The associations between near visual activity and incident myopia in children: A nationwide 4-year follow-up study

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Precis

Attending cram school more than 2 hours/day, may increase the risk of incident myopia in children.
This suggests the potential for reducing incident myopia by lessening near visual workload or by
increasing time outdoors.

1 **The associations between near visual activity and incident myopia in children: A nationwide 4-**

2 **year follow-up study**

3 **Abstract**

4 **Objective:** This nationwide population-based study aimed to examine the prospective association

5 between near visual activities and incident myopia in Taiwanese children aged 7-12 years old over a

6 4-year follow-up period.

7 **Design:** Prospective cohort design.

8 **Participants:** 1,958 children aged 7-12 years old from the Taiwan 2009 National Health Interview

9 Survey, which were linked to the 2009-2013 claims data from the National Health Insurance system.

10 **Methods:** Multivariable Cox proportional hazard models were used to estimate the associations

11 between three types of near visual activities, namely reading (< 0.5, 0.5-0.9, 1+ hour/day), use of

12 computer, internet and games (< 0.5, 0.5-0.9, 1+ hour/day), and 'cram school' attendance (< 0.5, 0.5-

13 2.0, 2.0+ hour/day), and incident myopia.

14 **Main Outcome Measures:** Prevalent myopia was defined as those who had at least 2 ambulatory

15 care claims (International Classification of Diseases, [ICD] 367.1) in 2008-2009. Incident myopia

16 was defined by those who had at least 2 ambulatory care claims (ICD 367.1) during the 4-year

17 follow-up period (2010-2013) after excluding prevalent cases.

18   **Results:** Overall, 26.8% of children had myopia at baseline, while 27.7% of those without myopia at

19   baseline developed incident myopia between 2010 and 2013. On average, they spent 0.68 ($\pm$0.86)

20   hour/day on computer/internet use, 0.63 ($\pm$0.67) hour/day on reading and 2.78 ($\pm$3.53) hour/day on

21   cram school. The results showed that children attending cram schools more than 2 hour/day (hazard

22   ratio [HR] = 1.31; 95%CI: 1.03-1.68) had higher risk of incident myopia. The effects of these

23   activities remained similar in sensitivity analyses.

24   **Conclusions:** Cram school attendance more than 2 hour/day may increase the risk of children's

25   incident myopia. This may be due to increased near visual activity or reduced time outdoors.

26

27   Keywords: incidence, near-sightedness, short-sightedness, elementary school, close visual activity

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Background

Myopia is one of the common disorders of the eye and the development of a high prevalence of serious myopia increases the risk of later health problems, such as glaucoma, retinal detachment and cataract [1]. A recent systematic review and meta-analysis based on a pooled data from 145 studies covering 2.1 million participants showed that the global prevalence of myopia was 28.3% in 2010. This figure is projected to increase rapidly from 34.0% in 2020 to 39.9% in 2030 and reach 49.8% in 2050 [2]. Although the increasing prevalence of myopia has already been observed in some countries, regional differences were evident. In 2010, the prevalence in East Asia (47.0%) was significantly higher than those in North America (34.5%) and Western Europe (28.5%). Countries in East and Southeast Asia such as China, Japan, South Korea, Singapore and Taiwan have been gripped by an unprecedented rise in myopia [3, 4]. Another systematic review and meta-analysis indicated that increasing time spent outdoors could be a simple behavioral change strategy for reducing the risk of developing myopia in childhood [5-7], but it is still unclear whether other modifiable behavioral risk factors are associated with incident myopia.

