

ONLINE FIRST PUBLICATION

Online first papers have undergone full scientific review and copyediting, but have not been typeset or proofread. To cite this article, use the DOI number provided. Mandatory typesetting and proofreading will commence with regular print and online publication of the online first papers of the *SMJ*.

School-based programme to address childhood myopia in Singapore

Vijaya Karuppiah¹, MBBS, MSc, Lilian Wong², MMed, Veronica Tay³, MBBS, MSc, Xiaojia Ge⁴, MSc, PhD, Lee Lin Kang⁵, BA, GradDip

¹Youth Preventive Service, ²School Health Service, ³Student Health Centre, ⁴Policy Research and Surveillance, National Registry of Diseases Office, ⁵Sectoral Workplace Outreach, Health Promotion Board, Singapore

Correspondence: Dr Vijaya Karuppiah, Director, Youth Preventive Service, Health Promotion Board, 3 Second Hospital Avenue, Singapore 168937. Vijaya_K@hpb.gov.sg

Singapore Med J 2019, 1–17

<https://doi.org/10.11622/smedj.2019144>

Published ahead of print: 4 November 2019

Online version can be found at
<http://www.smj.org.sg/online-first>

ABSTRACT

Myopia is a complex, multifactorial condition influenced by genetic and environmental factors. Singapore has one of the world's highest myopia rates. The National Myopia Prevention Programme was started in 2001 with the goal of delaying the onset and progression of myopia through public education and vision screening. Public education targeting children, youth and key stakeholders (parents and teachers) focused on increasing awareness of myopia and its complications, and good eye care habits. Regular school-based vision screening for early detection/management and monitoring of myopia prevalence found that from 2004 to 2015, myopia prevalence decreased from 37.7% to 31.6% among primary school students ($p < 0.05$). The decrease was the greatest between 2004 and 2007, from 37.7% to 32.3%, and was more stable thereafter at 31.6%–33.7%. Since age of onset and duration of progression are the most important predictors of high myopia in later childhood, it is encouraging that myopia prevalence has decreased among primary students.

Keywords: myopia, myopia risk factors, school-based vision screening

INTRODUCTION

In 2050, a total of 4,758 million people worldwide (49.8% of the world's population) are expected to be myopic, and 938 million people (9.8%) are expected to suffer from high myopia (myopia worse than -5.00D).⁽¹⁾ Myopia, commonly known as short-sightedness or near-sightedness, has remained one of the biggest public health challenges in Singapore, which has very high myopia rates. Myopia typically begins in early childhood and progresses during childhood.

Based on unpublished data from routine vision screening done by the School Health Service (SHS) using the Snellen chart, the prevalence of defective vision amounting to unaided visual acuity of 6/12 or worse among Primary 1 students was 33% in 2000, prior to the inception of the National Myopia Prevention Programme (NMPP). 65% of Singapore students suffered from myopia by the age of 12 years. Among these 12-year-old students, the prevalence of severe defective vision (i.e. unaided visual acuity worse than 6/60) was 13% (unpublished data).

Age of onset of myopia and duration of myopia progression are the most important predictors of high myopia in later childhood.⁽²⁾ Children with high myopia in the range of $\leq -5.0\text{D}$ to -10.0D ⁽³⁾ have higher risks of complications such as myopic macular degeneration,⁽⁴⁻⁶⁾ retinal detachment,⁽⁷⁾ glaucoma⁽⁸⁾ and blindness.⁽⁹⁾ There was concern that if such trends continued, more than 80% of the population would be suffering from myopia by adulthood, and among them, a high proportion would have high myopia.⁽¹⁰⁻¹³⁾ Given that Singapore has an ageing population, this would increase the burden on the healthcare system because of the greater need to provide treatment for myopia-related complications. As about 80% of male enlistees are myopic at the time of enlistment for National Service in Singapore, adjustments have to be made to accommodate the occupational demands of military duties, incurring

additional costs.^(11,14) The pool of candidates for National Service duties and military occupations that require good vision, such as pilots, would also be more limited.^(11,14)

NATIONAL MYOPIA PREVENTION PROGRAMME

To address the primary concern of high childhood myopia rates and the downstream public health concerns, the NMPP Steering Committee was formed in 2001. This committee comprised representatives from the Ministry of Education, Singapore Armed Forces, Ministry of Social and Family Development, National University of Singapore, Singapore Eye Research Institute, Optometrists and Opticians Board, Ministry of Health, and Singapore optometric and professional groups.⁽¹³⁾ To implement the scaled-up initiatives of the NMPP, the SHS employed a two-pronged approach to delay the onset and progression of myopia, consisting of public education to raise awareness and vision screening for early detection and management of myopia.

Public education

The following public education strategies were adopted: (a) targeted vision care education for children (kindergartens and primary schools) and youths (secondary schools), and for key stakeholders (parents and teachers) to facilitate an environment that promotes good eye care habits; (b) and the use of mass media to propagate the message of good eye care habits among the general public.

