What Factors are Associated with Myopia in Young Adults? A Survey Study in Taiwan Military Conscripts

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Purpose. We investigated the independent impact of potential risk factors on myopia in young adults.

Methods. A survey study was conducted with male military conscripts aged 18 to 24 years between February 2010 and March 2011 in Taiwan. The participants were examined using non-cycloplegic autorefraction and biometry. The participants provided data about potential risk factors, including age, parental myopia, education, near work, outdoor activity, and urbanization. Myopia was defined as the mean spherical equivalent of the right eye of $\leq$0.5 diopters (D).

Results. Among 5145 eligible participants, 5048 (98.11%) had refraction and questionnaire data available; 2316 (45.88%) of these received axial length examination. The prevalence of myopia was 86.1% with a mean refractive error of −3.66 D (SD = 2.73) and an axial length of 25.40 mm (SD = 1.38). Older age, having myopic parents, higher education level, more time spent reading, nearer reading distance, less outdoor activity, and higher urbanization level were associated with myopia and longer axial length. More computer use was related to longer axial length. All risk factors associated with myopia also were predictors of high myopia ($\leq$−6.0 D), with the exception of outdoor activity. Finally, an interaction analysis showed shorter axial length was associated with more time spent outdoors only at high urbanization level.

Conclusions. Older age, parental myopia, higher education level, more near work, less outdoor activity, and higher urbanization level were independent predictors of myopia. These data provided evidence to the multifactorial nature of myopia in young men in Taiwan. (*Invest Ophthalmol Vis Sci.* 2013;54:1026–1033) DOI:10.1167/iovs.12-10480

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Myopia has emerged as a major health issue in east Asia, because the prevalence of myopia has increased rapidly in the past few decades. In Taiwan, the prevalence of high myopia increased from 10.9% in 1983 to 21% of young adults in 2000.[1] A previous study on Singapore military conscripts found a myopia rate of 81.3% in 2009 (Saw SM, et al. *IOVS* 2011;52:ARVO E-Abstract 2490). However, myopia generally has been recognized as a problem beginning in childhood. As such, the exploration of associated risk factors is based mainly on study of individuals in this age group.[2] Few studies have examined this issue in young adult populations.

Although the causes of myopia are unclear, evidence supports a multifactorial cause with interplay between environmental and genetic factors. Previous studies have shown that parental myopia was a genetic factor in myopia.[3–6] Time spent in near work[5–11] and outdoor activities[3,4,9–11] were environmental factors that gained a great deal of attention. Outdoor activities were hypothesized to be a protecting factor of myopia. Although greater near work has been implicated in the development and progression of myopia, contradictory findings also have been reported.[9,10,12] It is possible that reading, computer use, and TV watching may have differential impacts on myopia. For instance, reading is associated with relatively dim light and/or small-sized words, whereas computer use is associated with flashing images, which involve different accommodative patterns. Further, different working distances associated with these viewing activities may affect myopia differentially.[13] Therefore, we examined the differential effects of these three types of near work activities.

Higher education level may be a factor critical to myopia in young adults. Education relates to socioeconomic background and large amounts of near work, such as reading and computer use. A previous study among a population of highly educated young adults found a high rate of myopia progression (86%) during law school.[12] It is necessary to clarify whether there are differential effects of education from other kinds of near work to understand further the pathogenesis of myopia.

Recently, researchers are paying more attention to the potential influence of urbanization on myopia.[11,14] Urbanization may be a factor including, but not limited to, several environmental factors, such as different kinds and levels of near work, outdoor activities, and education. Therefore, it would be beneficial to differentiate the unique impact of urbanization from these other factors.

Given that the factors influencing the risk of myopia in children may be different from those influencing the risk of myopia in young adults,[15] the aim of our study was to investigate whether each of the aforementioned factors is associated independently with myopia in young adults.

Materials and Methods

Our study was a survey of refractive errors in military conscripts presenting for medical screening and categorization. In Taiwan, all male citizens and permanent residents are required to enlist for

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mandatory military service (starting at 18 years of age) and undergo prior medical examination at specific hospitals approved by the Department of Health. Male citizens also are allowed to enlist while they are studying in college or graduate school (these men may be older at the time of enlistment). Conscripts cannot choose to report to another hospital and the medical examination is performed only once. Participants selected for this study were conscripts in Tainan City who came to Kaohsiung Veterans General Hospital Tainan Branch for military recruitment examinations. Located in the southern part of Taiwan, Tainan City is one of the five special municipalities in Taiwan and accounts for 8.08% of the country's population. A total of 5187 conscripts was examined between February 2010 and March 2011. The study adhered to the tenets of the Declaration of Helsinki. The methodology and materials used for the study were reviewed and approved by the Institutional Review Board of Kaohsiung Veterans General Hospital. Written consent was obtained from each participant before enrollment.

