Myopia in Singapore: taking a public health approach

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Myopia is a problem of public health concern in Singapore for three reasons. Firstly, the prevalence of myopia (more than −0.5 dioptres (D)) is one of the highest worldwide. Twenty per cent of Singapore children are myopic at 7 years at the start of their primary education,[1] with prevalence exceeding 70% upon completing college education.[2–4] Other population based studies showed myopia prevalence of 15% in preschool 4 year old children,[5] 80% in military conscripts,[6] and nearly 40% in adult Chinese aged 40 and older.[7] This is 1.5–3 times higher than similarly aged white or black populations in the United States,[8–10] and elsewhere.[11 12]

Secondly, a large proportion of Singaporeans has high myopia (more than −6.0 D), which has been observed across the whole age spectrum.[1 6 7] While the prevalence of high myopia is less than 2% in most Western populations,[10 11] approximately 10% of Singapore adults have the condition.[6 7]

Thirdly, available data suggest that both prevalence and severity of myopia have increased significantly over the past two decades. Based on serial cross sectional data from the Singapore Armed Forces, myopia prevalence in military conscripts has increased from 26% in the late 1970s, to 43% in the 1980s, 66% in the mid 1990s, and 83% by the late 1990s.[6 13 14] This is accompanied by a twofold rise in the proportion with myopia worse than −8 D, from 2% to 4% between 1993 and 1997.[4] A similar trend of increasing myopia prevalence has been observed in schoolchildren.[1 15]

The underlying explanation for high myopia prevalence and severity in Singapore is not well understood. Available data suggest that this phenomenon is not unique to Singapore. A high prevalence of myopia has also been described in other east Asian urban populations in Taiwan, Hong Kong, and Japan.[16–20] In Taiwan, a substantial increase in the prevalence of myopia in schoolchildren has similarly been observed over the past few decades,[16 17] although in Japan, the rates may have tapered somewhat.[8 19 20] Furthermore, sociodemographic risk factors for myopia in these populations appear to be similar to those reported in the West, and include higher education, higher income, and occupations associated with near work activities.[6–8] It is therefore likely that complex and multiple factors, both genetic and environmental, are involved.

In this paper, we systematically examine the impact of myopia in Singapore, propose a model to explain its high prevalence in the population, and outline a strategy for myopia control.

Defining the impact of myopia in Singapore

THE MEDICAL PERSPECTIVE

There is concern that blindness from myopia will become a substantial public health problem in the near future. With an ageing population (more than one third of Singaporeans will be older than 50 years by 2025[21]), and a rising trend of myopia prevalence and severity,[4 13 14] it has been projected that more than 80% of the entire adult population could be myopic within two to three decades, with a significant proportion having high myopia. Although low and moderate myopia appears to be more benign, high myopia may be associated with posterior vitreous detachment,[22] myopic macular degeneration,[23–25] peripheral retinal breaks, degeneration and retinal detachment,[26] and possibly glaucoma[27] and reduced contrast sensitivity.[28 29]

Nevertheless, the potential impact of myopia on blindness rates in the population is not clear. Data from blindness registry paint a gloomy picture, but are subjected to many sources of bias (for example, low participation rate, inaccuracies in diagnosis). For example, in Germany, which has relatively low myopia prevalence, 12–17% of blindness is reportedly attributed to high myopia.[30] In Denmark, 5% of registered blindness is related to myopia.[31] Similarly, in Singapore, blindness registry data indicate that myopia is the fourth leading cause of blindness.[32] However, population based prevalence survey data in the United States suggest that myopia is not a leading cause of either visual impairment[33] or blindness[34] in adults, although the rates of myopia are lower in the US population.[10] Thus, the full medical implications of a high myopia prevalence in Singapore are not known at this time.

THE PUBLIC PERSPECTIVE

Historically, the Singapore public did not perceive myopia as a serious problem. There were no associated social stigmata, while the wearing of spectacles may even be regarded as a norm in most Singapore schools. Ocular complications affected only a small proportion of individuals with severe myopia, with the majority experiencing little or no vision related problems. However, this attitude may be changing. Parents have been more vocal in expressing concern about the early onset of myopia in children,[35] while many are seeking a "quick fix" to myopia prevention.[36 37] Greater media attention on myopia has

increased political awareness, which has led to sustained research funding for myopia in Singapore.

