Age-Related Decreases in the Prevalence of Myopia: Longitudinal Change or Cohort Effect?

Donald O. Mutti and Karla Zadnik

PURPOSE. The prevalence of myopia shows a decline with age in cross-sectional studies. This pattern may represent an increase in the prevalence of myopia in younger generations, possibly through increased exposure to near work, or an intrinsic age-related decline in myopia prevalence. Data were analyzed from published studies to determine which of these two alternatives better explains the data: a cohort effect of changing prevalence by decade or a longitudinal effect of changing prevalence as a function of age.

METHODS. Prevalence data were taken from three studies conducted in the late 1980s and compared with those obtained indirectly from a national survey conducted in the early 1970s. The prevalence of myopia was then plotted as a function of age and year of birth.

RESULTS. The pattern of change in the prevalence of myopia as a function of age was consistent across all studies when data were scaled relative to the prevalence of myopia at age-range midpoints from 44.5 to 49.5 years. The pattern of change was not consistent as a function of year of birth. When the data were scaled relative to the prevalence of myopia among those with years of birth from 1940 to 1942 and plotted by year of birth, results from the early 1970s were offset from those of later studies by approximately 18 years.

CONCLUSIONS. The decline in the prevalence of myopia in older adults between the early 1970s and the late 1980s can be better explained by age than by year of birth. The prevalence of myopia appears to decrease because of an intrinsic age-related decrease in the amount of an individual's myopia rather than because of a cohort effect of increasing prevalence over time. The hypothesis that increasing environmental exposures to near work in recent decades have changed the prevalence of myopia is not supported by this analysis. (Invest Ophthalmol Vis Sci. 2000;41: 2103–2107)

Several recent studies document a declining prevalence of myopia with age in adults. The Beaver Dam Eye Study reported that the prevalence of myopia declined from 42.9% in those 43 to 54 years of age to 14.4% in those 75 years of age or older.1 The Baltimore Eye Survey found a similar trend across gender and ethnic groups. The prevalence of myopia in black men and white women, for example, decreased from 34.0% and 42.1%, respectively, at age 40 to 49 years to 10.5% and 12.9%, respectively, at age 80 years or more.2 The Framingham Offspring Eye Study reported that the prevalence of myopia declined from 52% in those 35 to 44 years of age to 20% in those 65 to 74 years of age.3 One explanation for this decline is that the prevalence of myopia increased during the middle decades of the 20th century. Those born in earlier decades have not been as heavily exposed to putative myopigenic factors such as near work and therefore have a lower prevalence compared with younger, more myopic generations with greater near work demands. An alternate explanation is that the prevalence of myopia has not changed appreciably over time, but is lower in older adults because it declines with age as a physiological change.

All three of these studies were performed within a narrow span of time in the mid- to late 1980s. Beaver Dam Eye Study data were collected in 1987 and 1988, the Baltimore Eye Survey was conducted from January 1985 through November 1988, and Framingham Offspring Eye Study examinations were conducted from May 1989 through October 1991.1-3 To distinguish between the two alternative explanations for changing myopia prevalences with age, we examined similar data collected during another period. Sperduto et al.4 reported the prevalence of myopia as a function of age using National Health and Nutrition Examination Survey (NHANES) data collected in 1971. These prevalences are nearly constant across ages in adults, from 27.7% of the right eyes of those 18 to 24 years of age to 24.8% of the right eyes of those 45 to 54 years of age.4 Unfortunately, Sperduto et al. did not report on ages older than 54 years. These are the ages at which The Baltimore Eye Survey and The Beaver Dam Eye Study begin, with the decline in prevalences occurring after these ages.1-3 The original reports of NHANES data do not stop between ages 45 to 54, however. They are available in tabular form to allow for estimation of trends in adults from ages 25 to 74 years.5 We therefore compared the prevalence of myopia from these three recent large studies to NHANES data obtained in 1971 as a function of both age and year of birth to determine which of the two alternative hypotheses better explains the data: a cohort effect...
of changing prevalence by decade or a longitudinal effect of changing prevalence as a function of age.