For years, vision care education in children and youth focused on reducing the duration of time spent on near work such as reading, writing and use of electronic devices. However, findings from the Singapore Cohort Study of the Risk Factors for Myopia revealed that outdoor activity could be protective against the development of myopia in children.⁽¹⁵⁾ This was further supported by findings from the Sydney Myopia Study presented at the 2006 International

Myopia Conference, which found that the only significant difference between myopic seven-year-old Singapore Chinese children and those of Chinese ethnicity in Sydney was the amount of time spent outdoors.⁽¹⁶⁾ Children in Sydney spent about four times as much time outdoors than Singapore children and spent less or hardly any time on tuition.⁽¹⁶⁾

Hence, outdoor activities became a key strategy in messages on good eye care habits to delay the onset of and prevent myopia among children, besides the continued efforts on reducing screen time. The promotion of outdoor activities has the secondary benefit of promoting overall health and wellbeing. Various age-appropriate, fun activities were developed and conducted for children to help convey these vision care messages: dramas, jingles, dance, and a mobile 'health lifestyle' bus. The NMPP even had a mascot called 'Captain Eye' whose function was to trigger recall of good eye care messages. Since that time, other studies have been published showing that additional time spent outdoors was associated with a reduced incidence of myopia among certain age groups.⁽¹⁷⁾

To educate teachers and parents, who play a critical role in creating a supportive environment for good eye care habits in school and at home, several programmes were introduced. In the early years of this initiative, training programmes that provided a more in-depth understanding of myopia were conducted for teachers. Subsequently, activities and resources were customised for children of different age groups, including activity cards for primary school students that could be used as a teaching aid. Teachers were also encouraged to motivate students to come up with their own creative ideas and activities to promote good eye care habits among their peers, which would earn them points towards getting a 'Captain Eye' badge for themselves. Teachers could thus save time in creating new activities, while students were empowered to take the lead in taking care of themselves.

To reach parents and families, school-based group counselling sessions were held. Seminars aimed to promote good eye care habits at home were organised for parents with

preschoolers and primary school-going children through a school-cluster approach to reach as many parents as possible. In Singapore, schools within the same vicinity (usually about ten schools) are grouped as a cluster to facilitate sharing of information and programmes, and for support under the Ministry of Education. Public forums were also organised regularly to help parents and families understand myopia, including the risks of complications, and provide tips on how to inculcate good eye care habits in their children.

The message was widely promoted to the general public through the mass media, including television commercials, the radio and popular parents' magazines. Information on childhood myopia was also readily available on the website of the Health Promotion Board, Singapore.

Vision screening

Routine vision screening is a key strategy in early detection and intervention of myopia. Long before the inception of the NMPP, vision screening was already part of SHS' school-based services⁽¹⁸⁾ for all primary and secondary students. In the 1950s, primary school entrants were practically free from defective vision.⁽¹⁹⁾ However, in the post-independence years (i.e. after 1965), an increase was seen in the number of children with defective vision. In 1988, 16% of Primary 1 and 50% of Primary 6 children had visual acuity of 6/12 or worse.⁽²⁰⁾ By 1996, 24.5% of Primary 1 and 60.4% of Primary 6 children had visual acuity of 6/12 or worse.⁽²⁰⁾

Since that time, vision screening has continued to be conducted annually in all schools. Following the inception of the NMPP, between 2002 and 2003, the scope for vision screening of the SHS was further expanded to include about 80,000 preschool children as young as five years of age. Preschool students and Primary 1 students who were found to have defective vision on routine screening were referred to Refraction Clinics (RCs) at the Student Health Centre, Health Promotion Board, for further assessment. Cycloplegic refraction was also made

available for students who required it, for more effective assessment of their vision at the RCs. Following assessment, children who required glasses were given a prescription to purchase spectacles at optical shops in the community. Children detected or suspected to have severe myopia, amblyopia or other eye conditions such as squint and ptosis were referred to paediatric ophthalmologists at one of the public hospitals or to an ophthalmologist in private practice, as chosen by the parents (Fig. 1). Students at higher educational levels were referred to optometrists in the community for further vision assessment and correction with spectacles. To ensure that students from poorer socioeconomic backgrounds were not deprived of necessary vision correction, through the NMPP, the Spectacles Voucher Fund⁽²¹⁾ was launched. These students would receive a SGD 50 voucher for spectacle frames, and their spectacle lenses were provided free of charge by a sponsoring partner.