THE EDUCATION PERSPECTIVE

The high myopia prevalence among Singapore schoolchildren is a particular problem.[1 38] The consistently strong evidence of an association between myopia and education[7–12] has raised concerns that the rapid rise in myopia prevalence may be related to higher educational attainment among Singaporeans.[2 6 39] However, whether myopia is related to education or to other socioeconomic factors (for example, urbanisation) is still unclear. For example, in a study of comparable schoolchildren aged 7–8 years, the myopia rate in Singapore Chinese (many originating from south China) was higher than in the city of Xiamen in south China.[40]

THE MILITARY PERSPECTIVE

National military service is required for all Singapore men. From the military perspective, myopia is important for various reasons. Firstly, correction with spectacles or contact lenses may be incompatible with the stringent occupational demands of many military vocations.[41] Spectacles cause interface problems with binoculars, night vision devices, protective masks, and other head mounted instruments. Determining a refractive error cut off for personnel selection has therefore been problematic, with conflicting requirements of meeting recruitment levels and maintaining high visual standards as a selection criterion.[42] At the Republic of Singapore Air Force, almost 20% of military pilot applicants are rejected based solely on refractive status.[43] Secondly, spectacle replacement presents a logistic problem in military field operations. For example, there is need for updated and customised refraction records of all myopic soldiers, and constant availability of optometry services.[41] Finally, there is a perception that myopia affects performance in visually demanding tasks like military aviation and marksmanship, although this remains unproved. Decreased contrast sensitivity at high spatial frequencies has been reported with increasing myopia severity,[28 29] and lower contrast sensitivity is associated with impaired perception of "real world targets,"[44] poorer flight performance in aircraft simulators,[45] and deficits in visual-spatial attention.[46] Few data on the direct association between myopia and military performance exist. Available studies have not found an association between myopia and shooting performance or military aviation.[47 48] A similar project in the Singapore military failed to detect significant differences in marksmanship scores between myopic and emmetropic soldiers (B Seet, unpublished data, 1999).

THE ECONOMIC PERSPECTIVE

In Singapore, direct costs related to the correction of myopia, including refractive eyewear and surgery, is expected to increase. In 1998, there were 816 optical outlets in Singapore, or one outlet for every 3800 people.[21] It has been estimated that myopic Singaporeans spend $US90 million annually on spectacles alone.[21] Refractive surgery has become increasingly popular in Singapore, with the number of excimer laser machines increasing from one in 1992 to eight in 2000. Refractive surgery is now the second most common procedure after cataract surgery, performed at a cost of about $3 million annually.[49]

There are also indirect costs related to treatment of myopia related complications, estimated at $2–2.5 million annually. About 300 retinal detachments are operated on each year (although not all are attributable to myopia),[50] and about 800 contact lens complications, including 80 cases of severe corneal ulcers, are treated at public hospitals (DTH Tan, unpublished data, 2000). In fact, contact lens wear is the main risk factor for corneal ulcers in Singapore.[51] Additional indirect costs are incurred by ongoing myopia research in Singapore, estimated to be $2–3 million annually.[52] Thus, there is a strong economic incentive to find an effective solution to myopia in Singapore.

Determinants of high myopia prevalence in Singapore

Despite extensive research, the aetiology remains unknown. It is discussed in detail elsewhere.[8 53–55] In this paper, we offer a three tier model of potential determinants of the high myopia prevalence in Singapore (Fig 1), based on a public health approach. This model forms the basis for several myopia intervention strategies described in the next section.

PROXIMAL FACTORS: GENETICS AND MOLECULAR BIOLOGY OF MYOPIA

Myopia has been postulated to arise from an underlying genetic predisposition that makes the eye more susceptible to environmental modification of its growth.[56 57] The relative contribution of genes (nature) versus environment (nurture) has been the subject of intense debate, and is probably complex.[54–56] For example, the high prevalence of myopia in Singapore and east Asia, compared with similarly aged white and black populations in other countries, may be related to ethnic variations in either genetic or environmental exposures.[58] However, several lines of evidence point to a strong genetic role. Variation in genetic exposure has been suggested as explaining differences in education adjusted myopia prevalence between young adult Chinese, Indians, and Malays in Singapore.[6 14] In Singapore military conscripts, there is a strong association of myopia and parental history of myopia (odds ratio of 3.6 for myopia, 5.2 for high myopia), as well as sibling history of myopia (odds ratio of 8.6 for myopia, 14.4 for high myopia).[4] In other east Asian populations, data from twin studies show significantly greater intrapair variance in refractive error among dizygotic compared with monozygotic twins.[59 60] Data from the

