The Changing Prevalence of Myopia in Young Adults: A 13-Year Series of Population-Based Prevalence Surveys

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PURPOSE. To determine the changing prevalence of myopia during the years 1990 through 2002 among the 16- to 22-year age group and identify possible risk factors.

METHODS. A retrospective study, based on 13 repeated prevalence surveys conducted over a 13-year period. The study subjects were all Israeli nationals belonging to the 16- to 22-year age group from the years 1990 to 2002. Refraction was determined by using subjective visual acuity followed by noncycloplegic autorefraction and subjective validation based on the autorefraction results. Mild myopia was defined as a refractive error of -0.50 to -3.00 D in at least one eye, moderate myopia as -3.25 to -6.00 D, and high myopia as more than -6.00 D.

RESULTS. There were 919,929 subjects (382,139 [42%] females and 537,790 [58%] males) included in the study. The overall prevalence of myopia increased from 20.3% in 1990 to 28.3% in 2002. The prevalence of high, moderate, and mild myopia significantly increased in males from 1.7%, 5.7%, and 11.6% in 1990 to 2.05%, 7.2%, and 16.3% in 2002, respectively (P < 0.001). In females, the prevalence of myopia increased from 1.9%, 6.6%, and 13.5% in 1990 to 2.4%, 9.2%, and 20.7% in 2002, respectively (P < 0.001). A correlation between myopia and the number of years of education was observed. Non-Israeli origin was found to be a significant risk factor for myopia.

CONCLUSIONS. During the 13 years from 1990 to 2002, the prevalence of myopia significantly increased among the Israeli population. Although there was an association with the level of education, gender, ethnicity, and origin, the prevalence of myopia increased on an annual basis, independent of these factors. (Invest Ophthalmol Vis Sci. 2005;46:2760–2765) DOI: 10.1167/iovs.04-0260

Myopia is defined as nearsightedness caused by an incongruity between the power of the optical elements of the eye and its axial length. The object image is projected in front of the retina, and corrective lenses are necessary to displace the image backward, thus producing a clear retinal image.

Although the causes of myopia are unclear, evidence supports both genetic and environmental components, among which are higher amounts of near work,1,2 years of education,3 and intelligence.4 Racial differences in the prevalence of myopia are well documented as well. The prevalence of myopia has been reported to be as low as 2% to 5% in Australian Aborigines5 and Solomon Islanders,6 and as high as 50% to 80% in Asian students.7 In a comparative study in urban Americans, the prevalence of myopia was found to be significantly lower in African American subjects than in whites.8 In a 1991 survey, conducted on an unselected sample of Israeli adolescents, the prevalence of myopia was estimated to be 18%.9

Many studies of the prevalence of myopia have been conducted over the past century, however population-based longitudinal surveys on this important problem are scarce.

In the past decade, evidence has accumulated suggesting a continued increase in the prevalence of myopia. The magnitude of the problem and its potential economic and social impact call for an in-depth study.10,11 The purpose of this population-based study was to determine the change in the prevalence of myopia in the 16- to 22-year age group, during the years 1990 to 2002, and to identify possible risk factors.

MATERIALS AND METHODS

Subjects

On reaching the age of 16, all Israeli nationals are considered candidates for security service and therefore are obliged by law to appear at the Israel Defense Forces recruiting office. This requirement does not include Israelis of Arab origin or Ultraorthodox Jews, who are exempted from military service by law. The candidates undergo an extensive examination process, including a comprehensive medical examination and sociodemographic profiling. All information regarding the candidates is stored in a large, computerized database, from which all the statistics for this study were extracted.

All candidates for military service aged 16 to 22 years who appeared before the recruitment office from 1990 to 2002 and underwent the medical examination were included in the study.

The medical examinations, as well as the entire process just described, are part of an obligatory screening plan encoded in Israeli law, and they therefore cannot be considered to be experimentation on human subjects. The privacy of the subjects was protected according to the guidelines set forth in the Declaration of Helsinki.