REVIEW OF NMPP-LED SCHOOL-BASED VISION SCREENING (2004–2015)

To understand how the programme was doing in its goal of reducing childhood myopia rates, myopia prevalence rates were determined for the years 2004 to 2015 for 12 sentinel primary schools and 12 sentinel secondary schools, in which lensometer readings from spectacles were taken during routine school-based vision screening. Lensometer readings were used as a surrogate for myopia, which was defined as a spherical equivalent greater than 0.5 dioptres. Children who were wearing contact lenses in either eye were also included in the analysis. To ensure adequate representation of students across the country, 12 primary and 12 secondary schools were selected according to the school zone to which they belonged (north, south, east or west) and school type (co-ed or single-gender school). De-identified data from approximately 20,000 primary school and 15,000 secondary school students each year between 2004 and 2015 were included in this analysis. Statistical significance of trends was examined by fitting a linear regression line to the natural logarithm of the myopia prevalence, with year

as the variable. A p -value < 0.05 was considered statistically significant. Confidence intervals (CIs) were reported for annual percentage change (APC) where relevant. APC was calculated as the exponential of $(\text{coefficient} - 1) \times 100\%$. Statistical analysis was performed using Stata 13.1 software (StataCorp, College Station, TX, USA).

The prevalence of myopia among students from the 12 sentinel primary schools decreased from 37.7% to 31.6% between 2004 and 2015 ($p < 0.05$; 95% CI -1.7% , -0.6%) (Fig. 2). The decrease in prevalence was greatest between 2004 and 2007, from 37.7% to 32.3%. Thereafter, the prevalence was more stable, ranging between 31.6% and 33.7%. Prevalence rates were observed according to educational level (Fig. 3a). This revealed a downward trend among Primary 3 ($p < 0.05$; 95% CI -3.1% , -0.5%), Primary 4 ($p < 0.05$; 95% CI -2.1% , -0.8%), Primary 5 ($p < 0.05$; 95% CI -1.7% , -0.8%) and Primary 6 students ($p < 0.05$; 95% CI -0.7% , -0.3%). When stratified by gender, the downward trend in prevalence rates was maintained, with higher myopia rates among female students ($p < 0.05$; APC -1.3% , 95% CI $[-2.0\%$, $-0.7\%]$) when compared to male students ($p < 0.05$; APC -1.0% , 95% CI $[-1.5\%$, $-0.4\%]$), except in 2015, when rates among male students were higher for the first time (Fig. 3b). When stratified by the three main ethnic groups in Singapore, the same downward trend was also observed among Chinese ($p < 0.05$; APC -1.0% , 95% CI $[-1.7\%$, $-0.4\%]$), Malay ($p < 0.05$; APC -1.8% , 95% CI $[-2.5\%$, $-1.2\%]$) and Indian ($p < 0.05$; APC -1.3% , 95% CI $[-1.9\%$, $-0.7\%]$) students, with the highest rates among the Chinese (Fig. 3c). A stable trend was observed among Primary 1 ($p > 0.05$) and Primary 2 ($p > 0.05$) students.

The increase in myopia prevalence, from 61.7% to 65.5%, among students from the 12 sentinel secondary schools was not statistically significant ($p = 0.15$; APC 0.2% , 95% CI $[-0.1\%$, $0.5\%]$) (Fig. 2). This trend was observed within each educational level except for Secondary 4, where the upward trend was statistically significant ($p < 0.05$; APC 0.5% , 95% CI $[0.2\%$, $0.8\%]$) (Fig. 4a). When stratified by gender, this upward trend was maintained and

was not statistically significant, with consistently higher rates of myopia among female students when compared to male students (Fig. 4b). When stratified by the three main ethnic groups, the same trend was observed, except among the Malay students, for whom the upward trend was statistically significant ($p < 0.05$; CI for APC 1.1% [0.7%, 1.5%]); the highest rates were similarly observed among the Chinese (Fig. 4c).

DISCUSSION

Among the potential environmental and behavioural risk factors for myopia and myopia progression, the following are most commonly reported to be lacking: exposure to green spaces, exposure to natural daylight, outdoor time and physical activity, together with an excess of near-work activities in children. In a recent meta-analysis, increased time outdoors was shown to be effective in preventing the onset of myopia and in slowing the myopic shift in refractive errors; however, it was not shown to be effective in slowing progression in eyes that were already myopic.⁽²¹⁾ More specifically, increase in exposure to green spaces at home, at school and during commuting was associated with a decrease in spectacles use among primary school students in Spain.⁽²²⁾ Increase in time playing in green spaces was associated with a reduction in the risk of spectacles use in longitudinal analysis.⁽²²⁾ Lack of daylight exposure, specifically, has been shown to lead to myopia progression.^(23,24) Sporting activity was shown to be preventive against myopia progression, while near work and computer work could be a risk factor for myopia progression if children spent at least three hours a day on these outside of school-related work.⁽²²⁾

Among primary school students, female students were found to have higher rates of myopia in each year except for 2015, when rates among male students were higher for the first time (Fig. 3b). This trend was also observed among secondary school students (Fig. 4b). However, the association of gender with myopia remains a controversial one. No gender

differences were found in the Beaver Dam Eye Study, a 15-year cohort study on macular degeneration.⁽²⁵⁾ In a local study, a significant correlation was found between onset of puberty and the age of peak axial length velocity in boys and girls. Thus, the apparent faster progression of myopia observed in girls may be related to their earlier onset of puberty.⁽²⁶⁾