**METHODS**

The Beaver Dam Eye Study examined 4275 subjects with phakic eyes using noncycloplegic autorefration (model 530; Humphrey, San Leandro, CA). Autorefractor findings were placed in a trial frame, and the refraction was refined according to the Early-Treatment Diabetic Retinopathy Study (ETDRS) protocol if visual acuity was 20/40 or worse. Myopia was defined as a more negative refractive error than $-0.50 \, \text{D}$ (unspecified whether this is the sphere or spherical equivalent). Data for this report were taken from their Table 2 for “Total,” both males and females. The Baltimore Eye Survey measured refraction for those with acuity of 20/50 or worse. Myopia was defined as at least $-1.00 \, \text{D}$ or more myopic spherical equivalent in at least one eye. Data are taken from their Table 2 for four groups: female, male, black, and white.

The Framingham Offspring Eye Study examined 1585 adult children of subjects participating in the Framingham Eye Study, measuring refractive error with an autorefractor (unspecified type). Although not specified in the text, autorefration was performed without cycloplegia (AO Reichert SR-IV; Reichert Instruments, Charlotte, NC). Refinements were made using retinoscopy or subjective refraction to reduce any effects from instrument accommodation. Myopia was defined as a more negative refractive error than $-0.50 \, \text{D}$ spherical equivalent. Data are taken from their Table 2 for four study groups: female, male, black, and white.

NHANES data are contained in a report on the refraction status among 9263 civilian, noninstitutionalized persons 4 to 74 years of age selected by a probability sampling design. Oversampling was used among the poor, preschool children, women of child-bearing age, and the elderly. The national estimates provided are based on weighted observations reflecting the national distribution of age, sex, and income class. The eye examination included measurement of the current glasses, followed by cycloplegic retinoscopy or trial frame subjective refraction for those with acuity of 20/50 or worse. The prevalence of myopia in our analysis was determined by combining data on the frequency of wearing a correction (NHANES Table 34) with the distribution of the powers of glasses and contact lenses (NHANES Table 13). Myopia was defined as $-0.10 \, \text{D}$ or more minus spherical equivalent. The probability of wearing a correction was obtained by multiplying the percentage responding that they had ever worn glasses or contact lenses by the percentage who still wear a refractive correction (Table 1). For ages 35 to 44 for example, 58.8% of the sample indicated that they had worn a correction at some time. Of those, 79.2% still wore a correction, indicating that 46.6% of the sample currently wore a correction. The prevalence of myopia was obtained by multiplying the probability of wearing a correction by the prevalence of correcting powers fitting the definition of myopia (Table 1). For ages 35 to 44, 66.6% of the 46.6% wearing corrections were wearing corrections with myopic powers, giving a prevalence of 31.0%.

The prevalences of myopia in each study were plotted by age and by year of birth and then examined for consistency of change between studies within each of these plots. If there were a cohort effect and the prevalence of myopia increased over time, the prevalence of myopia should be lowest for subjects born earlier in the century (1920, for example) and then should increase in a consistent manner to the highest prevalences for subjects born around 1940 who share common environmental exposures such as post-World War II prosperity and the introduction of television. A cohort effect would be inferred from a consistent pattern of change between studies in a plot by year of birth. In contrast, if a longitudinal effect of age were more important, then the prevalence of myopia should be highest for the youngest ages and then should decrease in a consistent manner to the lowest prevalences in the oldest subjects. A longitudinal effect of age would be inferred from a consistent pattern between studies in a plot by age. Because the NHANES data are from the early 1970s and the other studies are from the late 1980s, separated in time by approximately 18 years, a cohort effect would cause the NHANES data to be offset from those in the other studies in the age plot. The opposite would occur for a longitudinal age effect; the NHANES data would be offset from the others in a plot by year of birth (Table 2).

**RESULTS**

Various criteria for myopia can be used based on NHANES data: more myopic than $-0.10 \, \text{D}$, $-0.60 \, \text{D}$, or $-1.10 \, \text{D}$ spherical equivalent. Prevalences as a function of age and criterion for myopia are shown in Figure 1 along with the results for the other studies are from the late 1980s, separated in time by approximately 18 years, a cohort effect would cause the NHANES data to be offset from those in the other studies in the age plot. The opposite would occur for a longitudinal age effect; the NHANES data would be offset from the others in a plot by year of birth (Table 2).