Examination Procedures

As part of a standardized ophthalmic examination, all participants underwent non-cycloplegic autorefraction of both eyes using a nonaccommodative picture target with standard background illumination on the Canon R-F10 autorefractor (Canon Inc., Tokyo, Japan). A mean of three readings was obtained. Best corrected visual acuity (BCVA) was assessed using a Snellen chart. If the presenting visual acuity was less than 6/7.5, BCVA was determined after objective autorefraction and subjective refinement. All participants not achieving BCVA 6/7.5 were examined using slit-lamp biomicroscopy. Participants who did not achieve BCVA 6/7.5 and were suspected to have retinal disease were examined using indirect ophthalmoscopy following pupil dilation. Participants with significant ocular problems were excluded from military service and, therefore, from our study. The exclusion criteria applied include pathology affecting clarity of the ocular media, previous ocular surgery, strabismus, amblyopia, or BCVA less than 6/10 in either eye.

The following factors also were analyzed: axial length of the globe and body height. Axial length measurements were obtained using a Lenstar LS 900 noncontact biometer (Haag-Streit, Bern, Switzerland) by the trained staff. To reduce the burden on the individuals for medical examination, a systematic random sampling strategy (ratio 1:2) was used to select the participants. Every second conscript was chosen for axial length measurements. As height has been found to be related strongly to axial length,[16] we included height as a control variable in the analysis. Body height was measured using a standard wall stadiometer and was rounded to the nearest 0.1 cm.

Questionnaire

A one-on-one interview then was conducted at the eye clinic by a trained technician to obtain basic demographic information as well as a medical and refraction history. Participants were asked to complete a structured questionnaire that was designed to assess possible risk factors. These included risk factors, such as age, parental history of myopia, residential address, and highest level of education. To assess parental myopia, participants were asked whether one or two of their parents wore eyeglasses to correct nearsightedness. A parent was considered myopic if he or she used the spectacles primarily for distance vision and had been first prescribed spectacles before the age of 18 years. Behavioral factors in the most recent year, such as amount of time (number of hours per day) spent in reading, watching TV, computer work, and outdoor activities, as well as usual habit of reading distance (centimeter, cm) also were self-reported.

Definitions

The spherical equivalent (SE) was calculated as the numerical sum of the sphere and half the cylinder. Myopia was defined by a SE of −0.50 diopters (D) or less. High myopia was defined by a SE of −6.00 D or less. For homogeneous comparisons of eye refraction data, analyses were conducted on the right eye only because SE and axial length were highly correlated between the right and left eyes ($r = 0.95$ and $r = 0.97$, respectively). Education levels in the study participants ranged from junior high school to graduate school. According to the National Statistics of Regional Standard Classification,[17] all 451 cities/counties in Taiwan were stratified into 11 urbanization levels based on population. The different urbanization levels in this classification also reflected different degrees of population density and economic development.[17] Study participants were allocated to one of the 11 levels according to their residential address.

Data Analysis

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS version 16.0; SPSS, Inc., Chicago, IL). Correlation coefficient analyses were used to evaluate the relationship between right and left eyes, and between the refractive error and axial length. Multiple linear regression analyses were performed to assess the independent impact of the possible risk factors first on refractive error and then on axial length. Multiple logistic regression analyses were conducted for comparing risk factors of myopia and high myopia. All confidence intervals (CIs) were 95%.

Results

As part of a standardized medical examination, all participants reported to our hospital had to receive ophthalmic examination. A total of 5187 participants was examined between February 2010 and March 2011, with 42 individuals (0.81%) being excluded from the study due to the presence of the following factors: amblyopia (20), strabismus (5), corneal opacity (2), cataracts (2), glaucoma (3), retinitis pigmentosa (1), and previous ocular surgery (9). Of the 5145 eligible participants, 57 (1.11%) refused to participate and 40 (0.78%) were excluded because of incomplete or unreliable information (Fig. 1). Comparisons between the 5048 participants (98.11%) who completed the questionnaires and the 97 (1.89%) who did not revealed that the two groups did not differ significantly in terms of age (21.44 vs. 21.63 years, $P = 0.264$) and SE (−3.66 vs. −3.65 D, $P = 0.976$). Finally, a total of 5048 males aged 18 to 24 years was included in the current analyses. Among them, 2316 (45.9%) additionally received an axial length examination. Participants whose axial length was assessed had a mean age of 21.58 years (Table 1), significantly higher than those whose length was not assessed (21.32, $P < 0.001$). However, the refractive error did not differ between the two groups (−3.73 vs. −3.60 D, $P = 0.098$).