We found that Chinese students in Singapore had the highest rates of myopia. Similarly, Rudnicka et al reported in 2016 that East Asians had the highest prevalence of myopia, reaching 69.0% at 15 years of age (vs. 86.2% among Singaporean Chinese). Blacks in Africa had the lowest prevalence of 5.5% at 15 years of age.⁽²⁷⁾ Time trends in myopia prevalence over the last decade were weak in whites but increased by 23% in East Asians, with a smaller increase among South Asians.⁽²⁷⁾

An overall downward trend in myopia prevalence was observed between 2004 and 2015 among primary school students from the 12 sentinel schools; however, no decrease in prevalence rates was seen among the corresponding secondary school students (Fig. 2). It is possible that the prevalence of myopia did not decrease among secondary school students because the secondary school curriculum intensifies in preparation for major entrance exams for tertiary studies; hence, students spend less time outdoors, in green spaces and on sporting activities but spend more time on prolonged near work and computer work. In a Taiwanese study, among myopic children, students in higher school years had more myopic progression.⁽²⁸⁾ This was thought to result from Taiwan's educational system placing greater academic stress on students of higher school years.⁽²⁸⁾ A Chinese study also showed a higher prevalence of myopia in students of higher school years, and that older students spent significantly more time on near work and less time on outdoor activity.⁽²⁹⁾

Nevertheless, because age of myopia onset and duration of myopia progression are the most important predictors of high myopia in later childhood in myopic children,⁽²⁾ it is encouraging that myopia prevalence has decreased among primary school students.

Furthermore, the students from the 12 sentinel primary schools had the same routine school-based vision screening and NMPP-driven targeted vision care education, and received the same interventions when needed as students at other primary schools, making it reasonable to generalise that myopia prevalence has decreased among primary school students in Singapore. The additional step of obtaining lensometer readings for children wearing spectacles is not expected to change the behaviour of primary school students during routine screening in a way that affects the degree of myopia.

As with similar analyses involving data obtained during routine screening without a control group, the improvement in myopia prevalence cannot be definitively attributed to the SHS initiatives alone. Yet the pervasive nature of the school programmes and public education using mass media did not make it practically possible to have a control group. It would also have been unethical to exclude young children from vision screening, which is a basic component of child health programmes across most middle-income and higher-income countries. Data from this sentinel population of students remains critically useful for reliable quantification of the prevalence of the problem of myopia among children and youths and allows for ongoing and new public health interventions to be fine-tuned and introduced, respectively.

In conjunction with public health programmes, a locally developed mobile application called 'plano' has been developed to manage the use of smartphones and tablets among children, and can be another fun and innovative way to institute good eye care habits. The application can be installed in a handheld device and runs in the background, tracking face-to-screen distance, screen time, device-free activities and even poor posture. All these basic functions are available for free, with additional plans available for a fee. The child is incentivised to adopt the right habits through points and rewarded with outdoor activity, which has been shown to be protective against myopia. With the rapidly growing reliance on

smartphones and tablets in learning and day-to-day living in Singapore, this is an especially practical additional approach.

CONCLUSION

Myopia is a complex, multifactorial condition influenced by both genetic and environmental factors. By 2050, almost half of the world's population is expected to be myopic. This paper aimed to elucidate the public health steps taken in Singapore to combat this problem, report on the myopia prevalence rates between 2004 and 2015 among students in Singapore, and discuss the environmental factors that can potentially be modified through public health programmes. More studies are necessary to further our understanding of the causes of myopia.

ACKNOWLEDGEMENTS

We would like to acknowledge Prof Saw Seang Mei and her research fellow, Carla Lanca, from the Saw Swee Hock School of Public Health, National University of Singapore, Singapore, for assisting in the literature search.

REFERENCES

1. Holden BA, Fricke TR, Wilson DA, et al. Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050. *Ophthalmology* 2016; 123:1036-42.
2. Chua SY, Sabanayagam C, Cheung YB, et al. Age of onset of myopia predicts risk of high myopia in later childhood in myopic Singapore children. *Ophthalmic Physiol Opt* 2016; 36:388-94.
3. Morgan IG, Ohno-Matsui K, Saw SM. Myopia. *Lancet* 2012; 379:1739-48.
4. Curtin BJ. *The Myopias: Basic Science and Clinical Management*. Philadelphia: Harper and Row, 1985.

