LOSING FOCUS

Spiking rates of nearsightedness are becoming a global health problem—but a simple behavioral change could be the solution

By Diana Kwon

For kids in Singapore, the pressure for academic success is intense. After the regular six- to eight-hour school day, many children attend extra classes at private schools and devote long hours to homework in the evening. In recent decades as study hours have expanded, so has the country's rate of nearsightedness—to epidemic proportions. An astonishing 80 to 90 percent of newly minted high school graduates in Singapore are myopic. The same is true in China, Taiwan, Japan and South Korea—all places where kids now spend far more time hunched over a desk or computer than did previous generations. Rates are rising in other developed nations as well. In the U.S., the prevalence of myopia nearly doubled from 25 percent in the 1970s to 42 percent in the early 2000s.

If present trends continue, fully half the world—more than four billion people—will need glasses by 2050, according to projections made by researchers at the Brien Holden Vision Institute, headquartered in Australia. This alarming forecast, published in *Ophthalmology* earlier this year, was based on an analysis of 145 studies of myopia rates around the globe. "That was the first really worrying statistic," says Kovin Naidoo, a vision researcher at the University of KwaZulu-Natal in South Africa who was involved in the study. "Any public health problem

ILLUSTRATION BY *Adam McCauley*

that affects 50 percent of the population is a bloody important issue."

Myopic individuals have an eyeball that is slightly too long. This deformity causes images to fall in front of the retina, rather than directly on it, making objects that are far away appear blurry. Myopia typically starts in childhood or adolescence and continues progressing into the 20s when the eyes are fully grown.

For most shortsighted people, clear vision can easily be restored with contact lenses, glasses or surgery. But in severe cases, which physicians classify as "high myopia," the eyes continue to stretch to dangerous levels, increasing the risk for retinal detachment, cataracts, glaucoma and other conditions that can lead to blindness. Unfortunately, the new study predicts that cases of high myopia will *also* rise—from 3 percent of the global population in 2000 to 10 percent by 2050, leaving an estimated 938 million people at risk of losing their eyesight.

For a long time, researchers attributed nearsightedness to genetics, but this could not explain why myopia rates were so quickly reaching epidemic levels. Once it became clear that environmental factors were to blame, the first, most obvious culprit was increased time spent on close work—reading, writing and staring at screens. More recent studies, however, are converging around a different idea: bright sunlight helps to regulate normal eye growth, and too much time indoors—whether studying, playing video games or something else—derails this process. This revelation has opened the door to a new way to prevent myopia that may be easier than bucking cultural trends emphasizing schoolwork: get kids outdoors.

Bespectacled Bookworms

All sight begins with light. The pupil expands and contracts to control how much light enters the eye. The clear cornea and lens bend the light, focusing it directly on the sensitive nerve cells of the retina. Here the rod and cone cells come into play, converting light into electrical impulses that travel to the brain. When all goes well, this journey enables us to view the world around us. But a flaw at any point in this process will introduce problems.

When the eyeball is too long, it focuses light in front of the retina, sending the brain a blurry image. We can compensate by squinting our eyes, which reshapes the lens and adjusts the path of light. But this is only a temporary fix. After months of straining eye muscles to see blackboards, kids—or their parents or teachers—will realize they have a vision problem and get fitted for their first pair of glasses.

In Asia, such trips to the optician have been on the upswing for half a century. Some of the first evidence that a myopia epidemic was under way came from studies of military conscripts in Singapore. Because two years of military service is mandatory for all young men and all recruits have their eyes tested, researchers could look at nearly the entire male population. Over the years the data revealed a dramatic rise in shortsightedness: 26 percent in the late 1970s, 43 percent in the 1980s and 83 percent by the late 1990s. "We think the huge generational effect [occurred] because about 50 years ago, the school system was different—it was not so intensive," says epidemiologist Seang-Mei Saw, head of the myopia unit at the Singapore Eye Research Institute. "If you just speak to the older and the younger generations about what they did when they went to school, you know that the lifestyle has changed tremendously."

If present trends continue, fully half the world—more than four billion people—will need glasses by 2050. And high myopia, a condition that can lead to blindness, will triple.

