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Original Article

# Prevalence and risk factors for myopia in second-grade primary school children in Taipei: A population-based study

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## Abstract

*Background*: High myopia is associated with multiple ocular morbidities that may lead to irreversible blindness. Because high myopia in an adult is thought to be related to onset of myopia in very early childhood, detecting myopia early and working to improve modifiable risk factors may help reduce the development of high myopia. In this study, we tried to evaluate the prevalence of myopia and associated risk factors in second-grade primary school children in Taipei, Taiwan.
*Methods*: A questionnaire was distributed to the participants' parents, and their written informed consent was obtained before performing eye examinations that included visual acuity testing and cycloplegic autorefraction. Multiple logistic regression models were applied to assess possible risk factors associated with myopia. Myopia was defined as spherical equivalent of −0.50 D or less in either eye.
*Results*: The prevalence of myopia in the second graders was 36.4%. After adjustment for other characteristics, the following variables were significantly associated with a higher risk of myopia: male sex [odds ratio (OR) = 1.24, $p < 0.001$]; suburban residence (vs. urban; OR = 1.10, $p = 0.02$); lower maternal education level (OR = 1.25, $p < 0.001$); the presence of myopia in one parent (OR = 1.66, $p < 0.001$) or both parents (OR = 2.82, $p < 0.001$); time spent on near-work activity every day (OR = 1.21, $p < 0.001$); shorter visual distance when doing near-work activity (OR = 1.17, $p < 0.001$); and participation in an after-school tutorial program (OR = 1.20, $p < 0.001$). By contrast, resting after 30 minutes of near-work activity (OR = 0.84, $p < 0.001$) and spending more time participating in outdoor activities on weekends (OR = 0.91, $p = 0.03$) were significantly associated with a lower risk of myopia.
*Conclusion*: Our findings indicate that lifestyle and reading habits impact the development of myopia during early childhood. Behavior modification, such as more time spent outside during the day and limited near-work activity, may be a feasible strategy for curbing the increasingly high prevalence of myopia in Taipei.


*Keywords:* myopia; population-based study; prevalence; risk factor; schoolchildren

Conflicts of interest: The authors declare that they have no conflicts of interest related to the subject matter or materials discussed in this article.

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## 1. Introduction

The continuing increase in the prevalence of myopia in recent decades has become an important public health issue worldwide, especially in East Asia.[1−5] In Taiwan, the prevalence of myopia in 7- and 12-year-old children increased from 5.8% and 36.7% in 1983 to 21% and 61% in 2000, respectively.[2] Similarly, the prevalence of high myopia ($\leq -6.0$ D) in 18-year-old students increased from 10.9% in 1983 to 21% in 2000.[2] A recent review of myopia-progression studies supported the findings of Parssinen and Lyyra[6] and Donovan et al[7] that myopia progresses significantly faster in children with myopia onset at younger age. High myopia is associated with multiple ocular morbidities that can lead to irreversible blindness, seriously handicap the individual, burden the family, and pose a heavy socioeconomic burden.[8−10] In light of the vision-threatening complications of high myopia and the findings that high myopia is associated with early onset of myopia in youth, it seems prudent to focus attention on measures that help delay the age of myopia onset.

Although the mechanisms underlying the development of myopia are not clear, there is evidence that multifactorial interactions between environmental and genetic factors are involved. The prevalence of myopia is higher in populations in urban areas and in people of Chinese ethnicity.[11] Other risk factors for myopia include more time spent on near-work activity,[12,13] less time participating in outdoor activities,[14,15] higher educational level,[16] a parental history of myopia,[17,18] and a relatively hyperopic periphery.[19,20]

In recent years, ophthalmologists in Taipei, Taiwan have found that an increasing number of preschool children are afflicted with myopia. We speculate that this might be related to the fact that children in Taipei are usually given free access to smartphones and tablets starting in early childhood. Because these devices are convenient and are equipped with functions for chatting and game play, children tend to use them whenever and wherever they are, tremendously increasing the near workload on their eyes. To explore this possibility, we reinvestigated the prevalence of myopia and the risk factors related to myopia in young children in an era dominated by the use of mobile devices.