The demographic profile, potential risk factors, and myopia status of the study population are summarized in Table 1. More than half (53.1%) of the participants had at least one parent with myopia. Among the participants who had myopia, 33.1% had a father with myopia and 40.9% had a mother with myopia. Most (71.2%) of the study population had completed a college/university level education. The correlation coefficient analyses showed that male conscripts who were more educated were less likely to spend time outside ($r = -0.08$, $P < 0.001$) and watching TV ($r = -0.06$, $P < 0.001$), but were more likely to spend time reading ($r = 0.12$, $P < 0.001$) and using computers ($r = 0.03$, $P < 0.025$). There was a very high prevalence of myopia (86.1%), with mean refractive error of −3.66 D. The axial nature of the refractive errors could be seen by the strong correlation between the refractive error and axial length ($r = -0.82$, $P < 0.001$). The prevalence of high myopia also was high (21.2%, $n = 1071$).

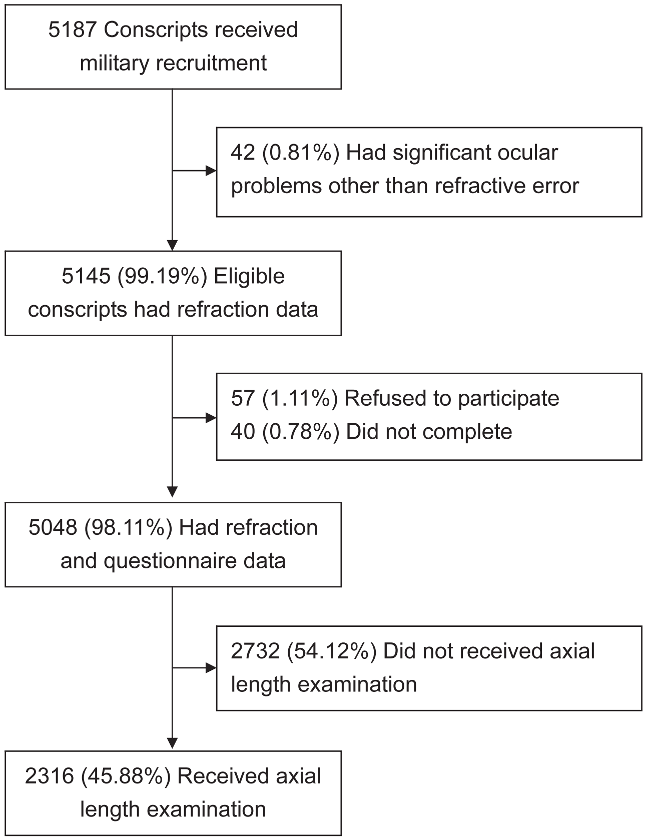

FIGURE 1. Flowchart detailing recruitment and examination of subjects into a study of refractive error among military conscripts in Taiwan.

As shown in Table 2, we used a multiple linear regression analysis to model refractive error and axial length predicted by potential risk factors. Higher refractive error was associated with older age ($P < 0.001$), having myopic parents ($P < 0.001$), higher education level ($P < 0.001$), nearer reading distance ($P < 0.001$), more time spent reading ($P < 0.001$), less outdoor activity ($P = 0.003$), and higher urbanization level ($P < 0.001$). Longer axial length also was related to older age ($P < 0.001$), having myopic parents ($P < 0.001$), higher education level ($P < 0.001$), nearer reading distance ($P = 0.048$), more time spent reading ($P < 0.001$), less outdoor activity ($P = 0.010$), and higher urbanization level ($P = 0.006$). In addition, the factors of computer use and body height were significantly related to axial length ($P = 0.001$ and $P < 0.001$, respectively). However, watching TV was not a significant predictor for refractive error and axial length ($P = 0.051$ and $P = 0.833$, respectively). In the separate regression analyses, we found most risk factors were more predictive of sphere than cylinder values. For example, higher sphere values were associated with older age ($P < 0.001$), having myopic parents ($P < 0.001$), higher education level ($P < 0.001$), nearer reading distance ($P < 0.001$), more time spent reading ($P < 0.001$), more time spent using computer ($P = 0.048$), less time spent watching TV ($P = 0.025$), less outdoor activity ($P = 0.002$), and higher urbanization level ($P < 0.001$). However, higher cylinder values were associated only with having myopic parents ($P < 0.001$) and nearer reading distance ($P = 0.021$).