In many recently industrialized Asian countries, high-intensity education has become the norm amid fierce competition for limited spots in the nations' universities. In Shanghai, for example, 15-year-olds spend about 14 hours a week on homework compared with six hours in the U.S. Nearsightedness is common among the intellectual elite. True to the stereotype of the bespectacled bookworm, people with higher levels of education, test scores and IQ are all more likely to need glasses. "There is remarkably consistent evidence that people who have more years of education are more myopic," says Ian G. Morgan, a longtime myopia researcher at the Australian National University.

The connection therefore seemed crystal clear: more education meant more time doing close work, thereby causing irregular growth. But a more detailed look at myopia research presented a hazier picture. Evidence emerged that it was the lack of time outdoors, rather

FAST FACTS

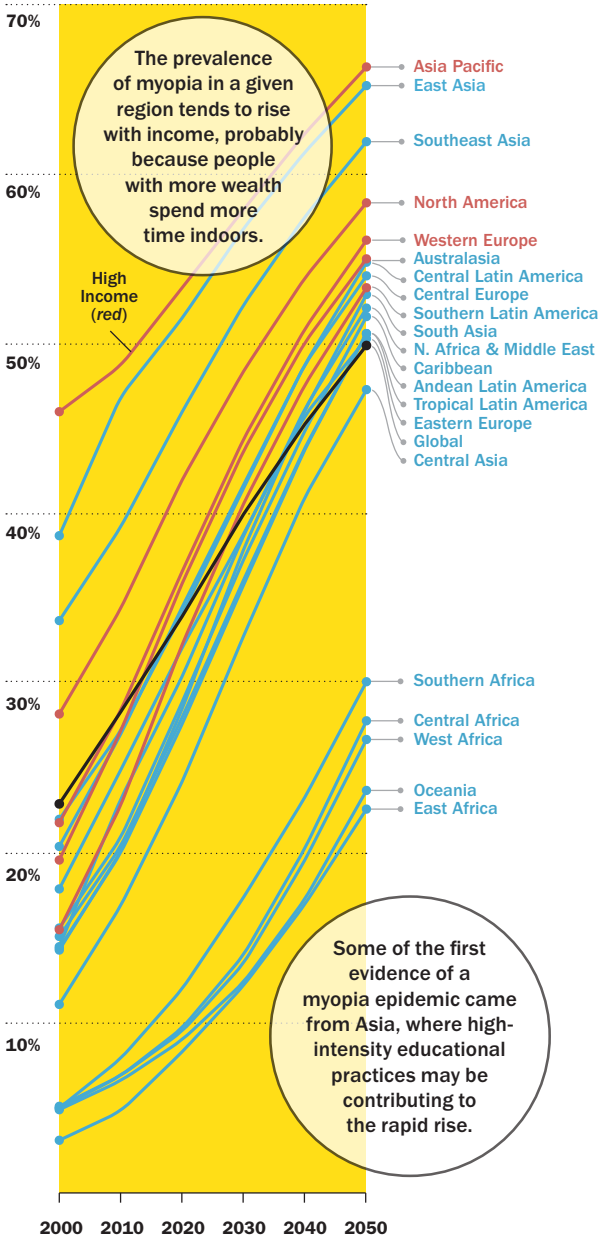
THE MYOPIA EPIDEMIC

1. By 2050 some researchers estimate that half the world's population will be nearsighted—an increase that suggests more and more people are at risk for serious vision problems.
2. Although researchers once attributed such shortsightedness to the eyestrain associated with "near work," such as reading or writing, newer evidence suggests light exposure is a critical factor in ensuring normal eye development.
3. Evidence in humans suggests that increasing children's time outdoors and in the sun can help stem the rising rates of myopia.

than time spent doing near work, that was behind the myopia boom. A 2007 study by researchers at Ohio State University was one of the first to support this conclusion. Using survey data from the parents of 514 grade-schoolers, it found that once time spent outdoors and parental myopia were taken into account, the effect of reading hours disappeared.

Around the same time, myopia researchers in Singapore and Australia, led by Kathryn Rose, then at the University of Sydney, conducted another questionnaire-based study comparing the prevalence of myopia in six- and seven-year-olds with Chinese ancestry in Sydney and Singapore. They found that although children in Sydney actually spent more time reading and doing near work, only 3 percent were myopic compared with 29 percent in Singapore. Australian children spent more time outdoors: more than 13 hours per week in Sydney compared with just three in Singapore. "Children in Australia actually did more near work because they read for pleasure, whereas the children in Singapore read only for school," says Morgan, who also took part in the study.