This citywide study evaluated the prevalence of myopia in second-grade primary school children in metropolitan Taipei at the start of the 2013 school year. The risk factors associated with having myopia at such a young age were investigated. This report is part of the Myopia Investigation Study in Taipei (MIT), which has the long-term aim of understanding and addressing the very high prevalence of myopia, the increasing severity of myopia, and the increasingly young age of myopia onset in Taipei.

## 2. Methods

### 2.1. Study design and participants

The MIT, which began in June 2013, is a 3-year population-based cohort study that includes myopia screening and eye care education. The design, rationale, and methods of the MIT have been described elsewhere.[21] In brief, all 19,374 second graders in metropolitan Taipei were invited to participate in the MIT. Questionnaires were distributed to all parents who provided consent for their second-grade children to participate before the eye examinations were performed. As part of the MIT, the Taipei City Government agreed to provide each participant with a free myopia evaluation at an MIT-associated medical facility during each semester for 3 consecutive years (a total of 6 evaluations), and the project also includes a case management intervention for children who have myopia that is detected during these examinations. In addition, the MIT established a monitoring committee comprising 11 senior ophthalmologists and four expert epidemiologists. Before the eye examination campaign began, the committee members defined and explained the standard operation procedure (SOP) for the eye examinations to all of the MIT-associated medical facilities to ensure that the facilities would follow the SOP for all of the MIT participants. Committee members paid regular visits to the MIT-associated hospitals/clinics to evaluate the eye examination procedures during the campaign. After the first eye examination period was completed (at the end of September 2013), all children were exposed to a large-scale eye care education program, which included lectures and an animated cartoon, to teach them about the prevention, treatment, and complications of myopia.

Here, we report the refraction data and questionnaire findings obtained from July 2013 to September 2013. The Institutional Review Board of Taipei City Hospital, Taipei, Taiwan approved the protocols used in this study (TCHIRB-1020501) prior to study initiation, and the principles of the Declaration of Helsinki were adhered to throughout. Written informed consent was obtained from a parent of each child. Of the 19,374 eligible second graders in Taipei in 2013, the parents of 16,486 (85.1%) children completed the questionnaire and provided consent for their child to participate. A total of 11,590 (70.3%) children underwent cycloplegic autorefraction.

### 2.2. Refraction assessment

The MIT monitoring committee held three training sessions for all participating medical facilities and their staff to explain the MIT SOP and how it should be implemented. Each examination had to be performed in compliance with the SOP as follows. Uncorrected and best-corrected visual acuity of the right and left eyes were measured after refraction and checked with an autorefractometer at least three times to obtain the average measure. Slit lamp examination was performed to rule out anterior segment conditions that would contraindicate the use of cycloplegic agents in each child. Two doses of 1% cyclopentolate drops were given 10 minutes apart, and refraction was checked 30 minutes after the second drop. If the pupil still responded to pen light stimulation, the examiner waited an additional 10 minutes before performing cycloplegic refraction. Instead of cyclopentolate, some MIT-associated medical facilities opted to use either 1% tropicamide or

0.5% phenylephrine hydrochloride/0.5% tropicamide to achieve cycloplegia for the MIT participants who were examined at their clinics. The spherical equivalent (SE) of the refractive error was calculated as the spherical value of the refractive error plus one half of the cylindrical value. Myopia was defined as an SE of −0.50 D or less after cycloplegia. Only data from the more myopic eye in each child were included in the study analysis.

### 2.3. Investigation of risk factors

The parents who provided consent for their children to participate completed a detailed questionnaire. Myopia risk factors were identified and assessed based on the results of the questionnaire at the beginning of the project. The collected demographic information included the sex of the child, the child's area of residence, parental characteristics such as maternal education level and parental myopia status, and the child's lifestyle and reading habits. Questions on lifestyle and reading habits pertained to TV viewing, performing near work, participating in outdoor activities outside of school, and participation in an after-school tutorial program. TV viewing pattern information included the distance to the television screen and the average time spent watching TV each day. Near-work questions asked about the use of a table lamp while studying, the age at which the child began doing near work, the average time spent on near work each day, the distance from objects when doing near work, whether the child had a 10-minute rest after doing 30 minutes of near work, and whether cellphones, computers, and tablets were used during the past year. A question about the average time spent playing outdoors after school on weekdays and weekends was also part of the questionnaire.