5. Ito-Ohara M, Seko Y, Morita H, Imagawa N, Tokoro T. Clinical course of newly developed or progressive patchy chorioretinal atrophy in pathological myopia. *Ophthalmologica* 1998; 212:23-9.
6. Avila MP, Weiter JJ, Jalkh AE, et al. Natural history of choroidal neovascularization in degenerative myopia. *Ophthalmology* 1984; 91:1573-81.
7. Pierro L, Camesasca FI, Mischi M, Brancato R. Peripheral retinal changes and axial myopia. *Retina* 1992; 12:12-7.
8. Mitchell P, Hourihan F, Sandbach J, Wang JJ. The relationship between glaucoma and myopia: the Blue Mountains Eye Study. *Ophthalmology* 1999; 106:2010-5.
9. See JL, Wong TY, Yeo KT. Trends in the pattern of blindness and major ocular diseases in Singapore and Asia. *Ann Acad Med Singapore* 1998; 27:540-6.
10. Au Eong KG, Tay TH, Lim MK. Race, culture and myopia in 110,236 young Singaporean males. *Singapore Med J* 1993; 34:29-32.
11. Wu HM, Yap EPH, Seet B, et al. Report on the study of myopia and its impact in a cohort of Singapore Armed Forces enlistees. Singapore: Defence Medical Research Institute, 1998.
12. Chew SJ, Chia SC, Lee LK. The pattern of myopia in young Singaporean men. *Singapore Med J* 1988; 29:201-11.
13. Seet B, Wong TY, Tan DT, et al. Myopia in Singapore: taking a public health approach. *Br J Ophthalmol* 2001; 85:521-6.
14. Rabin J. Correction of subtle refractive error in aviators. *Aviat Space Environ Med* 1996; 67:161-4.
15. Saw SM, Hong CY, Chia KS, Stone RA, Tan D. Nearwork and myopia in young children. *Lancet* 2001; 357:390.

16. Rose KA, Morgan IG, et al. Myopia, lifestyle, and schooling in students of Chinese ethnicity in Singapore and Sydney. *Arch Ophthalmol* 2008; 126:527-30.
17. Shah RL, Huang Y, Guggenheim JA, Williams C. Time outdoors at specific ages during early childhood and the risk of incident myopia. *Invest Ophthalmol Vis Sci* 2017; 58:1158-66.
18. Ministry of Health, Singapore. History of School Service in Singapore (Part 1): The Singapore Community Health Bulletin (No. 19-26). Singapore: Ministry of Health, 1928-1986.
19. Chew L, Vaithinathan R. Historical Overview of Eye Care by the School Health Service. In: Au Eong KG, Chew RYK, Yeo ACH et al, eds. *Primary Eye Care in Singapore: Looking Back, Looking Forward*. Singapore: Sight & Eye International, 2008.
20. School Health Service, Health Promotion Board. *School Health Service Annual Reports*. Singapore: School Health Service, 1986-1988, 1996.
21. Xiong S, Sankaridurg P, Naduvilath T, et al. Time spent in outdoor activities in relation to myopia prevention and control: a meta-analysis and systematic review. *Acta Ophthalmol* 2017; 95:551-66.
22. Dadvand P, Sunyer J, Alvarez-Pedrerol M, et al. Green spaces and spectacles use in schoolchildren in Barcelona. *Environ Res* 2017; 152:256-62.
23. Rusnak S, Salcman V, Hecova L, Kasl Z. Myopia progression risk: seasonal and lifestyle variations in axial length growth in Czech children. *J Ophthalmol* 2018; 2018:5076454.
24. Donovan L, Sankaridurg P, Ho A, et al. Myopia progression in Chinese children is slower in summer than in winter. *Optom Vis Sci* 2012; 89:1196-202.
25. Klein R, Klein BE, Knudtson MD, et al. Fifteen-year cumulative incidence of age-related macular degeneration: the Beaver Dam Eye Study. *Ophthalmology* 2007; 114:253-62.

26. Yip VC, Lin XY, Lee YS, et al. The effect of puberty on myopia in Singapore children. *Invest Ophthalmol Vis Sci* 2011; 52:3055.
27. Rudnicka AR, Kapetanakis VV, Wathern AK, et al. Global variations and time trends in the prevalence of childhood myopia, a systematic review and quantitative meta-analysis: implications for aetiology and early prevention. *Br J Ophthalmol* 2016; 100:882-90.
28. Wu PC, Tsai CL, Wu HL, Yang YH, Kuo HK. Outdoor activity during class recess reduces myopia onset and progression in school children. *Ophthalmology* 2013; 120:1080-5.
29. Sun JT, An M, Yan XB, Li GH, Wang DB. Prevalence and related factors for myopia in school-aged children in Qingdao. *J Ophthalmol* 2018; 2018:9781987.