**TABLE 1. Calculation of the Prevalence of Myopia from NHANES Data**

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>12–17</th>
<th>18–24</th>
<th>25–34</th>
<th>35–44</th>
<th>45–54</th>
<th>55–64</th>
<th>65–74</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ever wear glasses or contact lenses</td>
<td>36.8</td>
<td>53.0</td>
<td>54.2</td>
<td>58.8</td>
<td>89.3</td>
<td>94.9</td>
<td>96.7</td>
</tr>
<tr>
<td>Still wear them</td>
<td>82.1</td>
<td>82.9</td>
<td>77.6</td>
<td>79.2</td>
<td>96.8</td>
<td>98.5</td>
<td>97.8</td>
</tr>
<tr>
<td>Percentage wearing a correction (row 1 × row 2)</td>
<td>30.2</td>
<td>45.9</td>
<td>42.1</td>
<td>46.6</td>
<td>86.4</td>
<td>93.5</td>
<td>94.6</td>
</tr>
<tr>
<td>Corrections with any minus SEQ</td>
<td>87.1</td>
<td>84.8</td>
<td>77.6</td>
<td>66.6</td>
<td>40.0</td>
<td>19.8</td>
<td>15.7</td>
</tr>
<tr>
<td>Prevalence of myopia (row 3 × row 4)</td>
<td>26.3</td>
<td>37.3</td>
<td>32.6</td>
<td>31.0</td>
<td>34.6</td>
<td>18.5</td>
<td>14.8</td>
</tr>
</tbody>
</table>

Prevalence was calculated by multiplying the percentage of subjects wearing a correction by the percentage of correcting SEQ powers more minus than $-0.10 \, \text{D}$. 

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The basic pattern of change with age did not appear to depend on
the criterion chosen, particularly after the age of 40 years. The
prevalence of myopia increases in early adulthood, was rela-
tively stable from the early 20s to age 50 years and then
decreased after age 50 years. Myopia was defined as any minus
spherical equivalent in this report, to maintain consistency
with the treatment of NHANES data by Sperduto et al.4

Results using this criterion for NHANES data are displayed
in Figure 2, along with data from the three more recent
studies.1–3 In general, the prevalence of myopia decreased for
ages older than 40 to 50 years. Prevalences vary widely be-
tween studies, however, making it difficult to examine the data
for possible longitudinal or cohort effects. The prevalence of
myopia in young adults using NHANES data was approximat-
ely 30%, whereas the prevalence from Framingham data was
higher than 50%. If the NHANES data are “aged” by shifting
them to the right, under the assumption that these subjects did
not change in their prevalence of myopia but were examined
approximately 18 years later at the time of the three other
investigations, several NHANES data points would fall in line
with the Framingham data (e.g., age 39.5 and age 59.5 years for
NHANES data in Fig. 2), and some would not (e.g., age 49.5
years).

These comparisons would be simplified if the prevalences
were on a similar scale across studies. We assume that the
trends with age within a study are independent of any bias
from sampling, measurement method, or myopia criterion dif-
fences between studies. Therefore, rescaling data should
facilitate comparison between studies without obscuring any
such trends. Prevalences from each study were therefore re-
calculated as a percentage of the prevalence in age groups with
midpoints from 44.5 to 49.5 years and plotted as a function of
age (Fig. 3A). The reference age interval was chosen to fall
within 5 years of the first midinterval reported in the Baltimore
Eye Survey,2 44.5 years, and to be old enough to be relatively
unconfounded by accommodative effects during testing—i.e.,
aged more than 40 years. This same procedure was then used
according to year of birth, with the data recalculated as a
percentage of the prevalence among those born between 1940
and 1942 (Fig. 3B). The reference year 1942 corresponds to the
midinterval of the youngest subjects in the Baltimore Eye
Survey. As can be seen in Figure 3A where the data were scaled
with reference to the prevalence of myopia for the age interval
44.5 to 49.5 years and plotted as a function of age, the agree-
ment between studies was very close. These scaled relative
prevalences declined to 50% by age 60 years. The discrepancy
between studies as a function of age during the period of most
rapid change was on the order of only 5 years.