### 2.4. Statistical analysis

The overall prevalence of myopia and the prevalence of myopia in the population studied were estimated as stratified by the characteristics of the children and the parents. Simple and multiple logistic regression models were applied to investigate the association between myopia status (myopia vs. nonmyopia) and potential risk factors. Odds ratios (ORs) and their 95% confidence intervals (CIs) were calculated. Simple and multiple linear regression models were applied to examine the association between the SE and risk factors. Regression coefficient *B* and standard coefficient beta and their 95% CI values were calculated. Statistical analysis was performed using Statistical Analysis System Software (SAS version 9.3; SAS Institute, Cary, NC, USA). All $p$ values $< 0.05$ were considered statistically significant.

## 3. Results

The prevalence of myopia in our study population was 36.4%. The mean refractive error was $-0.29 \pm 1.23$ D for the more myopic eye in each child, and the distribution of the refractive error is shown in Fig. 1. Table 1 shows the characteristics of the participants. In this population, 57.0% had two myopic parents, and 31.4% had one myopic parent. Of the mothers, 72.1% had at least a college-level education. The majority of children started near work before 6 years of age and spent < 1 h/d outdoors after school on weekdays and < 2 h/d outdoors on weekends. A total of 72.4% of children participated in after-school tutorial programs. Cellphones, computers, and tablets were very popular in this group of children, and 88.5% of them had used these products in the past year.

The results of univariate and multivariate analyses of factors associated with myopia status are shown in Table 2. After adjustment for other characteristics, male sex (OR = 1.24, 95% CI = 1.15−1.34, $p < 0.001$), children living in suburban areas (vs. those living in urban areas, OR = 1.10, 95% CI = 1.02−1.19, $p = 0.02$), and children with mothers with a lower education level (OR = 1.24, 95% CI = 1.13−1.38, $p < 0.001$) had a significantly higher risk of myopia. Children

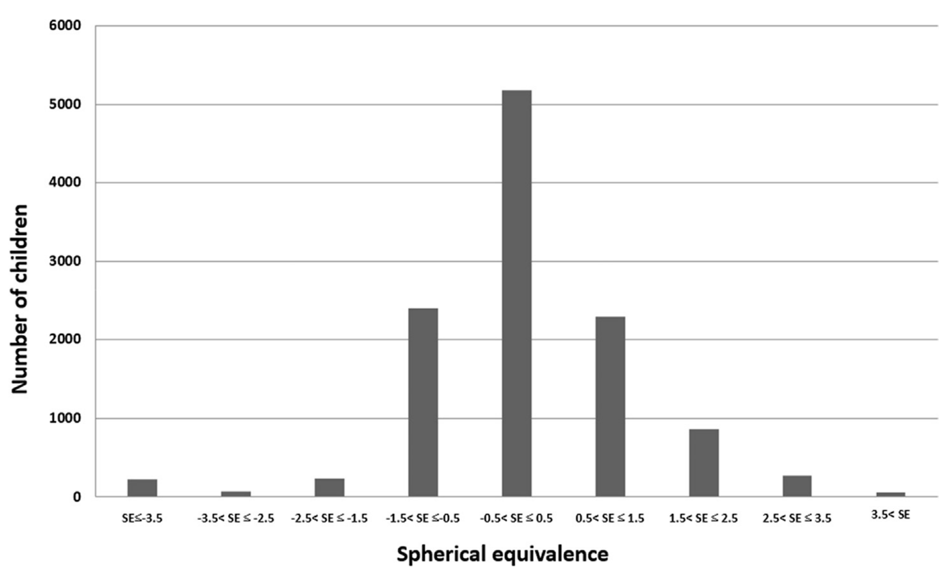


Fig. 1. Distribution of refractive error values in 8-year-old children in Taipei in 2013. SE = spherical equivalent.

