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Original Article

Relationship Between After-school Learning and School Myopia in Elementary School Students

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Purpose: Curricula and learning environments are relatively uniform throughout the school system. However, the duration and intensity of after-school learning are quite disparate and depend largely on the extent of urbanization. The purpose of the present study was to investigate the possible correlation between after-school learning and school myopia.
Methods: A total of 1,067 students from one urban and three rural schools, aged 7 to 12 years, participated in this study. Ocular examination included uncorrected visual acuity and non-cycloplegic refraction to obtain the best corrective visual acuity (BCVA). In addition, a multi-item questionnaire related to after-school learning was completed by parents and students. Statistical analyses included independent-sampling t-test, χ^2 Spearman correlation, and linear regression analysis.
Results: This cross-sectional study confirmed that students in each grade were on the average more myopic than those in the previous grade. A significant difference was also noted between urban and rural students in Grades 4, 5 and 6. Holistically, the degree of myopia correlated well with after-school environment, placement, and parental accompaniment, as well as with learning of English as a foreign language; computer, tablet or smart phone use; and outdoor physical activities. On linear regression analysis, 6 modulating factors of myopization were found. The most prominent was learning of English as a second language.
Conclusion: Since the length of the school day and curricula are identical or nearly identical across all elementary schools, the variations in the degree of myopia may be related to after-school learning. Factors that favor lower myopic refraction error include larger indoor space, less stressful learning environment, and less digital device use, as well as more outdoor activities. Surprisingly, in addition to medical intervention, family education is the starting point for myopia control.

Key words: After-school learning, after-school environment, learning intensity, school myopia.

Introduction

In Taiwan, the prevalence of school myopia has increased dramatically in recent decades. Among grade 6 elementary school students, the prevalence increased from 27.5% in 1986 to 65.8% in 2010.[1-4] This increase starts in kindergarten,[5] and continues into elementary and high school before leveling off during the college years.[1-4] It has been pointed out that the rapidly changing environment, specifically urbanization, is a major causative factor of school myopia and mass schooling of children

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that accompanies urbanization appears to promote this trend. [6] To evaluate the role of urbanization, linear regression modeling was applied to identify positive and negative factors that explain up to 65.9% of the variation in myopia risk.[7] Such factors include excessive near work, difference in corrective methods, and lag in optimal correction, including lag time in updating prescriptions when myopia worsens.[7-8] In comparison to these factors, diet, parental refractive error, lighting and other environmental factors, and outdoor sunlight exposure are not as influential.[7]

Previous studies have shown that the inter-grade changes in classroom hours correlate with changes in the prevalence of school myopia.[7-10] In addition, despite the pre-determined school curriculum, common to all elementary schools in Taiwan, there are variations in regular school hours which seem to contribute to inter-grade changes in school myopia.[4, 7-10] It would appear that myopization modulation operates in conjunction with in-classroom hours. However, since the school day and curriculum are identical or nearly identical in all elementary schools, the variations in the degree of myopia may be related to after-school learning, which in fact varies greatly, as it depends on learning stress[11] and, more importantly, the extent of urbanization.[12] Other reports have shown that extensive after-school classes lead to high prevalence of myopia in high performance groups,[13] and that learning stress, [14-15] i.e., the intensity of education, leads to the emergence of an epidemic of myopia. [16] In other words, greater levels of additional extracurricular instruction appear to correlate with higher prevalence of myopia.

The purpose of the present study was to investigate after-school learning factors that contribute to myopization and whether they vary according to level of urbanization. An administrative district in northern Taiwan that contains both rural and urban schools was chosen for this study. The myopization factors examined include after-school environment and placement, subjects and related activities. The contributions of these factors have not been examined in detail or elsewhere in Taiwan. Factors were identified, differences were assessed, and correlations with refractive error were evaluated.