The agreement between studies was much poorer when
data were scaled with reference to the prevalence of myopia
for those born between 1940 to 1942 and plotted as a function
of year of birth (Fig. 3B). The prevalence of myopia began to
increase in NHANES data for those born around 1912, but the
other studies suggested the prevalence increased for those
born around 1930—a difference of 18 years. It could be hy-
pothesized that there were two periods of increasing preva-
lence: 1912 and 1930. The NHANES data were inconsistent
with this notion, however. NHANES relative prevalences were
very similar at 0.95 and 1.00 for 1932 and 1942, respectively,
when the other studies were showing a dramatic increase.
Clearly, the fit is better when the data were plotted by age than
when plotted by year of birth. This suggests that the decrease in
the prevalence of myopia reported in recent studies is a prod-
uct of longitudinal changes in the prevalence of myopia with

<table>
<thead>
<tr>
<th>Plot by Age</th>
<th>Plot by Year of Birth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cohort effect</td>
<td>NHANES results offset from others</td>
</tr>
<tr>
<td>Longitudinal age effect</td>
<td>Consistent change for all studies</td>
</tr>
</tbody>
</table>

FIGURE 1. The prevalence of myopia from NHANES data using different criteria for myopia: (○), −1.10 D; (●), −0.60 D; and (□), −0.10 D. Data from Sperduto et al.4 are plotted for comparison. In all figures, age is plotted as the midpoint of the age range.

FIGURE 2. Prevalences of myopia from various studies plotted as a function of age: (○), NHANES data from Table 1; (□), Beaver Dam Eye Study1; (△), Baltimore Eye Survey2; and (■), Framingham Offspring Eye Study.3
Results from studies conducted nearly 20 years apart indicate that the prevalence of myopia decreases after approximately age 45 to 50 years as part of the aging process. There is some evidence for a physiologic basis for such a change, namely a decrease in the equivalent refractive index of the crystalline lens reported in recent biometric studies of older adults. The radii of curvature of the anterior and posterior surfaces of the crystalline lens are reported to steepen with age, with accompanying increases in the thickness of the crystalline lens and decreases in the depth of the anterior chamber. Each of these effects would create a more myopic refractive error if all other parameters remained constant, the first being the most important. Because the axial length of the eye does not appear to decrease with time, the proposed solution to this so-called “lens paradox” is a decrease in crystalline lens refractive index. We propose that this effect not only makes emmetropic and hyperopic adults more hyperopic but may also eliminate low degrees of myopia in older adults. Our analyses are based on cross-sectional data and therefore cannot document that changes in refraction occurred in individuals over time. Indeed, longitudinal data from young adult myopes indicate that their myopia continues to progress. However, retrospective longitudinal data for older myopic adults indicate that decreases in myopia can occur after age 40 years and predominate over myopic progression after age 50 years.

As in Sperduto et al., the only exclusions were for missing or incomplete data; subjects were not excluded from NHANES data on the basis of acuity or disease, including cataract. A bias toward a hyperopic shift with age may be created by cataract removal. The shift in the distribution of correcting powers for NHANES data were on the order of 3 D, from moderate myopia to low hyperopia, or from low myopia to moderate hyperopia. This magnitude of change was well below what would be expected from cataract extraction. Intraocular lens implantation could create near emmetropia after cataract surgery but was not in common practice in 1971 and is therefore an unlikely source of erroneous “emmetropization.” The impact of cataract surgery as judged from the increase in high plus corrections appears to be small, increasing from 1.8% of corrections at age 49.5 to 4.6% at age 69.5 years. Cataract extraction was not an issue in the other three studies, because subjects’ eyes were phakic.