The results of the multivariate logistic regression analysis are detailed in Table 3. The prevalence of myopia was associated significantly with older age ($P = 0.014$), having myopic parents ($P < 0.001$), higher education level ($P = 0.001$), nearer reading distance ($P = 0.006$), more time spent reading ($P < 0.001$), less outdoor activity ($P = 0.003$), and higher urbanization level ($P = 0.010$). Time spent using computers and watching TV per day were not related to myopia ($P = 0.411$ and $P = 0.417$, respectively). To assess the impact of risk factors on degree of myopia (Table 3), the 4348 myopic subjects were categorized further into low-to-moderate myopia (–0.5 to –6.0 D, $n = 3277$) and high myopia ($\leq$–6.0 D, $n = 1071$) groups. The prevalence of high myopia was associated significantly with older age ($P < 0.001$), having myopic parents ($P < 0.001$), higher education level ($P = 0.003$), nearer reading distance ($P = 0.008$), more time spent reading ($P < 0.001$), and higher urbanization level ($P = 0.002$).

We conducted another four regression analyses to test the possible interaction between outdoor activity and urbanization level. The regression models included all potential risk factors and product term for outdoor activity × urbanization level. For testing interaction effects, the values of outdoor activity and urbanization level were centered around zero to reduce multicollinearity.[18] We found outdoor activity × urbanization level interaction term was not related to spherical equivalent ($P = 0.449$), myopia status ($P = 0.451$), and high myopia ($P = 0.354$). However, outdoor activity × urbanization level interaction term was associated significantly with axial length ($P = 0.020$). Following the recommendations of Aiken and West,[18] the nature of the interaction was determined by plotting the relationship between axial length and outdoor activity at high and low levels of urbanization (defined as +1 and –1 SD from the mean). As illustrated in Figure 2, shorter axial length was associated with more outdoor activity only at high urbanization level ($b = -0.10$, $t\ (2316) = -3.57$, $P < 0.001$). In contrast, the relationship between axial length and outdoor activity was not significant at lower urbanization levels ($b = -0.02$, $t\ (2316) = -0.53$, $P = 0.594$).

DISCUSSION

The prevalence of myopia in our current sample population (86.1%, mean refractive error of –3.66 D, and axial length of 25.40 mm) was similar to that found in recent nationwide surveys in Taiwan,[1,19] which reported prevalence rates of approximately 84.0% among participants aged 16 to 18 years. The prevalence of high myopia was 21.2%, slightly higher than that found in a previous study (21.0%).[1] This evidence highlights the severity of the myopia problem in Taiwan.

The impact of genetic factors on the development of myopia has been described in previous studies.[4,5,20] We found that parental myopia was associated positively with all indicators of myopia and high myopia, suggesting that this is an important factor in identifying susceptible targets for visual health promotion. However, although previous studies have suggested that major genetic contributions to high myopia exist, it seems that myopia is multifactorial, and probably involves major environmental factors.[21]

Results from randomized controlled trials have shown that myopic children who receive multifocal lenses or antimuscarinic topical medication, such as pirenzepine gel, cyclopentolate eye drops, or atropine eye drops, exhibit significantly less myopic progression than children who receive placebo treatment.[22] However, use of many of these therapies is limited by side effects. In addition to pursuing treatment for myopia, there is a growing need to identify factors that might be amenable to intervention.