Materials and Methods

This project adhered to the Declaration of Helsinki regarding human research and received ethics approval. All parents, teachers, and students were informed of the procedures and consent was obtained from parents and students. Subjects were from 4 elementary schools in Tamsui District, New Taipei City (14 elementary schools total — 4 urban and 10 rural). There were a total of 1,067 students aged 7 to 12 years with no ocular or systemic diseases enrolled in this study. The participation rates of students ranged from 76.3% to 82.6% in each school and 80.7% (1067/1322) in total. All schools operated under the same basic nationwide school curriculum including study subjects, in-classroom hours, holidays and vacation times. The differentiation between urban and rural schools was based on Ministry of Education classification. Urban schools were those with more than 60 classroom groups of all grades, and rural schools were those with less than 12. This study involved one urban school and 3 rural schools. The numbers of participating students and means of refractive errors by grade are shown in Table 1.

Ocular examination included uncorrected vision measurement and refraction. With regard to refraction, the following were performed: non-cycloplegic refraction using a six meter target open-field autorefractor (Shin-Nippon Nvision K5001- Wide View, Japan) to obtain an average of three readings for each student, followed by fogged distance retinoscopy and subjective refraction to obtain the best corrected visual acuity (BCVA). Distance fixation target autorefraction and distance retinoscopy were employed to minimize student accommodation. Although non-cycloplegic auto-refraction of children tends to result in overestimation of myopia, on large-scale screening, such as in the present study, it is also impractical. This is not only due to the limitation of manpower, but also to the high doses of cycloplegics and short-acting tropicamide often used for myopia control in Taiwan. Dose-timing and cycloplegic refraction are issues. We used non-cycloplegic distance

Tab 1. ***Numbers of participants and mean refractive errors by school type and grade***

		School Grade						
		1	2	3	4	5	6	Total
N	Urban	133	94	96	96	120	154	693
	Rural	47	54	62	71	72	68	374
	Total	180	148	158	167	192	222	1067
	Urban mean refractive error (D) (SD)	-0.159 (0.775)	-0.569 (1.001)	-0.785 (1.403)	-1.194 (1.637)	-1.347 (1.515)	-1.800 (1.909)	-0.979 (1.528)
	Rural mean refractive error (D) (SD)	-0.092 (1.083)	-0.156 (0.978)	-0.722 (1.273)	-0.641 (1.219)	-0.869 (1.205)	-1.178 (1.527)	-0.661 (1.401)
	Total mean refractive error (D) (SD)	-0.1464 (1.148)	-0.4303 (1.009)	-0.7635 (1.355)	-0.9706 (1.503)	-1.1812 (1.430)	-1.6143 (1.821)	-0.8771 (1.495)

N = number of participants; mean refractive error and SD are both spherical equivalents (in diopter)

fixation target autorefraction supplemented with fogged retinoscopy, and retinoscopy with a distant fixation target. Use of both techniques can decrease overestimation by auto-refraction to less than 5%.[7]

All procedures were performed by graduate students under the supervision of faculty members of the School of Optometry. The refractive power needed to reach BCVA, conventionally known as the refractive error, was recorded as spherical equivalent (SE), calculated from the spherical power plus ½ of the minus cylinder.

Myopia was defined as SE of -0.50D or worse, i.e., with increasing absolute values. The participants were divided into 5 groups: (1) hyperopia: positive SE of +0.50D; (2) emmetropia: SE between +0.50D and -0.50D; (3) low myopia: SE between -0.51D and -3.00D; (4) medium myopia: SE between -3.01D and -6.00D; and (5) high myopia: SE beyond -6.00D, Subjects in groups (3)(4) and (5) presented with myopia. In addition, the participants and their parents were asked to fill out a questionnaire on after-school learning environment and courses . An internal consistency reliability test, on the pair-wise correlations between items, produced Cronbach α = .931. All items on the questionnaire were explained to the parents and the students. Items related to the environment included: (1) physical space (scored from 1-4, from spacious to crowded); (2) type of placement on weekdays (scored from 1-4, respectively, at home, at home with other lessons, after-school classes, and after-school classes plus other lessons); (3) after-school classes on weekends (scored 0-4, from 0 to 5-6 hours on each weekend); and (4) parental accompaniment (scored 1-4, from seldom to always). Items related to after-school learning classes included English as a second language, Chinese reading and composition, math/science, abacus operation/mental arithmetic, music, art, computer use, indoor and outdoor sports (scored 0-4, from an average of 0 to 4 hours per day). In addition, items related to time spent on after-school activities included: (1) school-related reading and writing, (2) leisure reading, (3) TV watching, (4) computer and tablet use, (5) mobile/smart phone use, and (6) outdoor activities such as jogging, running and ball-playing (scored 0-4, from an average of 0 to 4 hours per day).