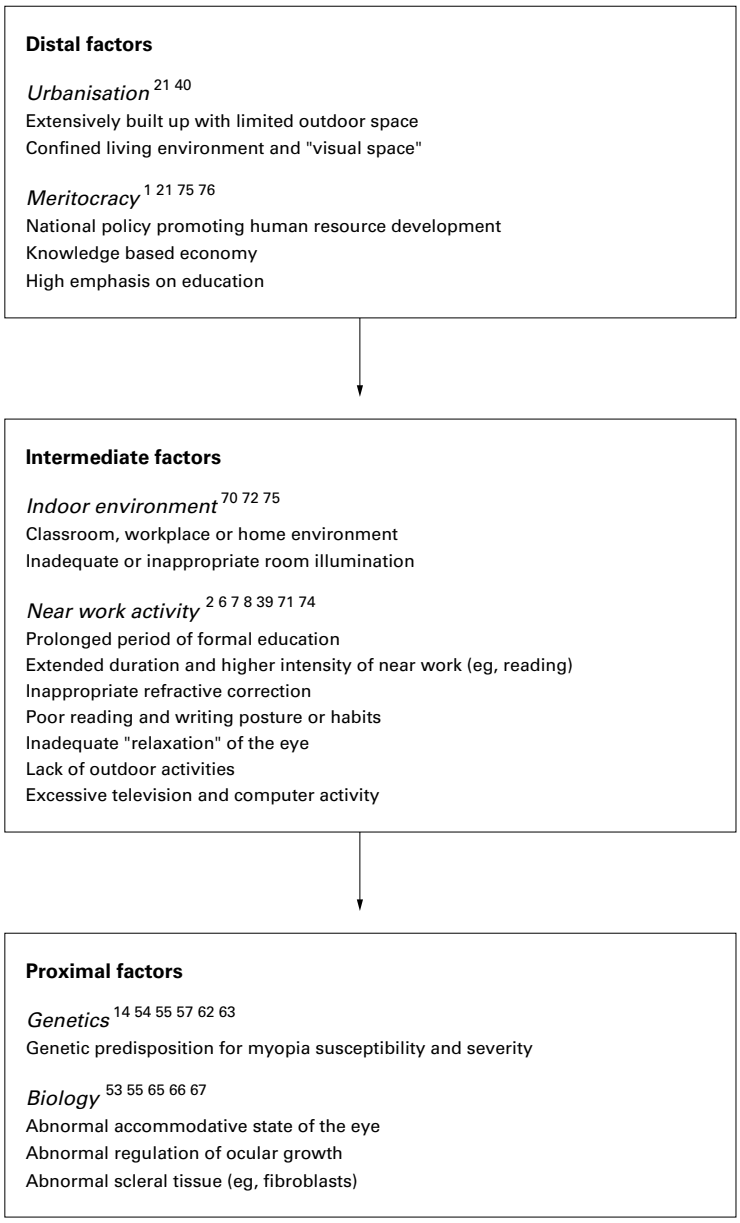

Figure 1 Possible determinants of high myopia prevalence and severity in Singapore.

Orinda LongitudinalStudy of Myopia suggested that parental history of myopia explained significantly more variance in the children's refractive error and ocular biometric components than near work activity.[61] At the molecular level, genetic loci for certain pathological variants of myopia have been localised.[62 63] Preliminary studies in Singapore are currently conducted to identify candidate genes for myopia.[64]

Nevertheless, the pathogenic pathways for myopia outcome are not clear. Some experimental studies suggest that myopia develops from failure of either the input or output components of the "active" visual feedback mechanisms that regulate eye growth.[55] For example, degrading the retinal images of animal models (input failure) has been shown to accelerate eye growth and myopia.[65] Several chemical modulators have also been suggested as having important molecular roles in the causation of myopia.[66 67]

INTERMEDIATE FACTORS: ENVIRONMENT RISK FACTORS FOR MYOPIA

In support of the "environmental" contribution of myopia, studies have shown earlier age of myopia onset in similar populations over time[17 20]; higher myopia prevalence in younger compared with older cohorts[18 68]; and weaker sibling association with myopia with increasing sibling age difference.[68] In east Asia, increasing prevalence of myopia has been attributed to changing "environmental" conditions over the past three generations.[69] Some of these factors in Singapore include having higher education,[2 6 7 39] near work related occupations,[7 70] and greater family income.[7] However, the exact relation between near work activity and development or progression of myopia remains to be established,[71] partly because quantification of near work is problematic.[55 72 73 74]

DISTAL FACTORS: SOCIETAL INFLUENCE ON MYOPIA

Largely ignored, distal factors may also be important in determining the rate of myopia in a given population. Singapore is an urban city state with a population of 3.8 million and a population density of almost 15 000 per square mile.[21] Ninety per cent of the population live in high rise apartments less than 1300 square feet in area, with a household average of 2.5 people per room.[21] The people lead primarily indoor lifestyles, owing to the relative lack of large open public spaces. However, although similar trends in myopia rates are seen in Taiwan, a large proportion of their population does not live in such conditions. Thus, whether the macroenvironment plays an important part in influencing the visual cues in developing eyes remains unclear.[54]

In addition, Singapore has also been described as a highly competitive society, with great emphasis placed on educational achievements in determining career choices and advancement. This is evident in public policies that have focused on developing the human resource to serve a knowledge based economy.[75 76] Societal trends over the past three decades include the early "streaming" of schoolchildren within the education system; the increasing proportion of Singaporeans, particularly females, attaining higher education; and the increasing participation of females in wage earning employment.[21] Similar social changes are seen in other countries like Taiwan, Hong Kong, and Japan. It is also possible that some of these factors are important in explaining the high myopia prevalence in east Asia.