Visual Acuity

As part of the standardized examination, each candidate had his or her best-corrected visual acuity determined by a qualified technician, using a standard Snellen chart. Subjects who could read at least all the letters but one of the 6/6 line, without optical correction, were assumed to have 0 D refractive error. Subjects wearing glasses or contact lenses who could read at least all the letters but one of the 6/6 line with their present optical correction had the power of this correction recorded and assumed as their present refraction. Refraction was performed if a candidate was unable to read all the letters but one of the 6/6 line. Initially, an objective noncycloplegic refraction was performed with an automatic refractometer (Speedy K; Nikon Corp., Tokyo, Japan; KR-8000 and KR7000S, Topcon, Tokyo, Japan and earlier models). This...
### Table 1. Characteristics of Candidates over 13 Years

<table>
<thead>
<tr>
<th>Year</th>
<th>Male, n (%)</th>
<th>Female, n (%)</th>
<th>&lt;12 y of Education</th>
<th>≥12 y of Education</th>
<th>Israeli Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>33212 (58.6)</td>
<td>23427 (41.4)</td>
<td>10472 (18.5)</td>
<td>46167 (81.5)</td>
<td>412 (7.5)</td>
</tr>
<tr>
<td>1991</td>
<td>40095 (58.1)</td>
<td>28953 (41.9)</td>
<td>9586 (13.9)</td>
<td>59462 (86.1)</td>
<td>415 (6.2)</td>
</tr>
<tr>
<td>1992</td>
<td>43015 (57.9)</td>
<td>31309 (42.1)</td>
<td>11282 (15.2)</td>
<td>63042 (84.8)</td>
<td>446 (6.0)</td>
</tr>
<tr>
<td>1993</td>
<td>41976 (56.6)</td>
<td>32179 (43.4)</td>
<td>10854 (14.6)</td>
<td>63501 (85.4)</td>
<td>458 (6.4)</td>
</tr>
<tr>
<td>1994</td>
<td>39809 (58.2)</td>
<td>28600 (41.8)</td>
<td>10606 (15.5)</td>
<td>57803 (84.5)</td>
<td>447 (6.6)</td>
</tr>
<tr>
<td>1995</td>
<td>37392 (61.0)</td>
<td>23877 (39.0)</td>
<td>9547 (15.3)</td>
<td>51922 (84.7)</td>
<td>393 (6.5)</td>
</tr>
<tr>
<td>1996</td>
<td>33889 (59.8)</td>
<td>22756 (40.2)</td>
<td>5474 (9.7)</td>
<td>51170 (90.3)</td>
<td>530 (7.1)</td>
</tr>
<tr>
<td>1997</td>
<td>37246 (57.3)</td>
<td>27789 (42.7)</td>
<td>7612 (11.7)</td>
<td>57418 (88.3)</td>
<td>421 (6.5)</td>
</tr>
<tr>
<td>1998</td>
<td>44001 (57.8)</td>
<td>32153 (42.2)</td>
<td>8787 (15.5)</td>
<td>57565 (88.5)</td>
<td>490 (6.6)</td>
</tr>
<tr>
<td>1999</td>
<td>46978 (59.0)</td>
<td>32669 (41.0)</td>
<td>9275 (16.6)</td>
<td>70572 (88.4)</td>
<td>475 (6.2)</td>
</tr>
<tr>
<td>2000</td>
<td>43773 (58.8)</td>
<td>30649 (41.2)</td>
<td>8437 (13.3)</td>
<td>65963 (88.7)</td>
<td>504 (7.0)</td>
</tr>
<tr>
<td>2001</td>
<td>46969 (58.6)</td>
<td>33247 (41.4)</td>
<td>9034 (13.1)</td>
<td>71022 (88.7)</td>
<td>602 (7.6)</td>
</tr>
<tr>
<td>2002</td>
<td>49435 (58.9)</td>
<td>34531 (41.1)</td>
<td>10010 (12.0)</td>
<td>73386 (88.0)</td>
<td>709 (8.6)</td>
</tr>
</tbody>
</table>

*P for trend*  
- Male: *P* < 0.01  
- Female: *P* < 0.01  

**Origin** was defined according to the 10% sample.

### Definition of Myopia Levels
Mild myopia was defined as a sphere of −0.50 to −3.00 D in at least one eye, moderate myopia as a refractive error between −3.25 and −6.00 D in at least one eye, and high myopia as myopia of more than −6.00 D. In addition, we calculated the prevalence of mild myopia with a stricter definition of −0.75 to −3.00 D for both genders.