A preliminary analysis showed no significant differences in refractive error between males and females, or between right and left eyes[9-10]. The data were therefore pooled, and only data from the right eye were analyzed. Statistical analyses included independent-sampling t-test, χ^2 Spearman correlation, and linear regression analysis and were conducted using the SPSS 20 software package

(Data Statistical Analysis Corporation, Taipei, Taiwan).

Results

The average refractive errors of each grade are shown in Table 1. Starting in Grade 2, each grade had higher myopic refractive error (i.e., higher absolute value) than the previous grade, especially for grades 1-2, grades 2-3, and grades 5-6. The same conditions appeared in both urban and rural schools. There were significant differences between grades 1 and 2 and grades 5 and 6 in urban schools and between grades 2 and 3 and grades 5 and 6 in rural schools [Fig. 1 and Table 2]. In addition, significant differences in urbanization between rural and urban students were noted in grades 4, 5 and 6 [Fig 2]. Moreover, the prevalence of medium myopia was significantly higher (p=.043) and that of hyperopia was significantly lower (p=.043) among urban students than among rural students [Fig. 3].

There were differences in myopia prevalence between our urban and rural samples. Which factors led to these differences? Table 3 shows that after school rural students stayed in less crowded physical spaces than urban students, whereas the latter spent more time attending after-school classes on both weekdays and weekends. There was less frequent parental accompaniment among urban students than among rural students. In addition, in terms of the correlation between refractive error and environmental variances, urban students with myopia correlated well with after-school space, placement, and parental accompaniment, whereas rural students with myopia only correlated well with parental accompaniment. In addition, partial correlation analysis indicated that refractive errors correlate with after-school space(r=0.112, p=0.001) and parental accompaniment (r=0.073, p=0.026) after adjusting for gender, area and grade. In addition, urban students correlated with after-school space (r=0.098, p=0.017) and rural students correlated with parent accompaniment(r=0.162, p=0.010) after adjusting for gender and grade.

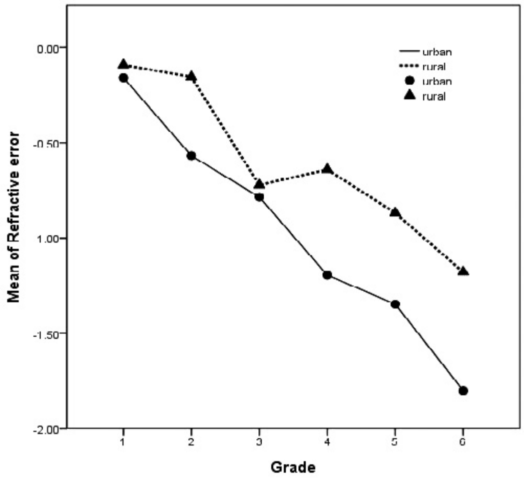

Fig.1. Differences in prevalence of refractive error between grades by school location. *Significant difference (p<0.05).

Table 4 shows that urban students attended more after-school classes than rural students,

Tab 2. ***T-test results by grade in urban and rural schools***

School Grade	1-2	2-3	3-4	4-5	5-6
t-test by grade in Urban	t=3.328* p=.001	t=1.166 p=.245	t=1.731 p=.085	t=0.663 p=.508	t=1.971* p=.049
t-test by grade in Rural	t=0.179 p=.858	t=2.348* p=.021	t=-0.325 p=.746	t=1.888 p=.052	t=1.968* p=.050
t-test by grade-Total	t=2.195* p=.029	t=2.254* p=.025	t=1.179 p=.240	t=1.242 p=.215	t=2.418* p=.016