Soaring Rates of Nearsightedness



TIFFANY FARRANT-GONZALEZ (*illustration*); SOURCES: "GLOBAL PREVALENCE OF MYOPIA AND HIGH MYOPIA AND TEMPORAL TRENDS FROM 2000 THROUGH 2050," BY BRIEN A. HOLDEN ET AL., IN *OPHTHALMOLOGY*, VOL. 123, NO. 5; MAY 2016 (*myopia prevalence*); GLOBAL BURDEN OF DISEASES, INJURIES, AND RISK FACTORS STUDY, INSTITUTE FOR HEALTH METRICS AND EVALUATION (*classifications by high-income region*)

Antimyopia Action

Clearly, being outdoors helps—but why? This question was hard to answer with human studies. To find the underlying mechanism, scientists needed to probe the chemistry inside the eye. To that end, researchers have induced myopia in animals such as chickens, tree shrews and monkeys. One way to do this is to prevent light from reaching the eyes by temporarily sewing them shut or covering them with frosted goggles. Without input from the outside world, the young animals' eyes overgrow and become severely nearsighted. A second and newer method is to place lenses over the eyes that focus images behind the retina. In consequence, eyes gradually compensate for the blurry image by becoming longer and myopic.

Much has been learned from these experiments, however disturbing they may sound. "I could tell from the chemistry of the retina in those monkeys which ones were myopic and which ones weren't," says Richard Stone, an ophthalmology researcher at the University of Pennsylvania. "And that was just astonishing."

These techniques revealed that when the retina detects blurry images, it releases chemical signals into the eye that control how large the eye will become and how quickly it will grow. "If you can convince the cells [in the retina] either by removing the blur or by chemical stimulation not to send the signals that cause the eye to elongate, then you can slow myopia," says Thomas Norton, a researcher studying myopia in animals at the University of Alabama at Birmingham.

Although scientists have yet to characterize all of the signals involved, one appears to be dopamine, a neurotransmitter that prevents eye growth. Light stimulates dopamine release, which suggests it could be mediating light's antimyopic effects. Indoors, light intensity is low—a typical office or classroom provides light levels around 100 to 500 lux. In comparison, a cloudy day can provide up to 15,000 lux, and a sunny summer day can offer up to 130,000 lux. "The current thinking is that the elevated outdoor light levels raise the amount of dopamine that is being produced and released in the retina and that this is counteracting the signals for the eye to get longer," Norton says.

A group of eye researchers at the University of Tübingen in Germany was the first to find convincing evidence for this idea. In 2009 they found that exposure to sunlight (30,000 lux)

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and very bright artificial lights (15,000 lux) successfully prevented experimental myopia from developing in chickens. Then, in 2010, they discovered that injecting a drug (spiperone) that blocks dopamine activity into the eyes of myopic chicks could abolish the protective effect of light. Soon after, another group found the same protective effect of light in monkeys. But dopamine is unlikely to be the whole story. A 2011 study in guinea pigs found, for example, that drugs that increased dopamine activity did not consistently prevent myopia.

Some researchers think that the timing of light exposure is important. Like many other systems in our body, such as body temperature and hormone release, the length of our eyeballs has a daily cycle—they tend to be longest at midday. Dopamine levels in the eye also fluctuate through the day. They rise during daytime and fall at night. Melatonin has the opposite pattern, increasing at night, and it, too, has a role in eyeball development. The fact that these temporally tied activities affect the eye's growth hints that the body's cycle of circadian, or daily, rhythms may be related to eye health as well. Debora L. Nickla of the New England College of Optometry and others are investigating whether distorted circadian rhythms might play a role in the development of myopia.

Early studies in chickens found that eyes grow excessively under constant light or constant dark. But according to Nickla, these studies do not provide an accurate picture, because circadian rhythms were too severely altered. She is now investigating what happens when these rhythms are more subtly disturbed. One of her recent studies, published this year in *Experimental Eye Research,* revealed that two hours of light (700 lux) in the middle of the night was enough to alter eye growth. These preliminary studies point to the possibility that as children spend more late nights browsing the Web or crouched over their textbooks, altered circadian cycles may take a toll on their developing eyes.