FIGURES

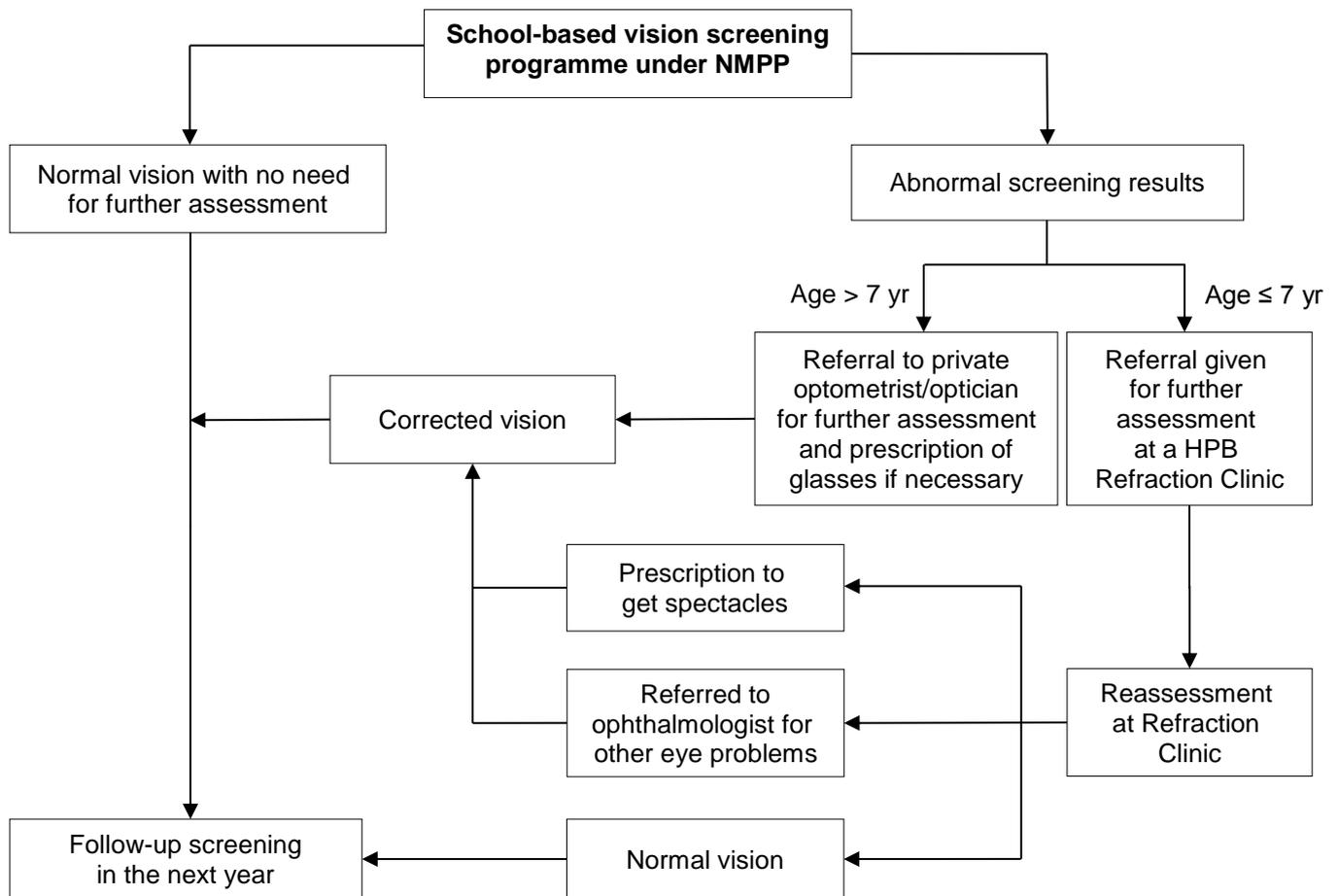


Fig. 1 Flowchart shows the selection process for vision screening services for schoolchildren. HPB: Health Promotion Board, Singapore; NMPP: National Myopia Prevention Programme

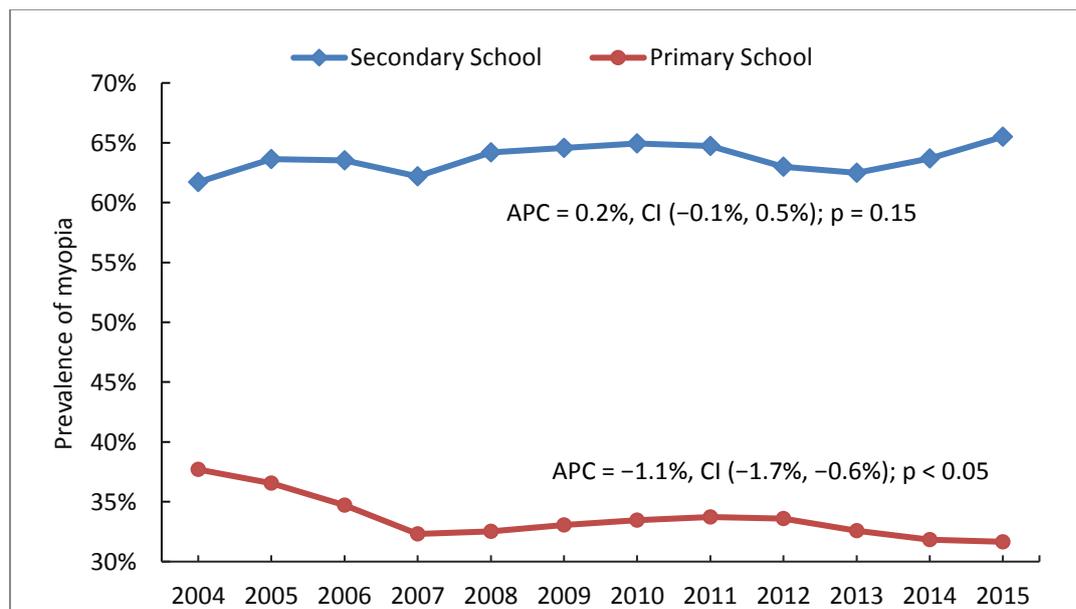


Fig. 2 Chart shows the prevalence rate of myopia among primary and secondary school students. APC: annual percentage change; CI: confidence interval

