

**WORLDWIDE DISTRIBUTION OF VISUAL REFRACTIVE ERRORS
AND WHAT TO EXPECT AT A PARTICULAR LOCATION**

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Estimates of the number of people worldwide with refractive error range from about 800 million to 2.3 billion. No prevalence data are available from the World Health Organization or from any other source relating to very large populations such as groups of nations, or whole countries. There are no prevalence figures for the population of even the United States. Numerous studies have been undertaken on small, but assumed to be biased, samples from disparate populations ... and extrapolations from these data have provided clues about refractive error distribution. For example, reviewing data from studies by Sorsby (672 individuals age 4-8), Wilbaut (2,398 newborns), Brown (4,431 adults) and Scheerer and Betsch (25,000 adults), Baldwin was able to plot frequency versus refractive error on a continuous diopter scale from plus (hyperopia) to minus (myopia) for each study, showing a family of essentially normal distributions, but with a shift in mean from low plus towards 0 diopters (emmetropia) as a function of age. Snyder using his own data plotted as bar graphs was also able to construct a "normal" distribution with the mean slightly positive for 393 subjects. Almost all longitudinal (over time) studies have shown approximations of normal distributions with a trend toward increasing myopia or lessening hyperopia as a function of age.

As for the proportion of an entire population with refractive error, Daniel Etyale of the W.H.O. reported at a special session on refractive error at an International Agency for Prevention of Blindness meeting in 2001, that 5 -15 percent of children are considered to have refractive errors, the majority of which are uncorrected, and that there is currently a need for population based studies to ascertain these figures. Although Vision 2020 (the current W.H.O.global initiative) imposes a mandate to correct refractive errors, little infrastructure and few resources are available to accomplish the task of correcting refractive errors. Etyale noted that while access to general medical services is possible for about 25 percent of populations in developing countries, access to medical eye care, including refraction, could be obtained by only about 10 percent.

In order to improve access, epidemiologic research on the types and distributions of refractive errors will enable more efficient planning to both improve access to care, including the provision of corrective eyewear (or other therapies as appropriate) and also to provide a basis to evaluate remedial progress. Although sufficient data have not been collected to accurately predict prevalence per diopter of correction for most populations, general prevalence information on the three types of refractive errors and of presbyopia can provide an orientation of what to expect. Hyperopia, for example, is usually present at birth, except in premature infants. Hyperopia decreases in magnitude through age 4 years, and the prevalence of hyperopia less than plus 1.25 D (an amount usually difficult to compensate accommodatively) is 4-7 percent between ages 5-20 years., remains constant through early middle age, then increases in populations aged 45 or more. Low amounts of hyperopia appear to be autosomal dominant and high amounts recessive. Hyperopia also occurs in patients with poorly controlled diabetes and in patients who've had cataract surgery. Myopia prevalence varies with age, race and sex, increasing at least through adolescence, and is present in 1 per cent of children at age 5 years, increasing to 8 per cent at age 10 years and about 15 per cent at 15 years. Myopia occurs slightly more frequently in females than in males. The prevalence of astigmatism may be as high as 70 per cent, if all amounts are included, but is considered to decrease to 3 percent if the extent is limited to 1.25 diopters or more. Astigmatism is classified according to the location of the corneal meridian having the greatest focusing power, shifting from near vertical in childhood to near horizontal by age 65. Low amounts of astigmatism are thought to be autosomal dominant. If astigmatism is greater than 1 diopter, it usually develops before age 2 years. Not a refractive error, presbyopia is due to a loss of accommodative ability. It usually starts between ages 38-45 years and the prevalence is 100 percent by age 55. Early onset is associated with hyperopia.

Factors that might account for refractive errors have been under consideration since the latter part of the 19th century. Nicati in 1879 found a higher rate of myopia in Jewish populations in Europe. Stephenson in 1919 discovered a rate of 10

percent for myopia in Jews compared with 1.2 percent for non-Jews working in the same environment. Sorsby analyzing refraction data from school children in 1933 found that from ages 10 to 14, Jewish school children presented with a myopia rate of 33.5 percent as opposed to the non-Jewish rate of 25.5 percent. Other studies around the same time by Gallus also showed a greater prevalence of high refractive errors among Jews for both myopia and hyperopia.

Crawford and Hammar, who examined over 100,000 school children in Hawaii in 1949, found clues to racial and ethnic differences affecting the prevalence and incidence of refractive disorders. Ten ethnic groups were represented: Japanese (41,684), partial Hawaiian (20,375), Filipino (9,732), Portuguese (6,562), Chinese (5,621), Caucasian (5,353), Hawaiian (2,758), Puerto Rican (1,764), Korean (1,036) and Spanish (193). Chinese school children exhibited the greatest amount of myopia (17 per cent), followed by Koreans (13 per cent), and Japanese (12 per cent). Myopia occurred within other groups in the following descending order: Caucasians, Spanish, Portuguese, Filipinos, Puerto Ricans, Partial Hawaiians and Hawaiians. Interestingly, hyperopia was found in 3 to 5 per cent for all the groups with the exception of the Portuguese who exhibited 10 per cent with this refractive error. As with the observations of Ware that 25 per cent of Oxford students had myopia greater than one diopter compared with only 0.2 percent of military school students, the arbitrary grouping of individuals will show clusters of refractive problems in much too small a sample size to appear normally distributed.