**Significant difference (p<.05).*

Table 3. ***Rural and urban differences in after-school environment and χ2 correlation between refractive error of urban and rural students and after-school environment***

Environmental variances	Urban Rural (mean±SD)	t	p	CI 95% Upper	CI 95% Lower	χ^2 Spearman correlation (p value) Upper Rural	Total
Physical space (from 0=very spacious to 4=very crowded)	3.33±1.02 2.92±0.96	6.045#	.000	545	278	0.118(.006)* 0.069(.252)	0.088(.011)*
Weekday placement (from 0 =at home with no learning) to 4=classes plus other lessons)	2.79±1.15 2.26±1.22	6.386#	.000	. 685	. 363	0.088(.038)* 0.044(.472)	0.078(.048)*
Classes on weekends (from 0 to 5-6 hours)	1.81±0.39 1.67±0.48	4.537#	.000	.203	.080	0.034(.419) 0.037(.539)	0.021(.544)
Parent accompaniment (from seldom to always)	2.52±1.50 2.95±1.52	-4.143#	.000	-.232	-.636	-0.108(.028)* -0.120(.004)*	-0.082(.017)*

*Significant difference (p<.05) *Significant correlation (p<.05).*

especially English as a second language, math/science, and music classes. On the other hand, computer class attendance was higher among rural students, corresponding to the government policy of improving the computing skills of students in rural areas. Furthermore, 40% or more of students attended English as a second language, Chinese writing, and math/science classes, with English language learning the main variance. The refractive error correlated with English language learning and Chinese writing classes in the urban group, but only with English language learning in the rural

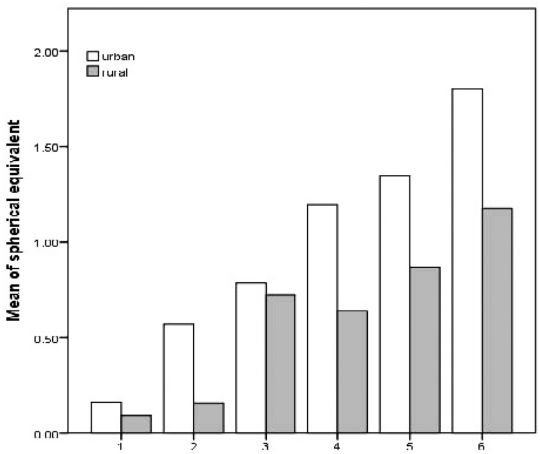

Fig.2. Differences in refractive error between urban and rural students by grade.
*Significant difference (p<0.05): Grade 4, t=2.257, p=0.026; Grade 5, t=2.242, p=0.027; Grade 6, t=2.207, p=0.029, and total, t=3.057, p=0.002

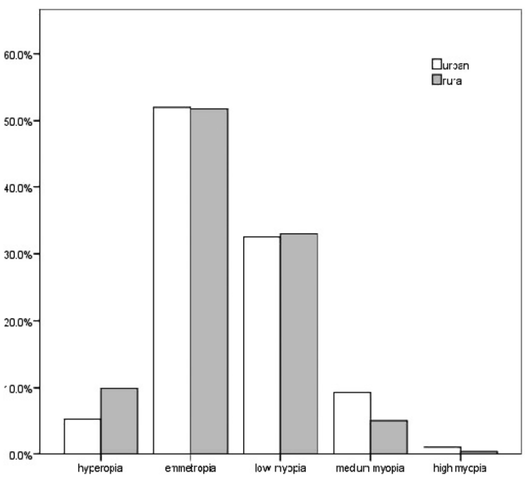

Fig.3. Differences in prevalence of refractive error between urban and rural students. *Significant difference (p<0.05).