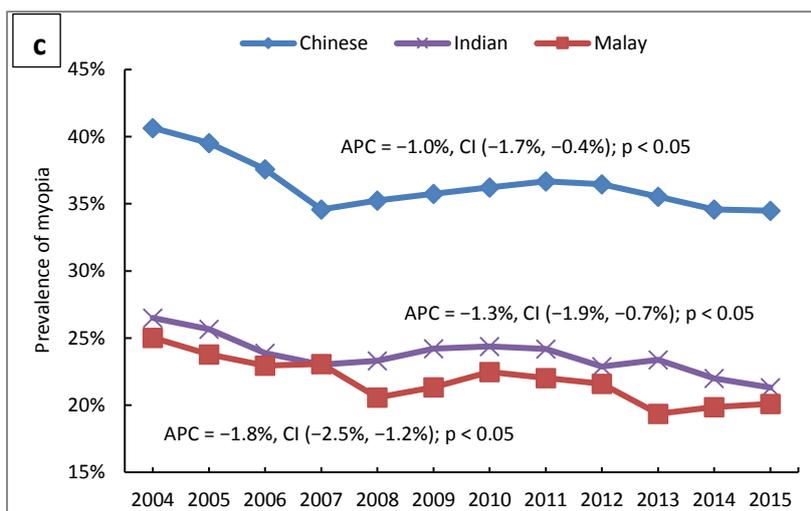
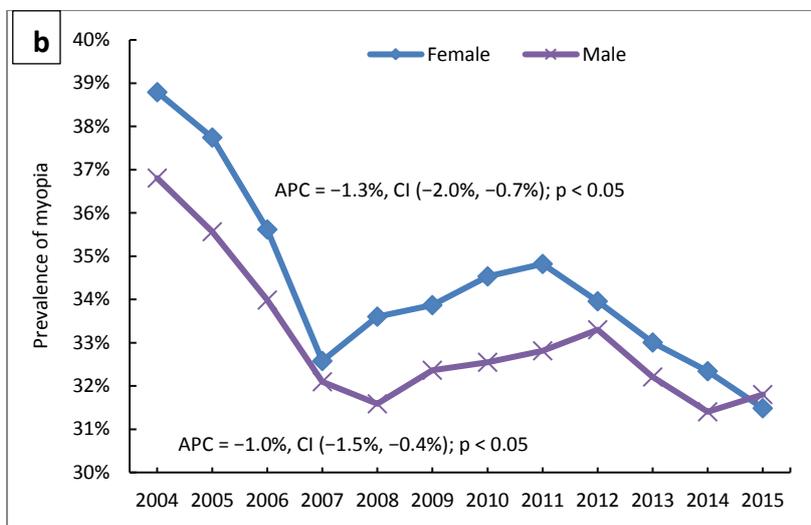
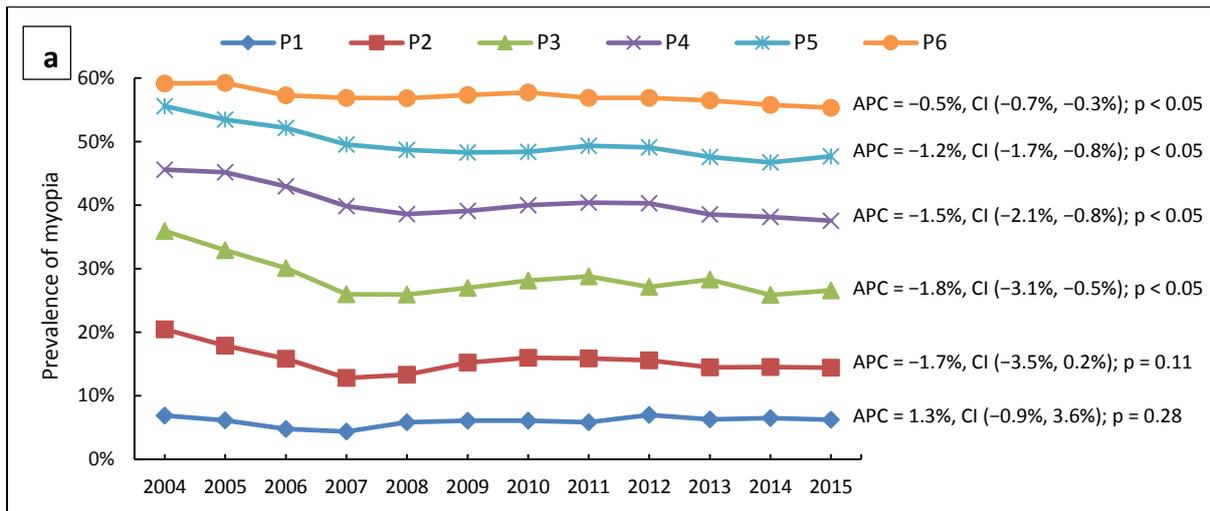