Children spend large amounts of time in games on smart phones, tablet computers and PCs, reading, and cram schools (also known as tutorial or coaching schools) [8], all of which involve close visual work [9]. Whether near work is a risk factor for the development of myopia in children has received attention in recent years. A systematic review and meta-analysis documented inconsistent

4

50   conclusions and heterogeneity across 14 studies (11 cross-sectional and 3 cohort studies), suggesting

51   more prospective cohort studies are needed to verify the relationships between near visual activities

52   and incident myopia [10]. To date, among the seven prospective cohort studies, only two reported that

53   more time spent in near visual work could increase the risk of myopia incidence [11, 12]; others revealed

54   no association [13-16]. Besides, these cohort studies may have suffered from methodological limitations

55   such as a short follow-up period [16, 17], high rates of participant attrition [11, 13, 14], low precision in

56   determining the onset time of myopia [13], and a small [16] or non-representative samples [12, 15].

57   To address these issues and strengthen the evidence base and inform school policy, the

58   present investigation extends these findings by prospectively studying a national sample of young

59   children aged 7-12 years old at baseline, and including assessments of a range of near visual

60   activities, over 4 years of follow-up. Thus, this nationwide population-based study aimed to examine

61   the prospective association between near visual activities and incident myopia in Taiwanese children.

62   We also included potentially confounding factors (i.e. outdoor leisure activities) in multivariable

63   analyses and conducted sensitivity analyses to test for the robustness of the findings.

64   **Methods**

65   Study design and sample

66   This was a prospective cohort study involving participants aged 7-12 in the Taiwan 2009

67 National Health Interview Survey who were linked to the 2008-2013 claims data from the National

68 Health Insurance system. The 2009 National Health Interview Survey comprised 25,636 participants

69 (under 12= 3,531; 12-64= 19,201; 65+= 2,904; overall response rate =84.0%), and was conducted by

70 the National Health Research Institutes and Bureau of Health Promotion Administration, Ministry of

71 Health and Welfare in Taiwan. Participants were selected using multistage stratified systematic

72 sampling design to select a nationally representative sample [18].

73   In 2009, 2,085 children aged 7-12 participated in the National Health Interview Survey.

74 Information about children was obtained using face-to-face interviews with an adult proxy

75 respondent (i.e. mother: 70.3%, father: 21.7%, and others: 8%) familiar with the child's health.

76 Among them, 1,958 (93.9%) respondents provided the consent to link the children's claims data

77 from the National Health Insurance program. The National Health Insurance program is compulsory

78 for all citizens starting from birth (coverage rate = 99.6% of the total population 23.1 million in 2009)

79 [19].

80   Ethical approval for this study was obtained from Taipei City Hospital Institutional Review

81 Board, Taiwan (reference number: TCHIRB-10404118-W).To ensure adequate data protection, all

82 data access and statistical analyses were conducted in the Health and Welfare Data Science Center,

83 Ministry of Health and Welfare, Taiwan.

84   Measures

85   *Outcome variable: Myopia*

86   Based on the claims data from the National Health Insurance Research Database in 2008-2013,

87   prevalent myopia was defined as those who had at least 2 ambulatory care claims (International

88   Classification of Diseases, Ninth Revision, Clinical Modification, [ICD-9-CM] as ICD 367.1) in

89   2008-2009. Incident myopia was defined by those who had at least 2 ambulatory care claims during

90   the 4-year follow-up period (2010-2013) after excluding prevalent cases. According to the

91   Implementation Regulations Governing Health Examinations to Elementary and Junior High School

92   Students in Taiwan [20], at the beginning of each academic year (from September of one year to June

93   of the next year), the annual vision screening was conducted in the school. Parents whose child (aged

94   7 or older) failed the vision screening were required by the school to take their child to a local eye

95   clinic for regular eye examinations. It is compulsory that documentation of the examination signed

96   by an ophthalmologist is submitted to the school health center. The nationwide completion rate for

97   receiving clinical evaluation was approximately 95% in the school year 2003 [21].

98   *Exposure variables: Near visual activities*

99   Time spent in three types of near visual activities during both weekdays and weekend days were

100 assessed, including reading (including read a book, magazine, comic, and story), use of computer,

101 internet and games, and cram school attendance (including doing homework, assignments, and

102 examinations). Cram schools are a common way of enhancing academic learning in Taiwan, and

103 involve attendance at private classes outside the regular school system in the evening or at weekends.