Table 4. ***Rural and urban differences in after-school classes and χ2 correlation between refractive error and after-school classes***

Classes	Urban Rural (mean score ± SD)	t	p	χ^2 Spearman correlation (p value) Upper Rural	Total	Attendance above 40%
English as a second language	2.40±1.47 1.22±1.39	11.76#	.000	0.13(.003)* 0.18(.002)*	0.191(.000)*	Yes
Chinese writing	0.78±1.04 0.64±1.09	1.89	.059	0.10(.019)* 0.05(.393)	0.078(.141)	Yes
Math/Science	1.14±1.41 0.63±1.09	5.61#	.000	0.08(.079) 0.05(.444)	0.019(.591)	Yes
Abacus operation/mental arithmetic	0.42±0.73 0.34±0.88	1.47	.141	0.30(.000)* 0.05(.377)	0.213(.000)*	
Music	0.94±1.24 0.42±0.94	6.34#	.000	0.25(.000)* 0.10(.055)	0.177(.000)*	
Art	0.50±0.82 0.38±0.87	1.94	.052	0.20(.000)* 0.10(.105)	0.156(.000)*	
Computer	0.56±1.03 0.74±1.04	-2.47#	.014	0.23(.000)* 0.13(.025)	0.218(.000)*	
Indoor sports	0.56±1.02 0.53±1.01	0.38	.701	0.06(.157) 0.06(.320)	-0.016(.614)	
Outdoor sports	0.61±1.02 0.53±1.01	1.17	.242	-0.15(.001)* -0.21(.001)*	-0.181(.000)*	

*# Significant difference (p<.05) *Significant correlation (p<.05).*

group. Partial correlation analysis demonstrated that English language learning plays a key role in urban(r=-0.152, p=0.000), rural(r=-0.192, p=0.003), and all students(r=-0.203, p=0.000) after adjusting for urbanization, gender and grade.

Table 5 shows that urban students have more homework than their rural counterparts. On the other hand, rural students spend more time on TV watching, digital device use, and outdoor activities after school. Neither homework nor TV watching correlated with student refractive error overall. However, digital device and mobile phone use, as well as outdoor physical activities did correlate with myopic refractive error. Moreover, partial correlation showed that both mobile phone use (r=-0.077, p=0.021) and outdoor physical activities(r= 0.185, p=0.000) correlate with myopia prevalence. This was identical in urban students (mobile: r=-

Table 5. ***Differences in after-school activities between urban and rural students and χ2 correlation between refractive error and after-school activities***

Classes	Urban Rural (mean score ± SD)	t	p	χ^2 Spearman correlation (p value) Upper Rural	Total
Reading and writing after school	1.26±0.68 1.13±0.69	2.726#	.007	0.072(.092) 0.027(.653)	.065(.062)
Leisure reading after school	1.96±0.91 1.89±0.82	1.153	.249	0.068(.114) 0.031(.599)	.064(.0661)
TV watching after school	1.63±0.93 2.12±0.99	-7.451#	.000	0.040(.346) 0.114(.055)	.038(.269)
Computer/tablet use after school	0.94±0.83 1.38±0.99	-7.100#	.000	0.140(.001)* 0.166(.000)*	.126(.033)*
Mobile smart phone use after school	0.74±0.62 0.94±0.62	-4.596#	.006	0.147(.001)* 0.144(.015)*	.124(.000)*
Outdoor activities after school	1.41±0.82 1.78±0.88	-6.694#	.000	-0.275(.000)* -0.163(.000)*	-237(.000)*

*Significant difference (p<.05) *Significant correlation (p<.05).*

0.080, p=0.037; outdoor: r=0.178, p=0.000). There was non-significant difference in rural students (computer: r=0.122, p=0.044, outdoor: r=0.131, p=0.030).

Additionally, linear regression analysis [Table 6] showed that VIF (Variance Inflation Factor) ranges from 1.041 to 1.175 indicating that each variable is an independent factor. English language learning stood out as the main factor for modulating myopization. Other positive and negative modulating factors included mobile/smart phone use, outdoor activities, parental accompaniment, after-school environment, and computer/tablet use. These 6 variables together made up about 0.357 of the association with the trend of myopization. The modulating factors among urban students were mobile/smart phone use, outdoor activities, English language learning, and after-school environment. The modulating factors among rural students were English language learning, computer/tablet use, and parental accompaniment. There were both similarities and differences in the trend of myopization between urban and rural students. It should be emphasized that risk factors of myopia development are diverse and uncertain.