Of the environmental factor contributing to myopia, there is considerable evidence that near work activity has an important role.[23] However, contradictory findings[10,12] and evidence of reverse causality[9] also have been reported. One explanation for

Table 1. Potential Risk Factors and Myopia Status among Taiwanese Young Men

Potential Risk Factors	Total Participants (n = 5048)	Participants with Additional Axial Length Examination (n = 2316)
Age 18 to 24, mean (SD), y	21.44 (1.63)	21.58 (1.48)
Parental myopia, n (%)		
None	2368 (46.9%)	1070 (46.2%)
Either	1807 (35.8%)	838 (36.2%)
Both	873 (17.3%)	408 (17.6%)
Participant's education level, n (%)		
Junior high school	285 (5.6%)	132 (5.7%)
Senior high school	1148 (22.7%)	419 (18.1%)
College/university	3593 (71.2%)	1755 (75.8%)
Graduate school	22 (0.4%)	10 (0.4%)
Reading distance, mean (SD), cm	35.23 (6.93)	34.94 (6.97)
Time spent in reading (SD), h/day	1.36 (1.88)	1.33 (1.85)
Time spent in using computer, mean (SD), h/day	3.81 (2.60)	3.96 (2.64)
Time spent in watching TV, mean, (SD), h/day	2.10 (1.68)	2.16 (1.72)
Time spent in outdoor activity, mean (SD), h/day	1.28 (1.74)	1.28 (1.74)
Urbanization level, person, n (%)		
200 to 499	0 (0.0%)	0 (0.0%)
500 to 999	16 (0.3%)	3 (0.1%)
1,000 to 1,999	222 (4.4%)	102 (4.4%)
2,000 to 4,999	630 (12.5%)	228 (9.8%)
5,000 to 9,999	144 (2.9%)	81 (3.5%)
10,000 to 19,999	750 (14.9%)	352 (15.2%)
20,000 to 49,999	690 (13.7%)	384 (16.6%)
50,000 to 99,999	710 (14.1%)	361 (15.6%)
100,000 to 499,999	1571 (31.1%)	719 (31.0%)
500,000 to 999,999	259 (5.1%)	65 (2.8%)
>1,000,000	56 (1.1%)	21 (0.9%)
Height, mean, (SD), cm	171.96 (5.76)	172.0 (5.72)
Myopia status		
Refractive error, mean (SD), diopter	−3.66 (2.73)	−3.73 (2.71)
Axial length, mean (SD), mm		25.40 (1.38)
Myopia, n (%)		
No	700 (13.9%)	304 (13.1%)
Yes	4348 (86.1%)	2012 (86.9%)
Low to moderate myopia, n (%)	3277 (64.9%)	1496 (64.6%)
High myopia (≤−6D), n (%)	1071 (21.2%)	516 (22.3%)

the inconsistent findings is that there is no universal definition of near work. Another possible explanation is the quantification of near work. Near work may have a different impact on myopia depending on the different working distances involved. Therefore, grouping all types of near work together, regardless of the distance involved, may lead to the neutralization of any overall effect among components with opposite effects. Hence, providing separate measures for different types of near work may provide a better prediction for myopia.

Similar to our study, three large-scale studies involving younger populations have reported separate measures for near work.[6,10,11] Saw et al.[6] and Zhang et al.[11] found that more time spent reading/studying was associated positively with myopia, whereas Lu et al. found no such association.[10] Based on a composite measure with video games, Zhang et al. found that there was a weak positive correlation between computer use and myopia,[11] whereas Lu et al. reported a weak protective effect with computer use.[10] We found that time spent reading and using a computer was associated with longer axial length, suggesting that each activity has a unique effect and a different mechanism in affecting myopia. As TV watching was not a predictor of myopia, the viewing distance may be too far to be considered “near” in Taiwan. It is worth noting that the average length of time spent using computers in our sample was quite high (3.8 h/day) in comparison to that reported in the three large-scale studies in schoolchildren[6,10,11] and the other types of near work in our study. This indicates that computer use may be an important factor contributing to myopia among young adults in Taiwan. Similar to Lu et al.[10] and Zhang et al.,[11] we found that there were negative relationships between reading distance and myopia. This finding supports the hypothesis that reading at a shorter distance may increase accommodative demand and, therefore, the development of myopia. However, it also is possible that myopes may favor a shorter reading distance.

