Hilly area	–0.75 ± 1.63 (54)	–1.11 ± 2.13 (27)	–0.38 ± 1.21 (46)	–2.31 ± 2.76 (30)
Remote area	0.09 ± 1.16 (104)	–1.83 ± 2.20 (111)	–0.47 ± 1.94 (108)	–2.28 ± 1.97 (103)
Service business area	–0.59 ± 1.42 (304)	–1.75 ± 2.33 (100)	–0.74 ± 1.60 (258)	–2.30 ± 2.26 (89)
Combination area	–0.30 ± 1.36 (218)	–1.65 ± 2.18 (127)	–0.48 ± 1.40 (195)	–2.16 ± 2.10 (138)
Taipei city	–0.88 ± 1.85 (325)	–2.48 ± 2.43 (197)	–1.03 ± 2.03 (321)	–3.12 ± 2.67 (222)
Kaohsiung city	–0.66 ± 1.58 (163)	–2.92 ± 2.48 (106)	–0.92 ± 1.87 (156)	–2.81 ± 2.33 (84)
Provincial cities	–0.76 ± 1.60 (459)	–2.83 ± 2.54 (377)	–0.85 ± 1.70 (397)	–3.23 ± 2.54 (197)

ANOVA test, $p < 0.0001$.

test and multiple comparisons test between separate strata or groups also demonstrated significant differences in mean refractive status among schoolchildren in cities, towns, and villages.

Discussion

In this nationwide survey of schoolchildren, we found that the prevalence of myopia was higher than in our previous study in 1995 [4]. At 7 years old, the prevalence of myopia had increased from 12% in 1995 to 20% in 2000; at 12 years old, it had increased from 56% to 61%; at 15 years old, it had increased from 76% to 81%; at the age of 16 to 18 years, the rate remained unchanged at around 84% in both 1995 and 2000. One possible reason for the increasing prevalence of myopia in Taiwan is the increased workload from formal education. Epidemiologic surveys have consistently found a higher prevalence of myopia in academically based populations that was related to the level of education [7–11]. Although we did not directly investigate whether there was a causal relationship between myopia and the type of schooling or educational environment, it is clear that myopia typically develops in children of young age and gradually increases in prevalence, as well as in severity, from grade school through graduate school.

Studies from Singapore [12] and Japan [13, 14] have also found an increase in the prevalence of myopia over the past several decades. Most schoolchildren

in these countries are in stringent academic programs [15–17]. Taiwan's rapid development within the past two decades, stressful lifestyle, and small and crowded living environments might all be factors contributing to the high prevalence of myopia.

In this study, schoolchildren in Taiwan were found to have not only an increased prevalence of myopia but increased dioptric power as well. The severity of myopia was higher than in our previous study in 1995 [4]. At 12 years old, myopic refraction increased from –1.10 D to –1.64 D in girls and from –0.98 D to –1.26 D in boys. At the age of 18 years, it increased from -3.92 D to –4.12 D in girls and from –2.71 D to –3.15 D in boys. The prevalence of high myopia was also greater than in our previous study in 1995 [4], at 24% compared to 20% in girls and 18% compared to 12% in boys at age 18 years. One reason for the high prevalence of high myopia in Taiwanese may be the young age at the onset of myopia. Myopia is commonly classified into early-onset myopia (myopia developing prior to the age of 15 yr) and late-onset myopia (myopia developing after the age of 15 yr) [1]. In Taiwan, the prevalence of myopia at 7 years old increased from 4% in 1986 to 12% in 1995, then to 20% in 2000. A study of Finnish schoolchildren found that myopia progressed faster in children with an earlier age of onset of myopia, and in children who had more severe myopia at initial examination [18]. Our 1995 study found that the mean ocular refraction became myopic at 9 years old, while in this study in 2000, myopic status developed at 8 years old. These findings indicate that the prevalence and severity of myopia are increasing in Taiwan.

Ocular components may change considerably with age and the progression of myopia. Newborns are usually hyperopic. In subsequent years, the ocular axis elongates with thinning of the lens and flattening of the cornea, which leads to emmetropia in children between the ages of 8 and 10 years [13]. In our study, the axial length showed close correspondence with the ocular refraction. The mean axial length at 9 years old was close to the values of emmetropic adult eyes in Taiwan [19]. Thereafter, the axial length increased with age and severity of myopia. The ACD became slightly deeper with increasing age. At 9 years old, the ACD was 3.57 mm in girls and 3.66 mm in boys. The ACD continuously increased with age and the progression of myopia. The mean ACD at the age of 12 years was 3.66 mm in girls and 3.72 mm in boys. It remained stable from the age of 13 to 18 years, around 3.69 mm in girls and 3.77 mm in boys. The mean lens thickness decreased from 3.57 mm in girls and 3.55 mm in boys at 7 years old to 3.42 mm in girls and 3.43 mm in boys at the age of 11 years. It remained unchanged from 11 to 15 years old, but increased after the age of 15 years. In contrast, no change was found in the corneal radius with increasing age or severity of myopia.

Gender could affect the distribution and severity of myopia. Our study found that the prevalence of myopia and the mean refractive status were higher in girls than in boys. The prevalence of high myopia was also greater in girls, especially after puberty. The NHANES data show that the prevalence of myopia is higher in females than in males [6]. The study in Finnish schoolchildren also found that myopia progressed faster in girls than in boys [1], and several other studies found similar results [12, 20]. However, the prevalence of anisometropia (> –2.0 D) in our study was not different between girls and boys, and also increased with age and the severity of myopia. A previous study found differences in ocular components between girls and boys [21]. In our study, the mean axial length in boys was greater than that in girls, while the mean refractive status was less myopic in boys. This may be due to the fact that boys are taller than girls. Eye size may be linked to body stature, with taller individuals having longer axial length [7]. The mean ACD in boys was slightly greater than that in girls, although the lens thickness in boys and girls was similar. The mean corneal curvature in boys was significantly flatter than that in girls in our study.

Taiwan is a rapidly developing urban country, and the schooling system is highly competitive. In this survey, we found that the prevalence and severity of myopia among students in cities were much higher than in remote and aboriginal areas. This finding suggests that environmental influences may play a role in the prevalence and extent of myopia. School systems in cities are more competitive than those in rural areas. Many children in cities also attend extracurricular classes after school hours or use computers at home at a very early age. Previous epidemiologic studies have suggested that close-work activity, such as reading, writing, and computer use, may be related to myopia development [22–26].

In summary, our findings demonstrate that the prevalence of myopia and high myopia has continued to increase over the past 15 years in Taiwan [2, 4]. In addition, the age of onset of myopia decreased from 12 years old in 1983 to 8 years old in 2000. At 7 years old, the mean prevalence of myopia in 2000 was 20%. The mean refractive status became myopic at 8 years old. The prevalence and severity of myopia in girls were greater than those in boys. Boys had a longer mean axial length, greater ACD, and flatter cornea than girls. The prevalence and severity of myopia continuously progressed with education level and age. The increase in axial length was correlated with the progression of myopia. However, corneal curvature remained unchanged during the progression of myopia. The role of minor changes in lens thickness and ACD in the progression of myopia needs further investigation.

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