104 Each type of activity was assessed using the following questions: 'On average, during a weekday

105 (Monday - Friday), how many hours/minutes in a day do you engage in this activity?' and 'On

106 average, during a weekend (Saturday - Sunday), how many hours/minutes in a day do you engage in

107 this activity?' The average time engaging in each type of activity per day was computed as follows:

108 (5×1 weekdays + 2×1 weekend day)/7, which were categorized into three groups (reading: < 0.5, 0.5-

109 0.9, 1+ hour/day; use of computer, internet and games: < 0.5, 0.5-0.9, 1+ hour/day; and cram school

110 attendance: < 0.5, 0.5-2.0, 2.0+ hour/day), based on previous studies [22, 23]. The content validity of all

111 of the items in National Health Interview Survey was reviewed by expert panels. The whole

112 questionnaire was then examined twice in pilot testing [18]. The research team undertook a sub-study

113 to further assess the reliability and validity of the measure among 49 elementary school students

114 (male/female=29/20, mean age= 10.24±0.43) and their caregivers in Taiwan. The results of 3-day

115 test-retest reliability and concurrent validity are shown in Appendix Table S1, demonstrating the

116 psychometric properties of these measures are adequate. Test-retest reliability of the time spent in

117 near visual activities with a 3-day interval was examined using Pearson's correlation ranged between

118 0.76 and 0.95 (*p*-value <0.001) and paired-samples t-tests (all *p*-values > 0.05). Concurrent validity

119   showed that Pearson's correlation coefficients between time spent in near visual activities self-

120   reported by children and their parents/caregivers, demonstrating a high correlation (.72-.85) between

121   the two groups. This provides some evidence of reliability and validity of these measures.

122   *Covariates*

123   Based on previous literature [4, 10, 24], the following potentially relevant factors were included as

124   covariates: (i) socio-demographic factors: sex, age (4-6, 7-8, 9-10, 11-12 years old), parents'

125   education level (junior high school or below, senior high school, and college above), household

126   monthly income (US dollar) (< 1000, 1000-1666, 1666-2333, and 2333+), and urbanization (urban,

127   suburban, and rural); (ii) outdoor leisure (session/week) (<1, 1-2, 3-5, and 6+); (iii) TV viewing (<2,

128   2-2.9, 3+ hour/day); (iv) Number of other eye disorders (0 vs. 1+): Including strabismus, amblyopia,

129   color-blindness, astigmatism, retinal diseases, and hypermetropia, which were measured by the items

130   of National Health Interview Survey.

131   Data analysis

132   Descriptive statistics for prevalent and incident myopia were calculated first to characterize the

133   sample structure. Chi-square tests were utilized to test for group differences in percentage of each

134   group of near visual activities and covariates. Previous research indicated that the use of

135   conventional level (*p* value = 0.05) may fail to identify variables known to be important. Covariates

136   with a *p* value <0.25 were included in the subsequent regression models for adjustment [25].

137   Means and SDs for time spent in different types of near visual activities were calculated

138   separately for age groups. One-way ANOVA was utilized to explore age group differences.

139   A multivariable logistic regression model was computed to assess the associations between near

140   visual activities and prevalent myopia (Model 1). Multivariable Cox proportional hazard models

141   were analyzed to address the prospective associations between near visual activities at baseline and

142   incident myopia (Model 2).

143   To assess the potential problems of confounding and under-diagnosed myopia, two sensitivity

144   analyses were conducted. Firstly, given that participants with more eye disorders might be at high

145   risk of myopia and also be less likely to engage in outdoor physical activities and near visual work,

146   the inclusion of these subjects may influence the near visual activity-incident myopia relationships.