Both our analysis and that of Sperduto et al. draw on NHANES data, yet prevalences calculated in Table 1 are generally higher by approximately 7 to 10 percentage points than those reported by Sperduto et al. There are three sources of missing data in NHANES that may be responsible for these differences. Only 35 groups of subjects from the planned 65 groups, or stands, received eye examinations. Medical history data for the full 65-stand sample used in Table 1 and the 35-stand subsample are very consistent, however, resulting in similar estimates of the percentage wearing a correction. Within the 35-stand sample, 27.2% of subjects were not examined. It was assumed that matching for age, sex, race, and income class replaced missing data in an unbiased fashion. A third source of missing data occurred because approximately 15% of subjects either had missing data or wore no glasses, had acuity from 20/25 to 20/40 that improved with a pinhole, did not undergo measurement of refractive error, and were therefore excluded from the analysis. Roughly 4% of subjects had insufficient refractive data, placing perhaps 11% of subjects in the latter category. Bias from excluding subjects who would be expected to have low degrees of myopia was reported to be small, estimated at approximately 1%, but the authors acknowledge that “there is no substitute for complete ascertainment.” Any of these people who had glasses but did not bring them to the examination would have been included as glasses wearers in the NHANES medical history and as myopes in our analysis of NHANES data but would have been excluded by Sperduto et al. Additionally, the roughly 4% of subjects with insufficient refractive data represent between 7.5% and 18.9% of subjects.
known to wear a correction.\textsuperscript{5} Again, these people would be represented as glasses wearers in our analysis but would have been excluded by Sperduto et al.\textsuperscript{4} It is difficult to estimate the precise impact of these missing data, but it may in part account for the 7- to 10-percentage-point difference seen in Figure 1. It is encouraging that these data follow a pattern similar to those from Sperduto et al.\textsuperscript{3} We therefore assume that scaling the data relative to the prevalence in a reference group results in an unbiased picture of change as a function of age, regardless of the source of the differences in prevalence for any one age group.

Our conclusions are based on comparison of several studies and are therefore more limited than if the data were drawn from a single study or were longitudinal. These studies differ in their sampling methods, in the regions of the country sampled, and possibly other sample demographics, and in measurement methods. The definition of myopia differed in magnitude, or was based on various criteria such as wearing glasses, on the self-report of wearing glasses, or on measured refractive error. The selection of ages for comparison was not always clear. The Framingham Offspring Eye Study included younger subjects, making the selection of the reference age somewhat arbitrary but perhaps not critical. Although these data could have been scaled with age 39.5 years serving as the reference group instead of 49.5 years, this would have resulted in a poorer fit by approximately 5 years on the x-axis for both Figures 3A and 3B, pointing to the same conclusion.

Another interesting feature of the Framingham Offspring Eye Study is the high prevalence of myopia among the young (\textgtrapprox 50\%) even with a conservative criterion for myopia.\textsuperscript{3} These data suggest that the prevalence of myopia may be increasing for those born after 1940 and may be coupled with a continual age-related decline. It should be acknowledged that our analysis can not rule out simultaneous cohort effects. Increases in the prevalence of myopia in more recent birth cohorts could be obscured by our recalculation of relative prevalences. Although some simultaneous cohort effect is possible, it seems unlikely to be a major one. Increasing prevalences in more recent birth cohorts would be inconsistent with the narrow range of prevalences found for similar birth years in the larger sample from NHANES (Fig. 2). The precise source of the divergence between these studies is unknown, but one possibility is accommodative effects in younger subjects from non-cycloplegic autorefractor used in the Framingham Offspring Eye Study. It is possible that a subject may be classified incorrectly as myopic because of instrument-induced accommodation, although he or she neither wears glasses nor has reduced uncorrected acuity. The impact on this current analysis should be minimal, because accommodative autorefractor effects would be expected to disappear with presbyopia. Despite the acknowledged limitations of our approach, it appears more likely that the roughly 2.5 times decrease in the prevalence of myopia among those 45 to 75 years old is predominantly, although perhaps not exclusively, an age-related change rather than a cohort effect.

National surveys of refractive error seem worthwhile investments from a public health standpoint of understanding the need for eye care but also for providing more precise information regarding the nature and cause of these trends. Asian countries such as Singapore report an increasing prevalence of myopia among nonpresbyopic adult males.\textsuperscript{10} Intense near work demanded by the reading and study that accompany an increasing level of education are cited as possible reasons for this increase in prevalence. Concerns about the possible effects of near work and education are shared by researchers in the United States, although all admit it is difficult to separate the effects of near work from hereditary factors.\textsuperscript{1,3,10} Determining whether prevalences among young adults are indeed constant over time will place a valuable perspective on whether computer use, playing video games, watching television, reading, and performing other forms of close work increase the risk of myopia. The increasing number of refractive surgeries performed in the United States also adds value to understanding the behavior of refractive error throughout a person’s lifetime. It is to be hoped that future surveys on the scale of NHANES will continue to examine trends in refractive error across the lifetime of increasingly “graying” Americans. Our analysis of data from the United States suggests that the age-related decline in the prevalence of myopia is more an intrinsic feature of aging than evidence for the impact of changes in near work demands over the years.

References