A Comparative Study of the Prevalence of Myopia and the Use of Overnight Orthokeratology and Low-dose Atropine for Children in East Asia and India

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Abstract: Myopia is recognized as a "major twenty-first-century public health problem," projected to affect 50% of the world's population by 2050." (Wang et al., 2020). High myopia is associated with a higher risk of sight-threatening diseases such as glaucoma and retinal detachment. It is a condition that has been increasing worldwide, especially in East Asia, where myopia rates are greater than 80% in middle and high school students (Wang et al., 2020). Myopia is more widespread in the younger generations living in urbanized Asian societies than in their Western counterparts, suggesting that the "epidemic of myopia in Asia" may be a "recent generational phenomenon" (Saw et al., 2014). This literature review summarizes pre-existing data and studies examining the prevalence of myopia and factors contributing to myopia progression in China, Japan, and India—among the countries most widely affected. As factors such as genetics, education, and diet vary between cities, regions, and countries, analyzing these variations can provide insight into strategies to prevent the growth of myopia and provide eye care accessibility to children at risk of myopia.

China: The prevalence of myopia in China was reported to be higher than in other countries and has increased remarkably in the past three decades. A study with Chinese children aged 6 to 9 calculated that genetic and environmental factors may affect myopia development by 12.5% and 87.5%, respectively (Zhang et al., 2020).

Genetics: Genetic factors have a significant effect on the onset of myopia. While the etiology of myopia includes a multitude of factors, heredity plays a significant role. Many studies have shown that children with myopic parents are more likely to be myopic than those with non-myopic parents, including the trend that having two parents with myopia poses a greater risk than having only one myopic parent. A study of 12-year-olds from Australia found that interactions between parental myopia and ethnicity were significant for spherical equivalent refraction (SER) and axial length (Ip et al., 2007). For children with parents with myopia, there were greater decreases in SER and increases in axial length in the children of East Asian ethnicity compared to those of European Caucasian ethnicity. A study from Guangzhou of children aged 5-15 years old, it was found that the prevalence of myopia was 88.9% in children with one parent who had myopia, 83.3% in those with two parents who had myopia, and 68.2% in those without myopic parents (Xiang et al., 2012).

Education: It has been well proven that the prevalence of refractive error is associated with education, and it is significantly higher in East Asia than in other regions and countries. The

phenomenon of "education fever" is well renowned in China and other Asian countries, as parents are heavily involved in their children's education and set high expectations for scholastic performance. 93% of parents in China pay for private tuition, with parents from Hong Kong ranking first in average spending on children's education from primary to undergraduate schooling (Chen et al.). Recent studies on school children in China revealed myopia prevalences ranging between 20% in young children in their early primary school years and 80% in 17-year-old pupils. This trend is likely because of the intensity of education that students undergo beginning from a young age. An investigation conducted from 2015 to 2017 found that from a total of 572,314 students, 43.8% and 37.4% of fourth graders attended after-school math and Chinese classes, respectively (Yang, 2021). This statistic has significant implications for the public health of children in China. Yang et al. state that a recent study found a positive correlation between years of education and myopia development, with every additional year causing an increase of -0.27 in myopic refractive error. A study from Eastern China by Wang et al. found that students from urban schools had higher rates of myopia prevalence, high myopia, and vision impairment because urban schools were "likely immersed in an intensive education[al] environment." This finding is consistent with previous studies comparing urban and rural locations of residency with the likelihood of myopia (Wang et al., 2020).

Diet: Diet is a critical environmental factor affecting ocular diseases, such as cataracts and age-related macular degeneration, which are more likely to occur with high myopia. An investigation analyzed several factors such as eating frequency, cooking methods, and food categories to find that Chinese dietary patterns and diet-related behaviors have changed over time from a "predominantly plant-based diet to a Western-style diet high in fat and animal foods" (Bu et al., 2021). Although the population of China generally enjoys carbohydrate-rich foods like fruits and vegetables and energy-rich foods such as meat and snacks, they have increased their fat intake and significantly reduced the intake of carbohydrates, energy, and protein. A study used a semiquantitative food frequency questionnaire to evaluate the relationship between myopia and dietary factors in Chinese schoolchildren, covering a wide range of nutrients such as energy intake, saturated fatty acids, iron, calcium, and vitamins A and C (Gazzard et al., 2010). It was found that higher saturated fat and cholesterol intake were associated with a longer axial length. However, the total daily intakes of all the other nutrients were not related to the prevalence of myopia or more myopic axial length and spherical equivalent.

