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A synopsis of the prevalence rates and environmental risk factors for myopia

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The prevalence rates of myopia are higher in urban Asian cities such as Hong Kong and Singapore. One observation over the past few decades is that the prevalence rates of myopia have been rising and there is an epidemic of myopia in Asia. The age-old question of the roles of nature and nurture in this process remains unanswered. The strongest evidence for an environmental link to myopia is near work activity. Childhood exposure to night lighting has also been explored in different studies but the results have been mixed. Twin studies, segregation analysis and association studies have demonstrated that hereditary factors play an important role in myopia development. The exact nature and interplay of genetic and environmental factors is not known and data suggest that environmental factors may interact with genetic factors to increase the risks of developing myopia. Future research is needed to identify specific modifiable lifestyle factors and genetic markers for myopia. This will enable preventive measures such as health education to be instituted.

Key words: epidemiology, myopia, prevalence rates, risk factors

There has been growing interest in myopia as a public health problem in Asia and other developing and developed countries because the prevalence rates of myopia appear to have increased over the past decades.[1-4] The pattern of geographical distribution of myopia has become more apparent in recent years. The general trend is that the prevalence rates of myopia are highest in urban areas of Asia such as Taiwan, Hong Kong and Singapore, and lowest in predominantly agricultural areas in non-Asian countries. This interesting phenomenon may arise if there are selective environmental and specific hereditary factors in urban Asian areas, which may lead to high prevalence rates of myopia.

PREVALENCE RATES OF MYOPIA

Comparisons of the prevalence rates of myopia in children from different studies are hindered by differences in the selection of the study population (general population versus selected group), age range of the population (adult versus children), definition of myopia, instruments used to measure myopia (questionnaire or refraction), the use of cycloplegia and the non-participation rate (Table 1).[2,5-10] In a joint effort to compare prevalence rates across different study populations, the Refractive Error Study in Children (RESC) was conducted in China, Chile, Nepal, rural India and urban India using the same sampling strategies, procedures to measure refraction and definitions of myopia.[4-8] It appears that the prevalence rates of myopia are higher in urban areas compared with rural areas (7.4 per cent in urban India and 4.1 per cent in rural India)[7,8] and the prevalence rates in Asia are generally highest in Chinese (55 per cent in 15-year-old male rural Chinese versus less than three per cent in rural Nepalese).[4,5] Other prevalence surveys include a study of 11,178 school children in Taiwan (prevalence rates of myopia were 12 per cent for six year olds and 84 per cent for teenagers 16 to 18 years).[2] The initial cross sectional results of the Singapore cohort study of the risk factors for myopia (SCORM) showed that the prevalence rates of myopia were 27.8 per cent in

Author (year/country)	N	Study population	Definition of myopia	Cycloplegia used?	Prevalence rates of myopia
Zhao[4] (2000/ China)	6134	Aged 5 to 15 years living in rural areas	At least -0.5 D	Yes	Absent in 5-year-olds, increased to 36.7% in 15-year-old males and 55.0% in 15-year-old females
Maul[6] (2000/ Chile)	6998	Aged 5 to 15 years in suburban Santiago	At least -0.5 D	Yes	3.4% in 5-year-olds, increasing to 19.4% in 15-year-old males and 14.7% in 15-year-old females
Pokharel[5] (2000/ Nepal)	5526	Aged 5 to 15 years in rural villages	At least -0.5 D	Yes	< 3% of all children
Dandona[7] (2002/ India)	4074	Aged 7 to 15 years living in rural villages	At least -0.5 D	Yes	4.1% of all children
Murthy[8] (2002/ India)	6447	Aged 5 to 15 years in urban New Delhi	At least -0.5 D	Yes	7.4% of all children
Lin[2] (1999/ Taiwan)	11178	Aged 6 to 18 years in schools in urban and rural Taiwan	At least -0.25 D	Yes	12% at age 6 years, increasing to 56% at age 12 years and 84% in teenagers aged 16 to 18 years
Chua[9] (1999/ Singapore)	1119	Aged 7 to 9 years	At least -0.50 D	Yes	27.8% in 7-year-olds, 34.3% in 8-year-olds, 43.9% in 9-year-olds