Table 1
Characteristics of the study participants.

| Characteristic | All participants ($n = 11,590$) | | Participants with myopia ($n = 4214$) | |
|---|---|---|---|---|
| | *N* | % | *N* | % |
| *Demographics & parental characteristics* | | | | |
| *Sex* | | | | |
| Female | 5455 | 47.1 | 1851 | 33.9 |
| Male | 6135 | 52.9 | 2363 | 38.5 |
| *Area of residence* | | | | |
| Urban | 6011 | 51.9 | 2133 | 35.5 |
| Suburban | 5579 | 48.1 | 2081 | 37.3 |
| *Maternal education level* | | | | |
| High school or less | 2834 | 24.5 | 989 | 34.9 |
| College or more | 8361 | 72.1 | 3078 | 36.8 |
| Unknown | 395 | 3.4 | 147 | 37.2 |
| *Parental myopia* | | | | |
| None | 1355 | 11.7 | 327 | 24.1 |
| One myopic | 3637 | 31.4 | 1120 | 30.8 |
| Both myopic | 6598 | 56.9 | 2767 | 41.9 |
| *Television (TV) watching habits* | | | | |
| *Distance to TV screen (m)* | | | | |
| <3 | 9196 | 79.3 | 3330 | 36.2 |
| ≥3 | 2006 | 17.3 | 730 | 36.4 |
| Unknown | 388 | 3.4 | 154 | 39.7 |
| *Time spent watching TV daily (h)* | | | | |
| <2 | 8972 | 77.4 | 3273 | 36.5 |
| ≥2 | 2346 | 20.2 | 844 | 36.0 |
| Unknown | 272 | 2.4 | 97 | 35.7 |
| *Near-work habits* | | | | |
| *Use of a table lamp while studying* | | | | |
| Yes | 9265 | 80.0 | 3401 | 37.0 |
| No | 1865 | 16.1 | 631 | 34.0 |
| Unknown | 460 | 4.0 | 182 | 39.6 |
| *Age when starting near work (y)* | | | | |
| <6 | 10,135 | 87.5 | 3710 | 36.6 |
| ≥6 | 1187 | 10.2 | 403 | 34.0 |
| Unknown | 268 | 2.3 | 101 | 37.7 |
| *Time spent on near work daily (h)* | | | | |
| <2 | 6750 | 58.2 | 2316 | 34.3 |
| ≥2 | 4490 | 38.7 | 1765 | 39.3 |
| Unknown | 350 | 3.0 | 133 | 38.0 |
| *Distance from near work (cm)* | | | | |
| ≥30 | 5635 | 48.6 | 1919 | 34.1 |
| <30 | 4495 | 38.8 | 1755 | 39.0 |
| Unknown | 1460 | 12.6 | 540 | 37.0 |
| *10-min rest period after 30 min of near work* | | | | |
| Yes | 4603 | 39.7 | 1547 | 33.6 |
| No | 4558 | 39.3 | 1767 | 38.8 |
| Unknown | 2429 | 21.0 | 900 | 37.1 |
| *Use of cellphones, computers, or tablets in the past year* | | | | |
| Yes | 10,056 | 86.8 | 3620 | 36.0 |
| No | 1336 | 11.5 | 522 | 39.1 |
| Unknown | 198 | 1.7 | 72 | 36.4 |
| *Outdoor activities* | | | | |
| *Time spent participating in outdoor activities after school (h/d)* | | | | |
| *On weekdays* | | | | |
| <1 | 9379 | 81.0 | 3444 | 36.7 |
| ≥1 | 1832 | 15.8 | 625 | 34.1 |
| Unknown | 379 | 3.3 | 145 | 38.3 |
| *On the weekend* | | | | |
| <2 | 7849 | 67.7 | 2893 | 36.9 |
| ≥2 | 3377 | 29.1 | 1182 | 35.0 |
| Unknown | 364 | 3.1 | 139 | 38.2 |
| *After-school tutorial program* | | | | |
| *Attending an after-school tutorial program* | | | | |
| Yes | 8388 | 72.4 | 3130 | 37.3 |
| No | 2877 | 24.8 | 961 | 33.4 |
| Unknown | 325 | 2.8 | 123 | 37.9 |
| Total | 11,590 | 100.0 | 4214 | **36.4** |

Bold value represents statistics significant.