Saving Sight

Although many questions remain about how light affects eye growth, faced with exploding rates of myopia, clinical researchers have begun testing myopia-prevention approaches involving light. Government agencies in Asian countries have started to push such interventions because of the overwhelming need.

In one study, which began in 2009, a group led by Pei-Chang Wu, an ophthalmology researcher at Kaohsiung Chang Gung Memorial Hospital, conducted a clinical trial in Taiwan with 571 elementary school students. Half of the children got an extra 80 minutes of outdoors recess each day for a year. The result: only 8 percent of those students developed myopia over the course of the study, whereas 17 percent of those in the other group needed glasses.

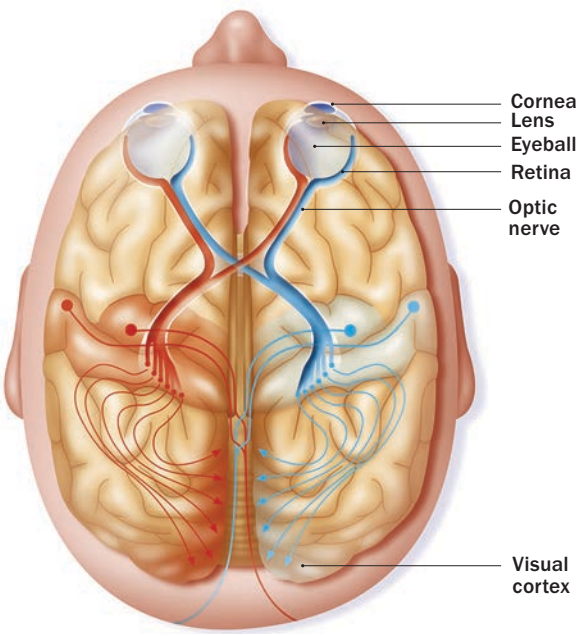
Around the same time, Morgan and his colleagues conducted a similar trial in Guangzhou, China. They found that children who received an extra 40 minutes of mandatory outdoor time every day for three years were 23 percent less likely to develop myopia than those who did not.

Sunlight can protect children from developing myopia, but whether it can slow down its progression in kids who already need glasses is unclear. "The results are mixed," Saw says. Some studies have found that outdoor time has a modest effect on progression. Others, such as Wu's study, found that being outdoors did not significantly alter outcomes for kids who were already myopic.

Yet simply delaying the age when children become myopic can have a major impact. Early onset increases the risk for high myopia because the eye has more time to stretch to pathological levels. Luckily, for those who have myopia, there are other treatment options that can help slow progression, including atropine eye drops and specially designed contact lenses [*see box on opposite page*]. "Myopia is a very difficult and persistent problem that is not going to go away easily," Norton says.

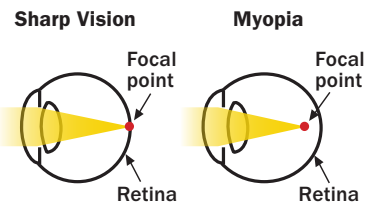
A Clear Future

In Asian countries with a culture stressing academic achievement, interventions that take time away from studying may not be the best option. "Even with the trial we did in Guangzhou," Morgan says, "by the end of the three-year period we were starting to get pushback from



Sharper Image

Sight begins when light bounces off surfaces and enters our eyes. Normally, the cornea and lens bring the resulting image to a focal point on the retina at the back of the eyeball. There it is converted into impulses carried by the optic nerve to the brain. The nearsighted eye is overly long so the image falls short and the retina receives a blurred version.



GETTY IMAGES (brain); SCIENTIFIC AMERICAN MIND (diagrams); SOURCE: ANDREI V. TKATCHENKO Columbia University Medical Center (diagrams)

Slowing Myopia Progression

Spending time in the sun can help prevent myopia or delay its onset, but it may not be helpful to children who are already nearsighted. Researchers are investigating a variety of interventions that have shown promise in slowing the aberrant eye growth that causes sight to worsen, which is crucial to preventing high myopia, a severe type that can lead to blindness.