Table 1. Prevalence rates of myopia in children

Author (year/country)	N	Study population	Definition of myopia	Prevalence rates of myopia
Wang[10] (1994/ United States)	4926	Adults 43 to 84 years	At least -0.50 D	26.2%
Katz[11] (1997/ United States)	5028	East Baltimore, 40 years and older	At least -0.50 D	22.7%
Wu[12] (1999/ Barbados)	4709	Black adults 40 to 84 years	At least -0.50 D	21%
Attebo[13] (1999/ Australia)	3654	Adults 49 to 97 years in the Blue Mountains	At least -0.50 D	15%
Wensor[14] (1999/ Australia)	4744	40 to 98 years urban and rural Victoria	At least -0.50 D	17%
Dandona[15] (1999/ India)	2522	All ages 25% urban and 75% rural	At least -0.50 D	19.4%
Wong[16] (2000/ Singapore)	1232	Chinese 40 to 79 years	At least -0.50 D	38.7%
Wu[17] (2001/ Singapore)	15095	16 to 25 years military conscripts	At least -0.50 D	82.2% in Chinese, 68.7% in Indians 65.0% in Malays

Table 2. Prevalence rates of myopia in adults

seven-year-olds, 34.3 per cent in eight-year-olds and 43.9 per cent in nine-year-old children in Singapore.[9] The most noticeable trend is that the prevalence rates of myopia in children living in urban Asian cities such as Singapore and Taiwan are much higher compared with rural Asian and non-Asian areas.

The prevalence rates of myopia in adults vary in different countries and different ethnic groups (Table 2).[10-17] The literature is difficult to interpret as the populations studied differ, the age range may vary, definitions of myopia may not be consistent and refraction techniques are not identical. Similarly, studies of trends over time may not be directly comparable because the sampling strategies, methods of refraction and characteristics of the study population may differ. In general, the prevalence rates of myopia seem to be highest in urban Asian areas such as Singapore (38.7 per cent in adults 40 to 79 years)[16] and lower in the United States and Australia (22.7 per cent in adults 40 years and older in East Baltimore;[11] 15 per cent in adults 49 to 97 years old in the Blue Mountains).[13] Data from the Baltimore Eye Survey (United States),[11] Beaver Dam Eye Study (United States),[10] Andhra Pradesh Eye Disease Study (India),[15] Visual Impairment Project (Australia)[14] and Tanjong Pagar Survey (Singapore)[16] reveal that the prevalence rates of myopia are higher in younger adults and lower in more elderly adults. In Singapore, the prevalence rate of myopia in Chinese male military conscripts (age 16 to 25 years) in 1996 was higher (83.2 per cent) compared with adult Chinese aged 40 to 79 years (38.7 per cent) examined in the same year.[16,17] These two studies may not be directly comparable as the study populations differ (male military versus adult population). It is possible that there may be a 'cohort' effect with an increasing prevalence rate of myopia over the past few decades, possibly attributed to a rise in reading activity in certain Asian cities. These differences in prevalence rates may also be due to intrinsic age-related decreases in an individual's myopia as he or she ages.[18] Cohort studies that document the refraction of individuals over time are needed to document any age-related changes; while secular trends may be determined from repeated surveys of refraction using the same methodology over time. Prevalence surveys of myopia should be population-based with appropriate sampling strategies, different definitions of myopia presented (for example, spherical equivalent [SE] at least -0.5 D, SE at least -0.75 D and SE at least -1.0 D), subgroup analysis performed by age, gender and ethnic group and controlled refractive techniques.

ENVIRONMENTAL RISK FACTORS FOR MYOPIA

The nature versus nurture question of myopia development has been studied for centuries and few researchers would question the argument that both environmental and genetic factors contribute to the development of myopia. However, the exact nature of the environmental factors and the relative contributions of each environmental factor remain elusive. Likewise, there are few data at present on the genetic markers for myopia. Whether environmental factors or genes play a more important role remains an unanswered question and it is possible that environmental factors may interact with genes to increase the risks of myopia.