Japan: Most studies studying the effect of genetic and environmental factors on myopia were performed in places such as China, Australia, and Singapore, but the lifestyle of children varies in Japan. Comparatively, there is an overall limited number of studies on the prevalence and factors causing myopia in children from Japan. The current rate of myopia prevalence in Tokyo is one of the highest compared to data from Singapore, Taiwan, and other Japanese cities. In 2019, a cross-sectional study of 1478 schoolchildren in Tokyo, Japan, found that 76.5% of

students from ages 6-11 and 94.9% of students from ages 12-14 had myopia (Yotsukura et al., 2019).

Genetics: Several studies have found an association between parental myopia and the prevalence of myopia in Japanese children. A study evaluating factors related to poor visual acuity (PVA) in children in grades 4-6 from Hiroshima demonstrated this relationship (Huang et al., 2018). Comparing children from the study with PVA, 75.8% had two myopic parents, 58.1% had one myopic parent, and 57.9% had no parents with myopia. Myopia is considered a cause of PVA. The study referenced in the previous section from Tokyo found that axial length was associated with parental myopia in elementary school students from Japan.

Education: The previous education system in Japan had been intensive and placed a significant emphasis on university entrance examinations. Students primarily underwent high-pressure education practices such as rote learning, cramming, and testing. The Yutori policy, which reduced hours spent in the classroom and the curriculum content, was introduced in 2002 as a less intense learning environment (Ishiko et al., 2021). The Japanese concept of *yutori* covers many aspects of daily life, and it is generally regarded as a state of psychological well-being and living with ease (Yamashita et al., 2001). It is difficult to accurately characterize the overall education system in Japan due to controversy with the policy because students were academically ranking lower. However, it can likely be said that Japanese students' lifestyles are different from those of Chinese students. It can be said that the introduction of the Yutori system might be related to the suppression of myopia progression. Since the system reduced time spent on primary subjects and began giving attention to integrated learning—problem-solving and learning to think independently—this reduced time spent on near-work activities such as reading, writing, and cramming (Ishiko et al., 2021). The study on visual acuity found that studying and reading books was associated with poor visual acuity. The average time spent studying was around two hours in the non-PVA group and around 3 hours in the PVA group during weekdays. Furthermore, compulsory Saturday classes were also phased out, giving students more opportunities to spend outdoors. Studies have reported the effect of increased time spent outdoors.

Diet: The traditional Japanese diet, known as *washoku*, is characterized by a "high consumption of fish and soybean products" and a "low consumption of animal fat and meat" (Gabriel, 2018). As Japan is among the nations with the highest average lifespan for men and women, it is widely known to be an essential factor in the longevity of the people in Japan. Gabriel et al. write that while the Japanese diet has a low fat intake, it is also characterized by a high salt intake. Contrarily, Westernized food contains more animal fats and simple carbohydrates. A study conducted with a sample of third-grade students from Kagoshima, Japan, found that the intake of westernized food "increases the serum cholesterol in Japanese-Americans." (Terasaki, 2017). In addition, more consumption of westernized food has been associated with higher BMI and

obesity in children (Terasaki, 2017). This relationship was confirmed in the study's cohort. The study by Terasaki et al. also claims that earlier studies show a "positive and significant correlation" between axial length and high BMI, although the exact mechanism causing this relationship is unknown (Terasaki, 2017). While the axial length was examined, refractive errors were not. Therefore, while the study does not state an explicit connection to myopia, the elongation of the axis plays a "significant role in the development of myopia in East Asian populations" (Terasaki, 2017).

India: Although India is the second most populated country in the world, the rise of myopia is often overlooked due to a lack of adequate nationwide prevalence data and studies detailing myopia trends over the years. It has one of the largest child populations in the world, as 30% of its population of one billion are under 15 years of age (Gopalakrishnan et al., 2022). One study predicting trends on the prevalence of myopia until 2050 shows that the pervasiveness of myopia in children from ages 5-15 increased from 4.44% in 1999 to 21.15% in 2019 (Priscilla et al.).

Genetics: According to a study by Gupta et al., there is little data available on the prevalence of myopia (Gupta et al., 2013). A hospital-based study from the Regional Institute of Opthalmology in central India found that the prevalence of childhood myopia was 16.5%, and family history was present in 18.53% of patients. There are few available studies that cite data from parental myopia. While some have observed the association of myopia with specific genes, Pujari et al. state that it is "less clear of now" due to a "lesser number of genetic studies" and a "more diverse subject profile" (Pujari et al., 2022).