Atropine Eye Drops	Orthokeratology (Ortho-K)	Multifocal Contact Lenses and Eyeglasses
Drops of atropine, a drug that blocks acetylcholine receptors in the eye, can stop or slow myopia's progress. Researchers have been investigating it since the 1990s. Initial studies found unwanted side effects—pupil dilation, eye muscle paralysis and blurry vision for close objects. Lower doses, however, have virtually no side effects and are even better at slowing progression than higher doses. Low-dose atropine is one of the most well-studied and promising treatment options. It is currently available in many Asian countries. In the U.S., the FDA has approved only the higher-dose option.	Ortho-K contact lenses temporarily flatten the cornea, the transparent layer at the front of the eyeball. Worn during sleep, they allow users to see clearly during the day. First used to correct blurry distance vision, randomized clinical trials have since demonstrated that they can also slow myopia progression. Ortho-K lenses are expensive—the initial fitting and the first pair of lenses can cost between $1,500 and $2,000. And some ophthalmologists worry that wearing lenses at night can increase the risk for eye infections.	Conventional corrective lenses—whether in glasses or contacts—have a single power, or focal length, which moves the image from behind the retina to directly on it. But these lenses cannot correct for the close objects at the periphery that appear fuzzy to a myopic eye. Studies have shown that this blurring effect can actually stimulate further eye growth (though at a much lesser rate than not wearing lenses at all). To prevent myopia from worsening, researchers have developed a new type of corrective lens with regions of varying focal lengths to deal with the differences at the fringes of vision. Recent human studies have confirmed their ability to reduce the progression of myopia.

parents saying, 'Look, you're wasting our children's time. If they weren't outside, they would be studying.'"

He and his colleagues are looking at alternative ways to get children the sunlight they need. One idea they are testing is a glass classroom, a greenhouselike structure where students can get up to 9,000 lux of sunlight. Such edifices are expensive to build, so they are also investigating another, more cost-effective option: bright study lamps that can shine up to 10,000 lux of light. Feasibility studies show that children are receptive to both techniques. The researchers hope to take these ideas into formal clinical trials within the next two years.

In Singapore, Saw and her colleagues are working to promote outdoor time. "Children wanted to be outdoors," Saw says. "But sometimes there were no opportunities." Using fitness trackers that measure time outside and guided weekend visits to the park, she believes, can help parents and teachers encourage kids to spend less time indoors.

Even in places where myopia rates are low, experts expect that prevalence will rise with increasing modernization. In Africa, for example, technology has advanced rapidly in recent years. "People have gone from no landline phones directly to mobile phones, and children are spending more time with computers," Naidoo says. "[We have] an opportunity to prevent the trends that have developed in the rest of the world."

Unfortunately, these regions currently have limited access to eye care. Proper prescriptions are crucial—leaving blurry vision uncorrected can actually worsen progression. To address this issue, Naidoo and his collaborators are working to implement programs to fit children in developing countries with glasses.

For now, the consensus is clear. Sunlight helps, especially for children who are not yet nearsighted. Taking youngsters outdoors, Morgan says, "is the cheapest and easiest option."

In a sense, the myopia epidemic is but one of many examples of how human progress has inadvertently separated us from healthful habits. Just as science has revealed that, like generations past, we, too, need to sleep seven hours, exercise regularly and eat a balanced diet, another simple way to improve our health may be to tear ourselves away from our desk lamps and electronic devices and spend some time outdoors soaking up the sun. **M**

MORE TO EXPLORE

- **Myopia.** Ian G. Morgan, Kyoko Ohno-Matsui and Seang-Mei Saw in *Lancet,* Vol. 379, pages 1739–1748; May 5, 2012.
- **Ocular Diurnal Rhythms and Eye Growth Regulation: Where We Are 50 Years after Lauber.** Debora L. Nickla in *Experimental Eye Research,* Vol. 114, pages 25–34; September 2013.
- **Global Prevalence of Myopia and High Myopia and Temporal Trends from 2000 through 2050.** Brien A. Holden et al. in *Ophthalmology,* Vol. 123, No. 5, pages 1036–1042; May 2016.
- American Academy of Ophthalmology on myopia: **www.aao.org/eye-health/diseases/myopia-nearsightedness**

From Our Archives

- **Look into My Eyes.** Arryn Robbins and Michael C. Hout; January/February 2015.