Determining the effect(s) of education on myopia in young adults is crucial. Consistent with previous studies,[20,24] we found that higher education level was associated with myopia after controlling for age. Education involves several types of near work, such as reading and computer use. Our findings, however, indicated that education still has an effect on myopia after controlling for time spent on several types of near work. This implies that education may reflect an accumulated or

Table 2. Multiple Linear Regression Analyses of Factors Associated with Refractive Error and Axial Length

	Refractive Error, D (n = 5048)			Axial Length, mm (n = 2316)		
Potential Risk Factors	Regression Coefficient (95% CI)	Mean Refractive Error (SD), Diopter	P Value	Regression Coefficient (95% CI)	Mean Axial Length (SD), mm	P Value
Age	−0.24 (−0.30 to −0.17)		<0.001*	0.12 (0.07–0.18)		<0.001*
Parental myopia						
None	−0.71 (−0.80 to −0.61)	−2.99 (0.05)	<0.001*	0.34 (0.27–0.41)	25.08 (0.04)	<0.001*
Either		−4.12 (0.07)			25.64 (0.05)	
Both		−4.52 (0.10)			25.77 (0.07)	
Education level						
Junior high school	−0.60 (−0.80 to −0.41)	−1.75 (0.11)	<0.001*	0.28 (0.13–0.43)	24.46 (0.10)	<0.001*
Senior high school		−2.74 (0.07)			24.85 (0.06)	
College/university		−4.09 (0.05)			25.60 (0.03)	
Graduate school		−6.10 (0.06)			26.74 (0.42)	
Reading distance, cm	0.03 (0.02–0.04)		<0.001*	−0.01 (−0.02–0)		0.048*
Time spent in reading, h/day	−0.18 (−0.22 to −0.15)		<0.001*	0.10 (0.07–0.13)		<0.001*
Time spent in using computer, h/day	−0.03 (−0.05–0)		0.057	0.03 (0.01–0.05)		0.001*
Time spent in watching TV, h/day	0.04 (0–0.09)		0.051	−0.003 (−0.03–0.03)		0.833
Time spent in outdoor activity, h/day	0.06 (0.02–0.10)		0.003*	−0.04 (−0.07 to −0.01)		0.010*
Urbanization level, n						
200 to 499	−0.10 (−0.13 to −0.06)	0 (0.0%)	<0.001*	0.04 (0.01–0.07)	0 (0.0%)	0.006*
500 to 999		−1.98 (0.37)			24.59 (0.06)	
1,000 to 1,999		−2.75 (0.17)			24.96 (0.12)	
2,000 to 4,999		−3.52 (0.11)			25.36 (0.09)	
5,000 to 9,999		−3.48 (0.22)			25.22 (0.15)	
10,000 to 19,999		−3.37 (0.10)			25.32 (0.07)	
20,000 to 49,999		−3.50 (0.10)			25.26 (0.07)	
50,000 to 99,999		−3.91 (0.11)			25.51 (0.07)	
100,000 to 499,999		−3.93 (0.07)			25.51 (0.05)	
500,000 to 999,999		−3.80 (0.15)			25.93 (0.16)	
>1,000,000		−4.32 (0.42)			25.69 (0.27)	
Height	−0.01 (−0.02–0.01)		0.330	0.03 (0.02–0.04)		<0.001*

* Indicates statistical significance.

synergistic effect of near work within a time period rather than near work per se.

Findings from a previous study suggest that the prevalence of myopia may be higher in the city than in the country.[7] However, a simple dichotomy of rural and urban may not encompasses adequately the complex spectrum of social environments. Ip et al.[14] and Zhang et al.[11] found that urbanization affected the prevalence of myopia based on a measure of population density. We assessed urbanization using an officially-defined measure, which reflects the population within an area. This measure has several advantages. First, it briefly reflects population density, which has gained support as a factor affecting myopia.[11,14] Second, this measure covers an area with the same governmental agency, implying that there is a similar administrative, social, and economic environment.[19] In contrast, given the same population density, the environment in a wider or a narrower area may be different because of varying numbers of residents.

We found that higher urbanization level was associated with all indicators of myopia after controlling for several factors. There are a number of explanations for this finding. First, there may be factors affecting myopia in urban settings that are yet to be identified. Urbanization usually is accompanied with environmental pollution, differences in green space, ambient light exposure, and residents' lifestyle, diet, and stress, all of which may affect myopia. Second, the effect of urbanization on myopia may reflect a synergistic effect of several factors. Indeed, there is evidence that interaction between risk factors may contribute the development of myopia.[25,26] It is possible that synergism among environmental factors may occur in urban settings.

Several previous studies have reported a protective effect of outdoor activities on myopia in children,[3–5,9] whereas a number of other studies found no such effect.[7,10,11] In our study, we found that time spent participating in outdoor activities was related significantly to myopia. The effect of outdoor activities on myopia may be confounded by other factors, such as urbanization. For example, school children in cities are likely to spend fewer hours partaking in outdoor activities than children in the countryside.[7] Controlling for these factors, our results provide rigorous evidence of the protective effect of outdoor activities on the development of myopia.