147   The Cox regression was therefore repeated after excluding those who had any other eye disorders

148   (Model 3). Secondly, previous research based on Taiwan insurance claim data found that some

149   physicians may categorize myopia diagnosis using ICD 367 instead ICD 367.1. Therefore, restricting

150   the diagnoses to 367.1 were likely to underestimate a number of children with myopia [21]. To mitigate

151   the potential bias of under-diagnosis, the Cox regression was therefore repeated based on the study

152   sample with the selection criterion of ICD 367 (Model 4).

153   All analyses were conducted using SAS 9.4 software and a *p* value < 0.05 was considered

154   statistically significant.

155

156   **Results**

157   *Characteristics of prevalent and incident myopia*

158   Table 1 shows characteristics of prevalent (2009) and incident (2010-2013) myopia in Taiwanese

159   children at baseline. Overall, 26.8% of children had myopia at baseline, while 27.7% of those

160   without myopia at baseline developed incident myopia between 2010 and 2013. At baseline, chi-

161   square tests show that children who had myopia in 2009 were more likely to be age 11-12 years,

162   have fathers and mothers with college or higher degree, higher household income, lived in urban

163   areas. They were also more likely to have more reading time, and attending more cram schooling.

164   They were more likely to watch TV relatively little (< 2 hour/day) and engaged in less outdoor

165   leisure activity and were more likely to have other eye disorders. Participants who had incident

166   myopia in 2010-2013 tended to be younger, lived in urban areas, and have fathers or mothers with

167   college or higher degrees, and enjoy a higher household monthly income. They spent more time in

168   reading and attending cram schools.

169   *Patterns of different types of near visual activities by age groups*

170   Patterns of different types of near visual activities stratified by age groups are shown in Table 2.

171   Among the three types of close visual work, school children spent the largest amount of time in

172   attending cram school, followed by computer/internet and reading. With the exception of reading, it

173   seems that time spent in cram school and computer/internet increase with age among elementary

174   school children.

175   *Associations between near visual activity and prevalent myopia*

176   After adjusting for potential confounders, multivariable logistic regression analyses (model 1 in

177   Table 3) showed that children who read more (0.5-0.9 hour/day: odds ratio (OR) = 1.28, p=0.006;

178   more than 1 hour/day: OR = 1.43, p=0.020), and spent more than 2 hour/day in cram school

179   (OR=1.65, p<0.001), were more likely to have prevalent myopia.

180

181   *Associations between near visual activities and incident myopia*

182   As model 2 in Table 3, Cox regression analyses showed that after covariates had been taken into

183   account, children who attended cram schools more than 2 hour/day were at increased risk of incident

184   myopia (HR=1.31, p=0.030). Similar results were observed in sensitivity analyses in model 3 and

185   model 4 after excluding participants with other eye disorders at baseline and using ICD367 for

186   myopia respectively. However, the relationship between incident myopia and reading was weaker

187   than those with cram school attendance. The relationship between incident myopia and reading (0.5-

188   0.9 hour/day) was a borderline significance across the model 2-4 ($p = 0.045$-0.052). In contrast, use

189   of computer/internet was not related to incident myopia in each model.

190

191   **Discussion**

192   This study fills the gap in the literature by using a nationally representative sample with a longer

193   follow-up period than previous research, having low rates of loss to follow-up because of the use of

194   ambulatory care claims data from the National Health Insurance Research Database. This nationwide

195   4-year follow-up study revealed that the association of different types of near visual activities on

196   incident myopia may be distinct. Among three types of close visual work, school children attending

197   cram school more than 2 hours a day may have a higher risk of incident myopia. In contrast, the

198   association strength between time spent in reading and incident myopia is weak, and only marginally

199   significant. Use of computer, internet and games is not related to incident myopia. The prospective

200   results were verified when adjusting for underlying covariates, including baseline socio-demographic

201   factors and outdoor leisure activities. Sensitivity analyses also supported the stability of these

202   findings.