Near work

In animal experiments, visual deprivation leads to a degradation of the retinal image and aberrant eye growth with local effects on the choroid and sclera.[3,19] Near work is one of the most frequently cited risk factors for myopia and several observations support this hypothesis. First, the prevalence rates of myopia may have increased over the past 10 to 20 years in Asia, though the data are not conclusive.[1,2] This possible rise cannot be attributed to genes as the genetic pool has not changed dramatically over this short period. Environmental factors such as a progressively more competitive education system may have had an increasing impact in recent years. Second, the prevalence rates of adult-onset myopia and rates of progression of myopia are highest in groups of individuals who spend long hours on intensive near work, such as microscopists, carpet weavers and visual display terminal workers.[20-22]

Prior studies conducted in Newfoundland, Israel and Hong Kong have found that near work or school attendance may be associated with myopia.[24-26] However, the estimates of near work were rather crude and as the studies were cross-sectional in nature, the 'cause-effect' relationship could not be determined. In cross-sectional studies, information on near work and myopia is determined at the same point of time, while in cohort studies, near work is evaluated at the beginning of the study and the incidence rate of myopia is determined later. More recent studies include the initial cross-sectional results of a cohort study investigating the environmental risk factors for myopia in Singapore school children aged seven to nine years (SCORM).[26] The multivariate adjusted odds ratio of higher myopia (SE at least -3.0 D) for children who read more than two books per week was 3.05 (95 per cent confidence interval [CI] 1.80, 5.18). The observed 'epidemic' of myopia in Asia may arise because of the increasingly stressful education system in Asian cities such as Singapore and the associated high levels of reading. However, at present, it would not be recommended to advise parents to discourage young children from reading as the evidence is not compelling and reading habits should continue to be nurtured. Future cohort studies with large sample sizes, different measures of near work and the associated parameters, as well as accurate cycloplegic refraction and biometry measures should be conducted.

The results of studies of the role of near work in influencing the rate of progression of myopia in children who are already myopic are less consistent. Although near work may lead to the development of myopia, its effects on the worsening and progression of myopia after myopia onset may be different. In studies of the progression of myopia, near work is assessed at baseline and associations with the subsequent rate of progression of myopia are determined. In a study of 153 myopic Singapore school children aged six to 12 years, near work was not associated with myopia progression;[27] while myopic children (n = 238) who spent more time reading had faster myopia progression rates in Finland.[28] Other potentially modifiable near work parameters that may be associated with myopia or myopia progression such as poor lighting while reading, reading while lying down and reading printed material within close distances have not been extensively studied in either cross-sectional or cohort studies.[29] Information collected has often relied on parental recall and is subject to misclassification bias. Future studies could examine the effect of near work on the progression of myopia in populations of varying age and ethnicity. There should be a large sample size, long follow-up time and low drop-out rate.

Night lighting

The relative duration of daily light and dark phases may influence axial length growth and development of refractive errors.[30,31] The findings from epidemiologic studies are mixed. A study of 479 children aged two to 16 years showed that children who slept with lights at night had higher risks of myopia.[32] However, confounders such as parental myopia were not assessed and the children were recruited from a select population (one tertiary eye hospital). Another study of myopic law students (n = 77) in the University of Pennsylvania found that students who were exposed to

5.6 hours or less of daily darkness were more likely to have faster rates of progression of myopia (defined as need for a stronger spectacle prescription during law school), compared with students exposed to more than 5.6 hours of daily darkness (97 per cent versus 76 per cent: p = 0.01).[33] This observation was not repeated in two population-based studies in United States and Singapore school children.[34-36] We propose that birth cohort studies should be conducted with detailed measures of the night-lighting habits of children before the age of two years with detailed refraction and biometry parameters.

Gene-environment interaction

The high prevalence rates of myopia in certain ethnic groups (Chinese and Japanese populations) suggest that genes play a major role but the apparent dramatic change in prevalence rates over the last generation indicates that environmental factors are also important. Twin studies conducted in the United Kingdom and Taiwan have found that the concordance rate for myopia is higher for monozygotic compared to dizygotic twins with estimates of heritability as high as 90 per cent.[37,38] However, heritability is population-specific and varies with different gene pools. Segregation analysis studies by Ashton[39] in Hawaii suggest that the results may be multifactorial. Genetic loci for high myopia have been identified (18p11.31, 12q 21-23, 7q36), and further genome-wide scans are being conducted to screen for the gene defects for myopia.[40-42] There was an allelic association between the trabecular meshwork-induced glucocorticoid response (TIGR/myocilin) gene and severe myopia in 104 Chinese families.[43] The high prevalence rates of myopia in Asia may be attributable to gene-environment interaction in populations with a genetic susceptibility to myopia and high levels of reading activity.