Findings from a previous study suggest that the protective effect of outdoor activities on myopia is associated with the total time spent outdoors, rather than with the level of physical activity.[27] Smith et al. postulated that time spent outdoors reduces the likelihood that children will have myopia, possibly because light levels are much higher outdoors than indoors.[28] However, although the difference in light levels between outdoors and indoors is obvious in urban settings, such a difference might be less significant in rural settings because of decreased housing density and the lack of tall buildings. It is interesting that our results showed that shorter axial length

TABLE 3. Multivariate Logistic Regression Analyses of Factors Associated with Myopia and High Myopia

Potential Risk Factors	Myopia (*n* = 5048)			Degree of Myopia (*n* = 4348)		
	Myopia	Non-Myopia	*P* Value	High Myopia (≤–6D)	Low to Moderate Myopia	*P* Value
Mean age (SD)	21.55 (0.02)	20.78 (0.07)	0.014*	22.00 (0.04)	21.40 (0.03)	<0.001*
Parental myopia (*n*, %)						
None	1935 (81.7%)	433 (18.3%)	<0.001*	331 (17.1%)	1604 (82.9%)	<0.001*
Either	1612 (89.2%)	195 (10.8%)		471 (29.2%)	1141 (70.8%)	
Both	801 (91.8%)	72 (8.2%)		269 (33.6%)	532 (66.4%)	
Education level (*n*, %)						
Junior high school	196 (68.8%)	89 (31.2%)	0.001*	11 (5.6%)	185 (94.4%)	0.003*
Senior high school	902 (78.6%)	246 (21.4%)		140 (15.5%)	762 (84.5%)	
College/university	3228 (89.8%)	365 (10.2%)		907 (28.1%)	2321 (71.9%)	
Graduate school	22 (100%)	0 (0%)		13 (59.1%)	9 (40.9%)	
Mean reading distance, cm (SD)	35.14 (0.11)	35.76 (0.27)	0.006*	34.73 (0.21)	35.28 (0.12)	0.008*
Mean time spent in reading, h/day (SD)	1.44 (0.03)	0.91 (0.06)	<0.001*	1.82 (0.07)	1.31 (0.03)	<0.001*
Mean time spent in using computer, h/day (SD)	3.82 (0.04)	3.74 (0.11)	0.411	3.90 (0.08)	3.79 (0.05)	0.411
Mean time spent in watching TV, h/day (SD)	2.07 (0.03)	2.25 (0.07)	0.417	1.95 (0.05)	2.11 (0.03)	0.272
Mean time spent in outdoor activity, h/day (SD)	1.24 (0.03)	1.52 (0.09)	0.003*	1.14 (0.04)	1.27 (0.03)	0.187
Urbanization level, *n*						
200 to 499	0 (0.0%)	0 (0.0%)	0.010*	0 (0.0%)	0 (0.0%)	0.002*
500 to 999	14 (87.5%)	2 (12.5%)		0 (0.0%)	14 (100.0%)	
1,000 to 1,999	174 (78.4%)	48 (21.6%)		29 (16.7%)	145 (83.3%)	
2,000 to 4,999	542 (86.0%)	88 (14.0%)		117 (21.6%)	425 (78.4%)	
5,000 to 9,999	121 (84.0%)	23 (16.0%)		30 (24.8%)	91 (75.2%)	
10,000 to 19,999	630 (84.0%)	120 (16.0%)		143 (22.7%)	487 (77.3%)	
20,000 to 49,999	589 (85.4%)	101 (14.6%)		135 (22.9%)	454 (77.1%)	
50,000 to 99,999	611 (86.1%)	99 (13.9%)		177 (29.0%)	434 (71.0%)	
100,000 to 499,999	1388 (88.4%)	183 (11.6%)		361 (26.0%)	1027 (74.0%)	
500,000 to 999,999	231 (89.2%)	28 (10.8%)		58 (25.1%)	173 (74.9%)	
>1,000,000	48 (85.7%)	8 (14.3%)		21 (43.8%)	27 (56.2%)	

* Indicates statistical significance.