Approach to myopia control in Singapore

Since the increasing prevalence of myopia was noted in the late 1980s, various agencies, including the ministry of health, school health services, and ministry of defence, have raised concerns about the condition.[1 4 13 38] However, early efforts to control myopia were largely institution based, lacking the mandate and

resources to manage the problem at the national level. This led to the formation of a multiagency National Committee on Myopia in the late 1990s, with objectives to formulate strategies to prevent and control myopia, as well as to centrally plan myopia research in Singapore. Such a committee ensures focus, integration, and sustainability of local efforts to manage the myopia problem. Increased public concern has also been critical in determining political interest and funding for myopia research.

THE VISION CARE PROGRAMME

There are presently a number of options for myopia prevention and control.[8 77] Many of these are directed at *proximal* factors, including topical eyedrops like atropine,[78] optical lenses,[79 80] rigid contact lenses,[81] intraocular pressure lowering agents,[82] biofeedback methods,[83] and traditional techniques like Chinese "eye relaxation" exercises.[84] However, the effectiveness of some of these methods is questionable, and there is inadequate scientific evidence for implementation in a population setting. Many clinical trials lacked randomisation, had high dropout rates, or failed to account for confounding.[8] On the other hand, it is difficult to prescribe interventions to reduce exposure to either *intermediate* or *distal* factors like education, near work, and living conditions.

In the absence of definitive interventions, a broad "vision care programme" was initiated in Singapore schools.[85] This is largely based on existing evidence that prolonged near work (and possibly poor visual environment) may contribute to myopia onset and progression, and on the hypothesis that relieving eye strain and promoting visual health will have beneficial effects. This programme comprises annual vision screening in schoolchildren, appropriate refractive correction, "eye relaxation" techniques, promotion of outdoor activities, and guidelines on classroom materials and illumination. An emphasis is placed on educating schoolchildren, parents, and teachers on general eye care, good reading habits, and myopia. The next phase of the programme is to combine these with clinical trials involving pharmacological and optical interventions,[78–81] or even controversial techniques like "eye relaxation" exercises.[84] This programme is intended to evolve as our knowledge of myopia increases.

PUBLIC EDUCATION AND CLINICAL PRACTICE GUIDELINES

The inconsistent results of current myopia treatment have generated confusion in an anxious population. The ministry of health has made efforts to conduct regular public forums, health fairs, and community based eye screening programmes in Singapore. To prevent excessive use and abuse of putative myopia treatment modalities, clinical practice guidelines are also issued to establish clear indications and limitations of contact lens[86] and laser refractive surgery,[87] in the management of myopia.

MYOPIA RESEARCH IN SINGAPORE

The goal of myopia research in Singapore lies in developing "practical" approaches that will ultimately modify the biological course of the condition, ideally to prevent the onset of myopia altogether. In line with this, basic science research is directed towards identifying genetic markers of myopia,[64] understanding cellular pathways of emmetropisation,[88] and developing animal models for clinical trials. Clinical research is centred on randomised trials to prevent or slow myopia progression (topical eye drops, rigid contact lenses),[81] and to correct myopia (refractive surgery trials).[87] Epidemiological studies evaluate putative risk factors of myopia in schoolchildren[1 15 71] military personnel,[4 6] and adults.[7 89] Finally, additional research in the military evaluates visual performance in myopes,[29 30] developing functional visual criteria for personnel selection,[4] and optimising visual function for myopes under different operational settings.[90]

Conclusion

The prevalence of myopia in Singapore is one of the highest worldwide. Current data indicate that both the rate and severity of myopia may be increasing over time. A similar epidemic appears to be occurring in other east Asian populations, and it is possible that ocular morbidity related to myopia may constitute an important clinical, public health, and economic problem over the next two to three decades. Because knowledge about myopia is incomplete and potential therapeutic measures have yet to be proved consistently effective, a pragmatic public health approach has been adopted in Singapore, comprising a "vision care" programme in schools, regular public education, and an integrated myopia research strategy.

Dedication

The authors dedicate this paper in memory of the late Sek Jin Chew, FRCS, PhD, (1959–98), who had been one of the driving forces behind myopia research in Singapore and internationally.

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