with two myopic parents had the highest risk of myopia (OR = 2.82, 95% CI = 2.41–3.29, $p < 0.001$), followed by those with one myopic parent (OR = 1.66, 95% CI = 1.42–1.95, $p < 0.001$). In terms of near-work habits, children who spent more time on near work every day (OR = 1.21, 95% CI = 1.11–1.33, $p < 0.001$), those who were closer to their near work (OR = 1.17, 95% CI = 1.08–1.28, $p < 0.001$), and those who did not have a 10-minute rest after 30 minutes of near work (OR = 1.19, 95% CI = 1.08–1.30, $p < 0.001$) had a significantly higher risk of myopia. After-school tutorial program participation and shorter time spent participating in outdoor activities on weekends were also significantly associated with a higher risk of myopia. Unexpectedly, after adjustment for other characteristics, children who used cellphones, computers, and tablets in the previous year had an 18% lower risk of having myopia than those who did not (95% CI = 0.72–0.92, $p = 0.001$). However, additional analysis found that among those who used these products in the past year, spending > 2 hours each day was associated with a higher risk of myopia (95% CI = 1.19–1.67, $p < 0.001$).

The associations between the SE of the study eyes and various potential risk factors are shown in Table 3. Sex, maternal education level, parental myopia status, near-work habits (including time spent on near work, distance when doing near work, resting following near work), and after-school tutorial program participation remained significantly associated with SE of the eye. In addition, starting near work at a younger age was significantly associated with a more negative SE.

## 4. Discussion

In this population-based study, the prevalence of myopia (≤ −0.50 D in the more myopic eye) in second-grade children in metropolitan Taipei was 36.4%. The prevalence of myopia was 31.6% when only the right eyes were included in the analysis. Table 4 shows the results of previous studies on the prevalence of myopia that were conducted in 8-year-old children in Taiwan and in other countries.[22–28] The high prevalence (> 30%) of myopia in Singapore and Hong Kong, and its increasing prevalence in Taipei in young children, highlights the urgent need for efforts to curb its rapid development in Asia.

Table 2
Associations between myopia status and possible risk factors.[a]

| Characteristic | Univariate analysis | | | Multivariate analysis | | |
|---|---|---|---|---|---|---|
| | *p* | Odds ratio | 95% CI | *p* | Odds ratio | 95% CI |
| *Demographics & parental characteristics* | | | | | | |
| Sex [male/female (ref.)] | **<0.001** | 1.22 | 1.13−1.32 | **<0.001** | 1.24 | 1.15−1.34 |
| Area of residence [suburban/urban (ref.)] | **0.042** | 1.08 | 1.00−1.17 | **0.02** | 1.10 | 1.02−1.19 |
| Maternal education level [H/C (ref.)] | 0.07 | 0.92 | 0.84−1.01 | **<0.001** | 1.24 | 1.13−1.38 |
| *Parental myopia* | | | | | | |
| One myopic/none (ref.) | **<0.001** | 1.40 | 1.21−1.61 | **<0.001** | 1.66 | 1.42−1.95 |
| Both myopic/none (ref.) | **<0.001** | 2.27 | 1.99−2.60 | **<0.001** | 2.82 | 2.41−3.29 |
| *Television (TV) watching habits* | | | | | | |
| Distance to TV screen [≥3/<3 m (ref.) | 0.880 | 1.01 | 0.91−1.11 | 0.52 | 1.04 | 0.93−1.15 |
| Time spent watching TV daily [≥2/<2 h (ref.)] | 0.652 | 0.98 | 0.89−1.08 | 0.89 | 0.99 | 0.90−1.10 |
| *Near-work habits* | | | | | | |
| Use of a table lamp while studying [Yes/No (ref.)] | **0.02** | 1.13 | 1.02−1.26 | 0.06 | 1.11 | 1.00−1.24 |
| Age when starting near work [<6/≥6 y (ref.)] | 0.07 | 1.12 | 0.99−1.28 | 0.20 | 1.09 | 0.96−1.24 |
| Time spent on near work daily [≥2/<2 h (ref.)] | **<0.001** | 1.24 | 1.15−1.34 | **<0.001** | 1.21 | 1.11−1.31 |
| Distance from near work [<30/≥30 cm (ref.)] | **<0.001** | 1.24 | 1.14−1.35 | **<0.001** | 1.17 | 1.08−1.28 |
| 10-min rest period after 30 min of near work [Yes/No (ref.)] | **<0.001** | 0.80 | 0.73−0.87 | **<0.001** | 0.84 | 0.77−0.92 |
| Use of cellphones, computers, or tablets in the past year [Yes/No (ref.)] | **0.03** | 0.88 | 0.78−0.99 | **<0.001** | 0.82 | 0.72−0.92 |
| *Outdoor activities* | | | | | | |
| *Time spent participating in outdoor activities after school* | | | | | | |
| On weekdays [≥1/<1 h/d (ref.)] | **0.03** | 0.89 | 0.80−0.99 | 0.30 | 0.94 | 0.85−1.05 |
| On the weekend [≥2/<2 h/d (ref.)] | 0.06 | 0.92 | 0.85−1.00 | **0.03** | 0.91 | 0.83−0.99 |
| *After-school tutorial program* | | | | | | |
| Attending an after-school tutorial program [Yes/No (ref.)] | **<0.001** | 1.19 | 1.09−1.30 | **<0.001** | 1.20 | 1.10−1.32 |