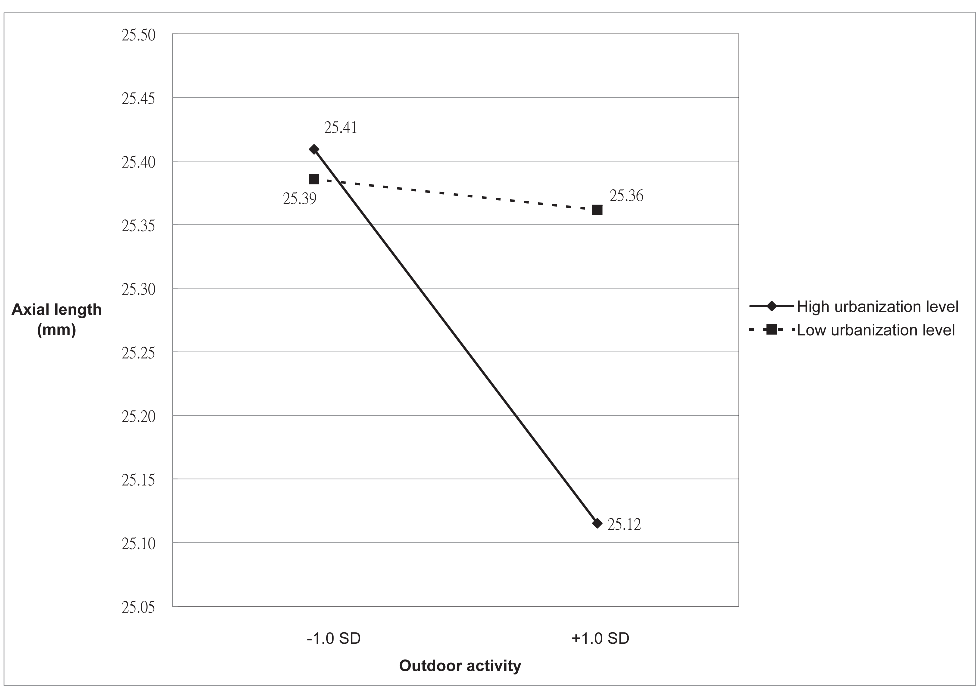

FIGURE 2. The interactive effects of outdoor activity and urbanization level on axial length.

was associated with more time spent in outdoor activities only at high urbanization level. Exposure to the significantly higher light levels encountered outdoors versus indoors at the higher urbanization levels might explain this finding. On the other hand, time spent in outdoor activities may not be equal to time spent outdoors. For example, our participants may not have reported the time spent walking to work or school as outdoor activity. In addition to typical outdoor activities, participants in rural settings may have been exposed to more ambient light outdoors than participants in urban settings. However, our results still suggested that outdoor activity may have an important role in the development of myopia, especially for individuals living in areas of high urbanization.

We also addressed the issue of factors affecting high myopia. In this context, young adults are more susceptible than school children because more myopes progress to high myopia during this age period.[1] We found that time spent in outdoor activities was a protective factor for myopia, but not high myopia. However, older age, having myopic parents, higher education level, more time spent reading, nearer reading distance, and higher urbanization level all were risk factors associated with high myopia. Although there is evidence to suggest that high myopia is determined by genetic factors to a greater extent than low myopia,[21] our results indicated that environmental factors and genetic factors contribute to the development of high myopia. In summary, we found that a number of factors were associated consistently with all indicators of myopia and high myopia, namely age, parental myopia, education level, time spent reading, reading distance, and urbanization.

Our study has some limitations that warrant mention. First, our measure of parental myopia was based on participants' self-reports. Self-reported measures of parental myopia may overestimate the proportion of parents who wore glasses to correct refractive problems other than myopia. Second, we did not enroll young female subjects, which limited the generalizability of our results. However, female subjects have more severe myopia than male subjects in Taiwan and Chinese societies,[1,10,19,25,29] suggesting that female subjects may have more risk factors than male subjects. Therefore, we believe that the risk factors identified in our study also may be applicable to young female subjects. Third, although we included three types of near work in our study, other types of near work activities were omitted. Smartphones and tablet personal computers are used widely by young adults in Taiwan and also may be important risk factors for myopia. As these devices are portable and have small screens, their use may offset the protective effect of outdoor activity. Finally, we were not able confirm how long participants resided in their nominated location. That is, we were not able to determine how many years the effect of urbanization was based on.

In conclusion, the prevalence of myopia is high among the young adult population in Taiwan. We found that older age, higher education level, parental myopia, more near work, including reading and computer use, less outdoor activity, and higher level of urbanization were independent predictors associated with the myopia in young conscripts. These data provide evidence of the multifactorial nature of myopia in young men in Taiwan.

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