In a twin study of Taiwanese students (n = 361), myopia was diagnosed by retinoscopy after cycloplegia. Monozygotic twins with concordant reading habits (concordance defined as less than one hour difference in reading activity) had a myopia concordance rate (concordance defined as less than 0.5 D difference) of 92.4 per cent compared with 79.1 per cent in monozygotic twins with discordant reading habits.[44] The myopia concordance rate was 62.0 per cent in dizygotic twins with concordant reading habits and lowest (37.8 per cent) in dizygotic twins with discordant reading habits. These results suggest that additive gene-environment interaction may be present. However, the index for hereditary factors was zygosity and not parental myopia. In a cohort study of Singapore school children, reading interacted with parental myopia to increase the risks of higher myopia (SE at least -3.0 D).[27] The findings were not duplicated in the Orinda Longitudinal Study of California children: no significant interaction between near work and parental myopia was present in pre-myopic children.[45] Further studies such as family-based association studies and studies of twins reared apart and together may help us better understand the interaction of genes and environment.

CHALLENGES FOR FUTURE RESEARCH

There is an 'epidemic' of myopia in Asia and several questions remain unanswered. Is there a true increase in the prevalence rates of myopia in Asia over the past few decades? Are the prevalence rates of myopia higher in all Asians compared with other races or are the rates higher primarily in the Chinese population? Myopia is also a public health problem in several countries such as Australia. Are the prevalence rates of myopia increasing and will they continue to rise in other countries such as Australia? Is myopia more common in the Chinese population in non-Asian countries such as Australia? We suggest that further well-designed studies could be conducted to address these questions. There is a need for repeated refraction surveys using the same sampling technique and methodology in Asian and non-Asian countries to estimate trends over time. The prevalence rates of myopia in urban cities in other predominantly non-Chinese Asian countries such as Indonesia, the Philippines and Thailand need to be determined. In addition, migration studies should be conducted to investigate the role of both genes and environment in different generations of Asian migrants.

The possible rising prevalence rates of high myopia (SE at least -6.0 D) may lead to an increased number of ocular complications such as myopic macular degeneration, tilted disc and retinal tears. Further studies should evaluate the pathological complications of high myopia at different ages and within different ethnic groups. The impact of age of onset of myopia, rate of progression of myopia and changes in axial length on the development of cataract, glaucoma, retinal tears, optic disc abnormalities and macular degeneration need to be further explored. Case control studies may be conducted to compare the proportion of myopes in cases with a specific ocular pathology (for example, patients with retinal tears) and normal controls. Myopia may also lead to diminution of visual function and quality of life. More research is needed on the evaluation of the compromises in visual function, impact on activities of daily living and loss of self-esteem among myopic individuals. Focus groups may be conducted to further develop and refine questionnaires on visual function, quality of life and utility values in myopic individuals.

It is important to decipher the environmental and genetic factors that may contribute to the rapid increase of myopia in Asia and other parts of the world. The aetiology of adult-onset myopia may be different from school myopia and the nature of the environmental factors and genetic markers that cause myopia to occur in adulthood should be closely studied. Another consideration is that the risk factors for the onset of myopia may differ from the risk factors that promote and accelerate the progression of myopia. Further studies that evaluate the lifestyle and genetic factors linked to the progression of myopia should be conducted. Researchers who are planning further epidemiologic studies of the risk factors of myopia should consider the following issues.

1. A cohort study is ideal as the temporal

relationship is well delineated.

2. Information on all possible confounders should be collected and appropriately accounted for in statistical analysis.
3. Accurate refraction and biometry measurements (axial length, anterior chamber depth, lens thickness and corneal curvature radii) should be made.
4. There should be sufficient power (at least 80 per cent) to examine risk factor associations.

The role of gene-environment interaction may be better understood if the nature of possible interaction between genetic markers for myopia and environmental risk factors such as reading are further evaluated. The prevention of the development and progression of myopia has become a priority in certain countries in Asia and prudent use of available research funding may facilitate the identification of modifiable risk factors. If preventable measures could be instituted, health education programs may be developed for the public and medical professionals. Nationwide vision care programs to prevent myopia may be considered and the efforts of researchers, the government and the public forged together to address myopia, a leading public health problem.

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