CI = confidence interval; H/C = high school or less/college or more.
Bold values represent statistics significant.
[a] Simple and multiple logistic regression models were used to examine the association between myopia status and risk factors.

The data in our study support the findings of other studies. We, too, found that a parental history of myopia,[17,18] spending more time on near work,[11,12] shorter distances when doing near work,[29] and doing near work continuously for > 30 minutes[29] were all associated with an increased prevalence of myopia. However, some of the results of our study are inconsistent with those of other studies.

Spending less time outdoors has been identified as a risk factor for myopia in recent years,[13,14] and some studies have found that there might be a threshold of around 10−14 hours spent outdoors/wk that is needed to prevent myopia.[30,31] In addition, Wu et al[15] found that outdoor activities during class recess have a protective effect on myopia onset and on myopic shift in children aged 7−11 years. One common theory is that brighter light explains why outdoor activities protect against myopia. Recent animal studies show that high ambient lighting retards the development of experimental myopia in chicks and monkeys.[32,33] Further, ambient light intensity can regulate the release of retinal dopamine and further control refractive development.[34−36] Similarly, we found that children who spent more time participating in outdoor activities on the weekends had a lower risk of developing myopia, but the risk of myopia was not lower in children who spent more time participating in after-school outdoor activities on weekdays. One plausible explanation is that many students in Taipei attend after-school tutorial programs after spending the day at school. They remain there until the late evening, and most of this time is spent on near work such as reading and writing. Only 15.8% of the children in our study spent > 1-hour outdoors after school. Because many of these outdoor activities took place in the evening or at night, they may not benefit the children in terms of myopia prevention due to the lack of bright light. Further studies are needed to investigate whether increasing outdoor after-school activities in the daytime reduces the risk of myopia.

Performing near work is associated with the prevalence of myopia.[11,12,29] Because of their rising popularity, we were interested in looking at whether the use of cellphones, computers, and tablets influenced the prevalence of myopia. We found that myopia prevalence was lower in children who had used these products in the previous year (86.8% of the participants). In fact, using these products seemed to be a protective factor for myopia. However, further analysis found that 6.2% of these participants who spent > 2 hours daily using these products tended to have a 41% higher risk of myopia than those who spent < 2 hours on them. One possible explanation is that some of the children who did not use these products during the previous year might be those who were prohibited from using such products because they had myopia.

It is important to prevent myopia in children as early as possible because myopic progression is faster in younger children.[7] One interesting finding of this study was that children who began doing near work at a younger age tended to have a more negative SE. This suggests that starting near work at an early age may expedite the process of emmetropization, which in turn increases the risk of that child developing myopia earlier than if he/she had not started near work at such a young age.

Table 3
Associations between the spherical equivalent and possible risk factors.[a]