203   This study demonstrates that close visual work, especially cram school attendance exceeding 2

204   hours/day, is positively associated with higher risks of developing myopia in children, supporting the

205   findings of previous cohort studies [10]. This is consistent with earlier findings of a cohort study [17].

206   Notably, time spent in cram school (2.78 hours/day) is much higher than those spent in reading (0.63

207   hour/day) and use of computer/internet and games (0.68 hour/day). This may partially account for

208   why the association of cram school attendance is stronger than those with reading and usage of

209   computer/internet and games in school children in Taiwan. However, the underlying mechanism

210   linking cram schooling and incident myopia remains unclear.

211   Like many newly industrialized countries in Asia, most families in Taiwan are nuclear with few

212   children. Given busy work schedules, most dual-earner parents are not able to pick up children from

213   school in time. Moreover, although parents sometimes do not provide help with children's

214   homework after work, they expect their children to be academically successful. Therefore,

215   enhancement of academic performance, especially in mathematics, science, and English courses,

216   could potentially be another key reason why cram schools are prevalent in Taiwan and other Asian

217   countries [26, 27]. It is possible that prolonged time spent in near visual work for homework,

218   assignments, and examinations at cram school may bring heavy pressure and hinder outdoor physical

219   play, which has been recognized as an underlying factor of myopia. It may be important for cram

220   schools to reduce the time spent in near visual activities and increase outdoor activities in order to

221   help prevent incident myopia. This strategy requires further investigation through intervention

222   studies.

223   A major strength of our study is conducted based on a nationally representative sample with a

224   prospective design, thus strengthening the evidence base with in greater generalizability. Second, the

225   data from large-scale health surveys was cross-linked with a national health insurance database with

226   more than 99% coverage nationwide. As the participation rate was high in the Taiwan National

227   Health Interview Survey (approximately 84% in 2009), the possibility of selection bias is small.

228   Finally, based on school health regulations of Taiwan, eye examinations are required for every

229   school child in elementary and junior high schools in each semester. Thus, the outcome variable –

230   incident myopia based on medical records is less likely to have been underestimated or diagnosed

231   with a delay. However, this approach may not work in other countries.

232   Despite of these strengths, several limitations of the present study should be also considered.

233   First, the measures of close visual work, including reading, use of computer, internet and games, and

234   cram school attendance, were self-reported, so could be subject to bias. In addition, these items have

235   not been validated against external objective measurements. Moreover, using baseline questionnaire

236   information alone but not annual information for close visual work might also result in bias. Second,

237   this study used claim data as a measure of myopia, which cannot be used to assess the severity of

238   myopia. Future studies should consider to examine the associations between close visual work and

239   incidence of high myopia. Nevertheless, the systematic regime of school-based monitoring of vision

240   problems in Taiwan may ensure the validity and minimize the problem of using claim data for

241   myopia. Finally, a potential confounder – outdoor activity, was assessed using sessions but not exact

242   duration. Furthermore, outdoor brightness was also not considered in the present study. This

243   limitation may partly explain why outdoor leisure activity was not a significant predictor of incident

244   myopia in the current study.

245   In summary, this study expands our understanding of how time spent in different type of near

246   visual activity is related to incident myopia in school children. It presents evidence that cram school

247   attendance for more than 2 hour/day may increase the risk of incident myopia in children. Notably,

248   time spent in cram school increases with age among elementary school children. Greater time spent

249   in cram schooling may increase the amount of near visual activity and at the same time deprive

250   children of time outdoors. These issues warrant further study.

251

252   **Funding (needed only if applicable)**

253   None.

254   **Disclosure of potential conflicts of interest**

255   The authors declare no conflicts of interest

256   **Informed consent**

257   A participant informed consent form from their parents/guardians was obtained before face-to-face

258   interviews.