Fig. 3 Charts show the prevalence rate of myopia among primary school students by (a) educational level; (b) gender; and (c) ethnicity. APC: annual percentage change; CI: confidence interval; P: primary

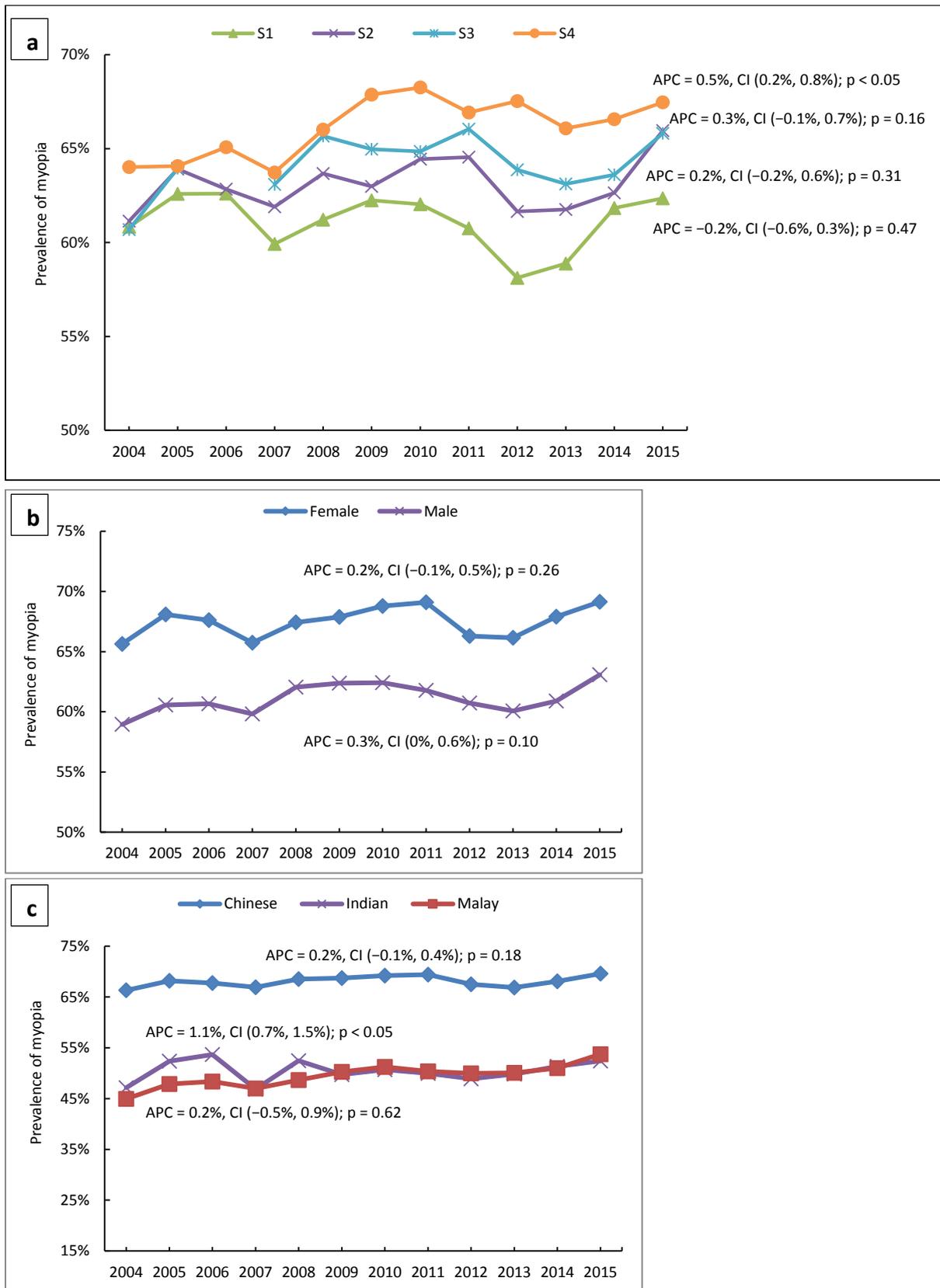


Fig. 4 Charts show the prevalence rate of myopia among secondary school students by (a) educational level; (b) gender; and (c) ethnicity. APC: annual percentage change; CI: confidence interval; S: secondary