| Characteristic | Univariate analysis | | | | | Multivariable analysis | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *p* | Regression coefficient *B* | Standard coefficient beta | 95% CI | VIF | *p* | Regression coefficient *B* | Standard coefficient beta | 95% CI | VIF |
| *Demographics & parental characteristics* | | | | | | | | | | |
| Sex [male/female (ref.)] | **<0.001** | −0.13 | −0.05 | −0.17 to −0.08 | 1.00 | **<0.001** | −0.13 | −0.05 | −0.18 to −0.09 | 1.01 |
| Area of residence [suburban/urban (ref.)] | 0.38 | −0.02 | −0.01 | −0.06 to 0.02 | 1.00 | 0.25 | −0.03 | −0.01 | −0.07 to 0.02 | 1.01 |
| Maternal education level [H/C (ref.)] | 0.13 | 0.04 | 0.01 | −0.01 to 0.09 | 1.01 | **<0.001** | −0.17 | −0.06 | −0.22 to −0.11 | 1.24 |
| *Parental myopia* | | | | | | | | | | |
| One myopic/none (ref.) | **<0.001** | −0.17 | −0.07 | −0.25 to −0.10 | 2.53 | **<0.001** | −0.28 | −0.10 | −0.36 to −0.20 | 2.89 |
| Both myopic/none (ref.) | **<0.001** | −0.53 | −0.21 | −0.60 to −0.46 | 2.53 | **<0.001** | −0.67 | −0.27 | −0.75 to −0.59 | 3.24 |
| *Television (TV) watching habits* | | | | | | | | | | |
| Distance to TV screen [≥3/<3 m (ref.)] | 0.85 | 0.01 | 0.00 | −0.05 to 0.07 | 1.01 | 0.64 | −0.01 | 0.00 | −0.07 to 0.04 | 1.03 |
| Time spent watching TV daily [≥2/<2 h (ref.)] | 0.76 | 0.01 | 0.00 | −0.05 to 0.06 | 1.01 | 0.97 | 0.00 | 0.00 | −0.06 to 0.06 | 1.10 |
| *Near-work habits* | | | | | | | | | | |
| Use of a table lamp while studying [Yes/No (ref.)] | 0.05 | −0.06 | −0.02 | −0.12 to 0.00 | 1.20 | 0.18 | −0.04 | −0.01 | −0.10 to 0.02 | 1.26 |
| Age when starting near work [<6/≥6 y (ref.)] | **0.003** | −0.11 | −0.03 | −0.19 to −0.04 | 1.20 | **0.02** | −0.08 | −0.02 | −0.16 to −0.01 | 1.22 |
| Time spent on near work daily [≥2/<2 h (ref.)] | **<0.001** | −0.12 | −0.05 | −0.17 to −0.08 | 1.02 | **<0.001** | −0.10 | −0.04 | −0.15 to −0.05 | 1.05 |
| Distance from near work [<30/≥30 cm (ref.)] | **<0.001** | −0.14 | −0.06 | −0.19 to −0.09 | 1.10 | **<0.001** | −0.10 | −0.04 | −0.15 to −0.05 | 1.16 |
| 10-min rest period after 30 min of near work [Yes/No (ref.)] | **<0.001** | 0.12 | 0.05 | 0.07−0.17 | 1.21 | **0.002** | 0.08 | 0.03 | 0.03−0.13 | 1.29 |
| Use of cellphones, computers, or tablets in the past year [Yes/No (ref.)] | 0.80 | 0.01 | 0.00 | −0.06 to 0.08 | 1.13 | 0.11 | 0.06 | 0.02 | −0.01 to 0.13 | 1.16 |
| *Outdoor activities* | | | | | | | | | | |
| *Time spent participating in outdoor activities after school* | | | | | | | | | | |
| On weekdays [≥1/<1 h/d (ref.)] | 0.06 | 0.06 | 0.02 | 0.00−0.12 | 1.01 | 0.42 | 0.03 | 0.01 | −0.04 to 0.09 | 1.06 |
| On the weekend [≥2/<2 h/d (ref.)] | 0.26 | 0.03 | 0.01 | −0.02 to 0.08 | 1.01 | 0.15 | 0.04 | 0.01 | −0.01 to 0.09 | 1.07 |
| *After-school tutorial program* | | | | | | | | | | |
| Attending an after-school tutorial program [Yes/No (ref.)] | **<0.001** | −0.13 | −0.05 | −0.18 to −0.08 | 1.08 | **<0.001** | −0.13 | −0.05 | −0.18 to −0.08 | 1.11 |

CI = confidence interval; H/C = high school or less/college or more; VIF = variance inflation factor.
Bold values represent statistics significant.
[a] For statistical analysis, simple and multiple linear regression models were used to examine the association between the degree of myopia and risk factors.