259   **Abbreviations and Acronyms:**

260   ICD = International Classification of Diseases; HR = hazard ratio; OR =odds ratio; TV = Television

References

261   1.   WHO. Impact of increasing prevalence of myopia and high myopia: report of the Joint World

262   Health Organization. Brien Holden Vision Institute Global Scientific Meeting on Myopia. Sydney,

263   Australia: University of New South Wales, 2015.

264   2.   Holden BA, Fricke TR, Wilson DA, et al. Global prevalence of myopia and high myopia and

265   temporal trends from 2000 through 2050. Ophthalmology 2016;123(5):1036-42.

266   3.   Ding B-Y, Shih Y-F, Lin LL, et al. Myopia among schoolchildren in East Asia and Singapore.

267   Survey of Ophthalmology 2017.

268   4.   Rudnicka AR, Kapetanakis VV, Wathern AK, et al. Global variations and time trends in the

269   prevalence of childhood myopia, a systematic review and quantitative meta-analysis: implications for

270   aetiology and early prevention. British Journal of Ophthalmology 2016;100(7):882-90.

271   5.   French AN, Ashby RS, Morgan IG, Rose KA. Time outdoors and the prevention of myopia.

272   Exp Eye Res 2013;114:58-68.

273   6.   Rose KA, Morgan IG, Ip J, et al. Outdoor activity reduces the prevalence of myopia in children.

274   Ophthalmology 2008;115(8):1279-85.

275   7.   Xiong S, Sankaridurg P, Naduvilath T, et al. Time spent in outdoor activities in relation to

276   myopia prevention and control: a meta-analysis and systematic review. Acta Ophthalmol

277   2017;95(6):551-66.

278   8.   Morgan IG, Rose KA. Myopia and international educational performance. Ophthalmic Physiol

279   Opt 2013;33(3):329-38.

280   9.   Saunders TJ, Vallance JK. Screen Time and Health Indicators Among Children and Youth:

281   Current Evidence, Limitations and Future Directions. Appl Health Econ Health Policy 2016.

282   10.   Huang HM, Chang DS, Wu PC. The Association between Near Work Activities and Myopia in

283   Children-A Systematic Review and Meta-Analysis. PLoS One 2015;10(10):e0140419.

284   11.   French AN, Morgan IG, Mitchell P, Rose KA. Risk factors for incident myopia in Australian

285   schoolchildren: the Sydney adolescent vascular and eye study. Ophthalmology 2013;120(10):2100-8.

286   12.   Jones-Jordan LA, Mitchell GL, Cotter SA, et al. Visual activity before and after the onset of

287   juvenile myopia. Invest Ophthalmol Vis Sci 2011;52(3):1841-50.

288   13.   Guggenheim JA, Northstone K, McMahon G, et al. Time outdoors and physical activity as

289   predictors of incident myopia in childhood: a prospective cohort study. Invest Ophthalmol Vis Sci

290   2012;53(6):2856-65.

291   14.   Jones LA, Sinnott LT, Mutti DO, et al. Parental history of myopia, sports and outdoor activities,

292   and future myopia. Invest Ophthalmol Vis Sci 2007;48(8):3524-32.

293   15.   Saw SM, Shankar A, Tan SB, et al. A cohort study of incident myopia in Singaporean children.