Recent studies have continued to reveal variations in refractive error among different groups, such as reported this year in the Archives of Ophthalmology. Data from 29,281 people in the US, western Europe and Australia over 40 years of age showed a prevalence for hyperopia (plus 3D or greater) of 9.9 percent, 11.6 percent, and 5.8 percent, respectively, and for myopia (minus 1D or more) 25.4 percent, 26.6 percent, and 16.4 percent for these population samples. In a very different environment, Dandona et al collected data on refractive error from 2,522 subjects of all ages in Hyderabad, India, as part of the population-based Andhra Pradesh eye

disease study. In younger subjects (15 years or less), myopia was found in 4.4 percent, hyperopia 59.4 percent and astigmatism among 6.9 percent, while in adults (greater than 15 years old) myopia rose to 19.3 percent, hyperopia fell to 9.8 percent, and astigmatism was detected in 12.9 percent. It was noted in this study that if astigmatism rates were extrapolated to the 255 million urban population of India, 2.5 million children would have this condition not concurrent with myopia or hyperopia, and presumably would need correction for the astigmatic error not as spherical equivalent.

Ming-Zhi Zhang and others also studied astigmatic error greater than 1D cylinder in children, aged 6 to 7 years in Singapore and Xiamen, China finding a wide variation in prevalence rates for Xiamen city (6.8 percent); Xiamen countryside (8.7 percent); and in Singapore (17.1 percent). Remarkably, Kleinstein and his co-investigators of the Collaborative Longitudinal Evaluation Ethnicity and Refractive Error Study Group found in a study population of 2,523 children in Birmingham, Alabama a high prevalence in a similar ethnic group of Asians (33.6 percent had astigmatism of 1D or more) as well as a higher prevalence in Hispanic children (36.9 percent !). Such an extensive need for correction of astigmatic error found in Birmingham compares with the findings of InFOCUS teams in northeast Mexico, northern Guatemala and southern Nicaragua, where clusters of high prevalence and high refractive errors were detected among children (prevalence 10 percent or more, mostly with greater than 2 D cylinder and as much as 10 D). Less dramatic, but still significant astigmatic errors 2 D or more were found in Baltimore school children (3.1 percent) and from the NHANES (National Health and Nutrition Examination Survey) as reported by Macias et al where astigmatism as a component of refractive error contributing to visual impairment (VA 20/50 or worse) was found to increase with age, and where the astigmatic component prevalence ranged from 21.2 percent in young males to as high as 57.3 percent in elderly females (80 years or older). Other special groups such as mentally handicapped children also show sufficiently high astigmatic refractive error (37.1 percent according to Junyent et al) to warrant attention and a need for correction.

Out of 611 conditions (infectious, dystrophic, metabolic, neurologic, perceptual, etc.) that have a negative effect (harmful, unpleasant, interfering with a normal life), "refractive eye disorders" rank number 7, with an overall prevalence of 44.1 percent. Higher prevalences were found for only diarrhea, headaches, respiratory conditions, dental caries, cytomegalovirus and herpes infections). As for the World Health Organization, correction of refractive errors is a component of the current global initiative to reduce avoidable or treatable blindness, Vision 2020, which is considered a current top priority and challenge for all nations of the world. Correction of refractive errors, however, means correction of all refractive errors, hyperopia, myopia *and* astigmatism. Spherical correction for hyperopia or myopia may contain an additional spherical equivalent component to improve vision with small amounts of astigmatism (less than 2 D), but will not be sufficient for greater visual distortion imposed by corneal or lenticular astigmatic distortions. Although current efforts to provide refractive correction for refractive errors often attend to spherical correction only (for hyperopia, myopia and a spherical equivalent for astigmatism), there is sufficient evidence to correct astigmatic errors, as well. The fact that two eyes may require individual prescriptions should be taken into account, as well.

As for anticipating what to expect at any particular location where correction of refractive errors will be provided, unless data were available for that specific population, extrapolations from other populations will not be valid.

In summary it can be taken into account that:

- large populations show a normal distribution of refractive errors;
- the mean for a particular large population may be shifted towards hyperopia or myopia;
- refractive error distribution may exhibit kurtosis (skewness) that may not affect the "stability" or "robustness" of an overall normal distribution;

- dynamic changes in refractive status are a function of age (illustrated with emmetropization as the eye grows in axial length, where hyperopia diminishes and myopia, if present, continues to increase until the eye stops growing;
- as a consequence of morphologic changes in the eye, especially during growth, refractive status changes and a single time isolated refraction examination is insufficient to provide adequate determination of a prescription for refractive correction;
- a sufficient frequency of astigmatic refractive error exists, often in high amounts, throughout different population groups and occasionally in subpopulation clusters to warrant the availability of prescription eyewear with cylinder correction; and
- regardless of location, eyeglass prescription eyewear should be available to correct a full range of spherical and cylindrical errors, specific for each eye, although high power lenses would be needed in smaller quantities (unless prevalence data were available for that specific location showing an abundance of a particular refractive condition).

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