A previous study found that people with higher educational levels had a higher prevalence of myopia.[16] Accordingly, their children might have a higher risk of myopia due to both genetic factors and exposure to an environment similar to that of their parents. However, in multivariate analysis, our study found higher maternal education to be a protective factor for children against the development of myopia. We speculate that mothers with higher educational levels might

Table 4
Prevalence of myopia in 8-year-old children in Taipei.

| Author (year) | Study design/study area | Cycloplegic refraction | Myopia definition | Prevalence |
|---|---|---|---|---|
| Our study (2013) | Population-based, cross-sectional/Taipei, Taiwan (urban & suburban) | Cycloplegic autorefraction | ≤0.5 D in the right eye | 31.6% |
| | | | ≤0.5 D in either eye | 36.4% |
| Hsiao et al (2010) [a] | Population-based, stratified sampling/Taiwan | Cycloplegic autorefraction | ≤0.5 D in the right eye | 28.3% |
| Saw et al (2002)[22] | School-based, cross-sectional/Singapore | Cycloplegic autorefraction | ≤0.5 D in the right eye | 34.7% |
| Fan et al (2004)[23] | School-based, cross-sectional/Hong Kong | Cycloplegic autorefraction | ≤0.5 D in the right eye | 37.5% |
| Murthy et al (2002)[24] | Population-based/New Delhi, India (rural) | Cycloplegic retinoscopy | ≤0.5 D in the right eye | 5.67% |
| Dandona et al (2002)[25] | Population-based/Andhra Pradesh, India (rural) | Cycloplegic retinoscopy | ≤0.5 D in either eye | 2.83% |
| Goh et al (2005)[26] | Population-based/Gombak district, Malaysia (suburban) | Cycloplegic autorefraction | ≤0.5 D in either eye | 14.0% |
| He et al (2004)[27] | Population-based, cluster sampling/Guangzhou, China (urban) | Cycloplegic autorefraction | ≤0.5 D in either eye | 14.0% |
| Naidoo et al (2003)[28] | Population-based/South Africa | Cycloplegic autorefraction | ≤0.5 D in either eye | 2.9% |

[a] According to the data reported by the Taiwan's Health Promotion Administration.

be more knowledgeable about the impact of high myopia on visual function and make greater efforts to reduce the risk of myopia.

This study has several strengths. First, it is a large-scale population-based study that invited all second-grade children in Taipei to participate. Unlike many other myopia population studies, our study did not use a sampling strategy, which may have helped minimize potential selection bias. Second, the parents of all of the 11,590 children included in the analysis completed the questionnaire, and all of the children underwent cycloplegic refraction. This provided an opportunity to comprehensively assess the risk factors associated with myopia in a very young population. Third, an SOP was established before the examinations were performed; holding three information and training sessions ensured that the staff at participating facilities understood how to perform examinations according to the SOP. We also had a monitoring committee to inspect the MIT-associated medical facilities to make sure that they adhered to the SOP.

However, our study also had some limitations. First, this study only analyzed the baseline examination data, plus it had a cross-sectional design. This made it difficult to draw any causal inferences from the results. Follow-up studies that collect longitudinal data may help improve this aspect of the study. Second, although there was an SOP for performing the eye examinations, bias could not be completely excluded because the examinations were performed at different MIT-associated medical facilities. Third, three different agents could be used for cycloplegic refraction, and each MIT-associated medical facility might choose any agent for any of their participants throughout the project. Although 1% tropicamide and 0.5% phenylephrine hydrochloride/0.5% tropicamide are considered acceptable and effective cycloplegic agents for Asian children,[37,38] they may have cycloplegic effects that differ from that of cyclopentolate. Further studies are ongoing to better understand the difference in cycloplegic effects for these three cycloplegic agents. Fourth, although written informed consent and completed questionnaires were obtained from 85.1% of all second-grade children in Taipei, only 11,590 (70.3%) underwent cycloplegic autorefraction and were included in the final analysis. Notably, there were no significant differences in the baseline demographic characteristics, such as sex and urbanization, between the 11,590 participants and the 19,374 eligible children in Taipei City.

In conclusion, this study demonstrated that there is a high prevalence of myopia in second-grade primary school children in Taipei. These children are more likely to develop high myopia in the future and are at risk of further visual impairment. The results highlight the importance of adequate outdoor activity and restricted near-work activity for preventing early onset myopia in childhood. The epidemiological findings of this study should be considered by policy makers, educators, and public health professionals who devise health and educational interventions aimed at reducing the prevalence of myopia in Taiwan and other Asian countries.

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