294   Invest Ophthalmol Vis Sci 2006;47(5):1839-44.

295   16.   Wu PC, Tsai CL, Wu HL, et al. Outdoor activity during class recess reduces myopia onset and
296   progression in school children. Ophthalmology 2013;120(5):1080-5.
297   17.   Tsai DC, Fang SY, Huang N, et al. Myopia Development Among Young Schoolchildren: The
298   Myopia Investigation Study in Taipei. Invest Ophthalmol Vis Sci 2016;57(15):6852-60.
299   18.   Shih Y-T, Hung Y-T, Chang H-Y, et al. The design, contents, operation and the characteristics
300   of the respondents of the 2001 National Health Interview Survey in Taiwan. Taiwan Journal of
301   Public Health 2003;22(6):419-30.
302   19.   Jiang YD, Chang CH, Tai TY, et al. Incidence and prevalence rates of diabetes mellitus in
303   Taiwan: analysis of the 2000-2009 Nationwide Health Insurance database. J Formos Med Assoc
304   2012;111(11):599-604.
305   20.   Education TMo. Implementation Regulations Governing Health Examinations to Elementary
306   and Junior High School Students. In: Education TMo, ed. 2003.
307   21.   Fang YT, Chou YJ, Pu C, et al. Prescription of atropine eye drops among children diagnosed
308   with myopia in Taiwan from 2000 to 2007: a nationwide study. Eye (Lond) 2013;27(3):418-24.
309   22.   Chang T-W, LIN, Y.-H., Tsai, H.-F., Chang, H.-Y., Wu, C.-M. Preliminary exploration of
310   sedentary activities and daily behaviors in Taiwanese children: results of the 2005 National Health
311   Interview Survey. Taiwan National Health Interview Survey REsearvh Brief 2006;5:1-12.
312   23.   Lo K-H, Pan, L.-Y. P., Lin, M.-C., Chang, H.-Y., Shih, Y.-T. The analysis of special physical
313   inactivity higher energy intakes and body mass index of children in Taiwan: results of 2001 National
314   Health Interview Survey. Taiwan Journal of Public Health 2003;22(6): 474-782.
315   24.   Foster PJ, Jiang Y. Epidemiology of myopia. Eye (Lond) 2014;28(2):202-8.
316   25.   Hosmer DW, Lemeshow, S., & Sturdivant, R. X. . Applied logistic regression (3rd ed.). NJ:
317   John Wiley & Sons, 2013.
318   26.   Chiu S-C, Chung Y-C, Pai L-W, Chang S-F. Using a Qualitative Triangulation Method to
319   Explore the Challenge of Myopia Prevention in School Children for the Role of School Health
320   Nursing. International Journal of Nursing 2016;3(1):55-64.
321   27.   Tsai, Fang, Huang, et al. Myopia Development Among Young Schoolchildren: The Myopia
322   Investigation Study in Taipei. Invest Ophthalmol Vis Sci 2016;57(15):6852-60.

Table 1 Characteristics of prevalent and incident myopia in Taiwanese children at baseline (Taiwan, 2009-2013)

Variables in 2009	Prevalence (2009)			Incidence (2010-2013)		
	n	(%)	p for χ^2	n	%	p for χ^2
Socio-demographic						
Sex			0.325			0.457
Male	970	27.8		700	28.6	
Female	986	25.9		731	26.8	
Age			<0.001			<0.001
7-8 (Grade 1-2)	567	12.0		499	34.5	
9-10 (Grade 3-4)	666	29.1		472	28.6	
11-12 (Grade 5-6)	723	36.4		460	19.4	
Father's educational level			<0.001			<0.001
Junior high school or below	504	18.7		410	22.2	
Senior high school	825	26.8		604	26.3	
College+	600	33.7		398	35.4	
Mother's educational level			<0.001			<0.001
Junior high school or below	393	18.3		321	19.9	
Senior high school	974	27.4		707	26.3	
College+	548	32.5		370	36.2	
Household monthly income			<0.001			<0.001
< 1000 (US dollars)	439	17.5		362	21.3	
1000-1666	546	24.7		411	25.8	
1666-2333	413	32.0		281	33.5	
2333+	481	33.5		320	33.8	
Urbanization			<0.001			0.325
Urban	309	32.0		210	29.1	
Suburban	1364	27.4		990	28.3	
Rural	255	18.0		209	23.4	
Near visual work						
Computer/internet/video game			0.664			0.919
< 0.5 (hr/day)	996	26.2		735	28.2	
0.5-0.9	416	27.6		301	26.9	
1+	513	28.3		368	27.7	
Reading			<0.001			<0.001