Education: While the rates of myopia in children in India are not as high as those in East Asia, studies have found that the prevalence of myopia in the country is increasing. Studies have reported a prevalence of myopia of 13.1% in schoolchildren in North India, with an annual incidence of 3.4% (Agarwal et al., 2020). The North India Myopia Study found that the hours of reading and writing per week and using computers were significant risk factors for myopia progression (Agarwal, 2020). This study also showed a rise in the prevalence of myopia in rural schoolchildren, which is a "novel epidemiological finding" challenging the fact that myopia was less prevalent in rural areas compared to urban areas. However, other studies have shown a more strongly proven association that a higher prevalence was observed in urban schools with similar mean age groups. The authors of this investigation reported that nearly 50% of the children had a progression in myopia with a mean increase of -0.27 D of myopia. Contrarily, outdoor activities had an inverse association with myopia progression (Agarwal, 2020).

Diet: Wheat is a common staple of the North Indian diet, eaten unrefined in the form of *chapati*, a type of flatbread. The consumption of peppers is also in parts of North India. In comparison, more rice is consumed in South India. Overall, a study found that the share of calories of whole

grains in India was higher than those of fruits, vegetables, meat, fish, and eggs. The Indian diet is shifting toward higher fat and lower carbohydrate content, with high intakes of dairy and added sugar in India (Sharma, 2020). A recent analysis that compared the Indian diet with the EAT-Lancet reference diet found that diets in India tend to be unhealthy. A potential reason cited for this phenomenon was low affordability, as it was found that healthy food groups such as "fruits, vegetables, and animal products" were "the most expensive among the major food groups in the world" (Sharma, 2020). While there are currently very few studies examining the effects of diet on Indian children, one study examining the type of diet in first-year Indian MBBS students completed a statistical analysis. It was found that the "odds of myopia co-existing" in vegetarian participants was 1.28 times that compared to those who were non-vegetarian (R.S. et al.). However, it was also claimed that this trend did not reach the study's level of statistical significance (R.S. et al.).

Myopia Control: Due to the high prevalence of myopia, it is essential to explore effective strategies to control the progression of the condition. While there are no interventions to cease the development of myopia, there are many treatment options that can slow or decrease it. Many methods have been used, including bifocal and multifocal lenses, soft and gas-permeable contact lenses, topical atropine, and orthokeratology (OK) lenses (Lee et al., 2017). According to a study by Yuan et al. in 2021, " many studies have assessed the efficiency of OK lens and atropine" for controlling myopia in children. This study cites an investigation from Japan on overnight OK on axial elongation in childhood myopia, claiming that the increase in axial length for over two years was 0.39 mm in the OK lens group and 0.63 mm in the single-vision spectacle glasses group. Several studies have proved the safety of OK lenses, and the benefits of this method outweigh the adverse effects. As they are worn overnight, benefits include "freedom from vision correction during waking hours, [fewer] activity restrictions…[fewer] symptoms of dryness and itching compared to soft contact lenses, and significant slowing of axial elongation," making them an ideal option for children. (Lipson et al.). Overall, Yuan et al. write that OK lenses can induce a "40-60% mean reduction in axial elongation" compared to single-vision lenses in correcting myopia.

Additionally, atropine drops have also been proven to be effective. A five-year study of atropine treatment showed that 0.01% atropine is "effective for slowing myopia progression" with "negligible side effects." At the end of the study, it was found that the overall progression of spherical equivalence was significantly lower in the 0.01% group in comparison to the 0.1% and 0.5% atropine groups (Yuan et al., 2021).

Conclusion: In conclusion, this literature review has found the highest rates of myopia in children from East Asia, with higher rates in China and Japan compared to North and South India. Genetics, level of outdoor activity, near-work activity, urban versus rural environments, and diet are all factors that have been associated with the progression of myopia. Regarding the

last factor, the diets in the countries studied in this paper have all recently shifted toward higher-fat, Western-style diets. Higher saturated fat, higher cholesterol intake, and high BMI were associated with longer axial length. Furthermore, 0.01% atropine drops and orthokeratology lenses have been proven effective strategies for slowing myopia progression in children. Therefore, it is imperative to consider such factors to improve children's eye health and quality of life.

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