Discussion

The cross-sectional pattern of mean myopic refractive error in 6 elementary school grades in the present study is in agreement with that of previous studies, with some statistically significant inter-grade differences. [1-5, 7-10] It is still unknown if this pattern reflects a longitudinal increase, as school myopia is generally progressive. Both positive and negative modulators of myopization

Table 6. ***Linear regression analysis of key variables, in descending order of contributing weight***

					Statistical Change	
		R	R^2	*Adjusted* R^2	*Z beta*	*VIF**
Urban	1) Mobile/smart phone use	*.181*	.033	.031	.232	.984
	2) 1+outdoor activities	*.279*	.078	.074	-.219	.906
	3) 2+English as a second language	*.324*	.105	.100	.191	.955
	4) 3+after-school environment	*.337*	.114	.107	.109	.924
Rural	1) English as a second language	*.266*	.071	.066	.412	1.340
	2) 1+Computer/tablet use after school	*.359*	.129	.120	.291	1.343
	3) 2+parental accompanying time	*.409*	.167	.154	-.197	1.003
Total	1) English as a second language	*.197*	.039	.038	.250	1.155
	2) 1+mobile/smart phone use	*.271*	.073	.071	.168	1.041
	3) 2+outdoor activities	*.329*	.108	.105	-.203	1.126
	4) 3+parental accompanying time	*.342*	.117	.113	-.093	1.054
	5) 4+after-school environment	*.351*	.123	.117	.079	1.175
	6) 5+Computer/tablet use after school	*.357*	.128	.121	.087	1.172

** Variance inflation factor*

were identified, in addition to those described previously. [7]

Some of these modulators may be due to the part of the learning process that requires attention, i.e, intensity, known as learning stress. Studies from Taiwan have shown that myopization may result from increasing class time and educational pressure combined with reduction in outdoor time. [20] There is an association between learning stress and myopia, especially from Grades 5 to 6. [18-19]

Learning stress may explain the differences in myopia, especially medium myopia, between urban and rural students in grades 4 to 6. This difference is more specific than in previous reports based on schools from different geographic locations. [17-22] It also seems to reflect higher learning intensities in urban schools starting from Grade 4, or a cumulative stress that finally manifests as medium myopia.

The school hours are fixed by the Ministry of Education of Taiwan with only minor variations allowed among individual schools. With the nearly uniform curriculum within the elementary school system, after-school learning should play a far greater role in school myopia modulation. Indeed, the results of this study provide evidence that subject-related learning intensity and after-school activities are modulators of myopization. For example, except for more computer training among rural students, urban students spent more time after school studying various subjects. Of particular interest is that English language learning correlated well with myopic refractive error.

There was also correlation between myopic refractive error and after-school activities, especially digital device use and outdoor physical activities, in agreement with previous studies. [23-30] We also found that, regardless of urban or rural setting, the time spent on computer, tablet or smart phone contributes to myopization, supporting a commonly-held, yet unsubstantiated, belief.

Our results further showed that after-school environment, placement and parental accompaniment are modulating factors. In general, rural students are exposed to more spacious and less effort-demanding environments, and are accompanied more by their parents than their urban counterparts. These factors appear to favor lower myopic refractive error. Indeed, open space in the rural setting has often been cited as being beneficial for reducing myopia progression. [23-30] Similarly, more activities and less study time after school result in the need for less effort and attention.

It remains unclear as to why parental accompaniment is a modulating factor. We speculated that this is not simply a passive presence. Parents may be more attentive leading to timely correction, [8,31] and may follow official recommendations for correct reading distances and rest intervals. [7] It should be noted that even though parental accompaniment is a negative myopization modulator, after-school activities are often chosen by parents, who may unwittingly play a role in dictating the occurrence of other factors, some positive, during the developmental stage when children are most susceptible to myopization.

Conclusion

Since the school day and curriculum are identical or nearly identical in all elementary schools, the variations in the degree of myopia may be related to after-school learning. Factors that favor lower myopic refraction error include more spacious area indoors, less stressful learning environment, and less digital device use, as well as more outdoor activities. Surprisingly, in addition to medical intervention, family education is the starting point for myopia control.

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