< 0.5 (hr/day)	905	23.1		696	23.7	
0.5-0.9	528	31.3		363	34.7	
1+	490	30.0		343	28.6	
Cram school attendance			<0.001			0.029
< 0.5 (hr/day)	675	15.9		568	23.8	
0.5-2.0	259	27.8		187	30.5	
2.0+	960	34.5		629	30.2	
Lifestyle behaviors						
TV watching			<0.001			0.473
< 2 (hr/day)	625	35.5		403	27.8	
2-2.9	540	28.9		384	30.0	
3+	757	18.9		614	26.4	
Frequency of outdoor leisure			<0.001			0.735
< 1 (sessions/week)	506	26.7		371	29.1	
1-2	735	31.7		502	28.5	
3-5	269	24.2		204	25.5	
6+	443	20.8		351	26.5	
Health Status						
No. of other eye disorders			<0.001			0.029
0	1481	20.6		1176	28.9	
1+	473	46.5		253	22.1	

Table 2 Average activity hours per day (mean ± SD) by age groups (Taiwan, 2009-2013)

Age groups	Computer/internet	Reading	Cram school
1. 7-8	0.41±0.64	0.65±0.71	2.29±3.49
2. 9-10	0.70±0.85	0.64±0.65	2.84±3.54
3. 11-12	0.86±0.96	0.60±0.66	3.10±3.50
Total sample	0.68±0.86	0.63±0.67	2.78±3.53
p-value[a]	<0.001	0.240	0.001

Table 3 Multivariable Logistic and Cox regression analyses for the effects of different types of close work on prevalent and incident myopia (Taiwan, 2009-2013)

Types of close work	Model 1 (n=1956) 2009 Prevalent myopia			Model 2 (n=1431) 2010-13 Incident myopia			Model 3 (n=1176) 2010-13 Incident myopia			Model 4 (n=1077) 2010-13 Incident myopia		
	ORs	95% CI	*P*-value	HRs	95% CI	*P*-value	HRs	95% CI	*P*-value	HRs	95% CI	*P*-value
Computer/internet/video game												
< 0.5 (hr/day)	1.00			1.00			1.00			1.00		
0.5-0.9	0.79	0.58-1.06	0.120	1.00	0.76-1.31	0.981	1.04	0.77-1.40	0.807	1.06	0.81-1.39	0.661
1+	1.05	0.78-1.40	0.761	1.14	0.89-1.48	0.306	1.24	0.95-1.63	0.114	1.12	0.87-1.43	0.381
Reading												
< 0.5 (hr/day)	1.00			1.00			1.00			1.00		
0.5-0.9	**1.50**	**1.13-1.99**	**0.006**	**1.30**	**1.01-1.67**	**0.045**	**1.32**	**1.01-1.74**	**0.045**	1.28	1.00-1.63	0.052
1+	**1.43**	**1.07-1.91**	**0.020**	1.07	0.82-1.40	0.637	1.05	0.79-1.41	0.734	1.10	0.85-1.42	0.480
Attending cram schools												
< 0.5 (hr/day)	1.00			1.00			1.00			1.00		
0.5-2.00	1.28	0.87-1.90	0.214	1.19	0.85-1.67	0.302	1.24	0.86-1.78	0.248	1.26	0.91-1.75	0.166
2.0+	**1.65**	**1.24-2.19**	**<0.001**	**1.31**	**1.03-1.68**	**0.030**	**1.46**	**1.12-1.89**	**0.005**	**1.35**	**1.07-1.71**	**0.013**

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Model 1: Covariates = age, parental educational levels, household income, urbanization, TV watching and outdoor leisure activities, and eye disorders (variables with p-values < 0.25 for incident myopia in Table 1)

Model 2: Covariates = age, parental educational levels, household income, and eye disorders (variables with p-values < 0.25 for incident myopia in Table 1)

Model 3: sensitivity analyses excluding eye diseases

Model 4: sensitivity analyses excluding eye diseases and using ICD367