### Years of Education
All candidates are obliged by the recruitment office to complete a form with sociodemographic data including years of education. The data are validated again on the day of recruitment. The prevalence of myopia was recorded annually for five groups based on school years: 8 or fewer and 9, 10, 11 and 12 or more. It should be emphasized that all candidates are given the opportunity to complete a full 12 years of education before recruitment.

### Origin
Origin was classified according to the father’s country of birth. If this was Israel, it was defined according to the paternal grandfather’s place of birth. It was then categorized into three origin groups: Western included subjects whose country of origin was in Europe (excluding Turkey), the Americas, Australia, or South Africa; Eastern included subjects whose country of birth was in Asia, Turkey, North Africa, or Ethiopia; and Israeli included subjects whose country of origin was Israel (both their father and paternal grandfather were born in Israel).

Because the Israeli Defense Forces (IDF) determines a person’s origin according to the father, the database used in this study does not include information about the mother’s origin.

### Data Analysis

The yearly prevalence of the three levels of myopia was calculated separately in males and females. The statistical significance of the yearly trend was calculated by using the \( \chi^2 \) test for trend. The prevalence of the three levels of myopia between males and females of the entire group was compared with the \( z \)-test. The prevalence of myopia according to the number of years of education was calculated and the statistical significance of the trend was examined using the \( \chi^2 \) test. Bivariate analysis of gender and level of education were conducted. The level of myopia in each education group (<12 or ≥12 years) was calculated with gender stratification. The rate ratio (the prevalence of myopia in the higher level of education group divided by the prevalence of myopia in the lower education group) and 95% confidence intervals (CI) for having each level of myopia according to the level of education were calculated. We also calculated the rate ratio and 95% CI of the prevalence of each level of myopia (mild, moderate, and severe) between 2002 and 1990. These calculations were performed with gender stratification. Finally, we performed a multivariate analysis of individual data of a randomly selected sample of 10% of each year's data, using logistic regression models. This analysis was performed because of the large number of subjects in the original database (919,929). The sample size gives a power of 100% when comparing the prevalence of myopia among the different gender, origin, year of recruitment, and level of education groups. In these models, the outcome variable was myopia (of any kind or different levels in each model); the independent variables were gender, years of education, and origin (as categorical variables); and the continuous variable was the year of recruitment.

### RESULTS

Since 1990, a total of 991,929 candidates for security service (382,193 [42%] females and 537,790 [58%] males, aged 16 to 22 years, had visual acuity evaluated in accordance with the protocol described herein. Basic characteristics of the subjects in each year are presented in Table 1. When calculated separately for each year of recruitment, the candidates’ average age was 17.

The overall prevalence of myopia in this age group increased over the 13 years of the study, from 20.3% in 1990 to 28.3% in 2002. The prevalence increased among the males from 19.0% in 1990 to 25.5% in 2002 (34.1% increase; \( P \) for trend < 0.001), and from 22.08% in 1990 to 32.27% in 2002 (46.2% increase; \( P \) for trend < 0.001) among the females (Fig. 1). Furthermore, these findings were validated in the subgroup analysis of the three different levels of myopia for both genders (\( P \) for trend < 0.001 for all three levels of myopia in both genders). Among the males, the rate ratio of the prevalence of mild, moderate, and severe myopia from 1990 to 2002 was 1.41 (95% CI: 1.36–1.46), 1.26 (95% CI: 1.20–1.33), and 1.21 (95% CI: 1.09–1.33), respectively. Among females, these rates were 1.53 (95% CI: 1.48–1.59), 1.39 (95% CI: 1.31–1.48), and 1.26 (95% CI: 1.13–1.42), respectively.

To ascertain that the increase in the prevalence of mild myopia was not influenced by our relatively liberal definition of mild myopia (−0.50 to −3.00 D), we recalculated the prevalence with a stricter definition (−0.75 to −3.00 D) for both genders. Again, we found that the prevalence of myopia ac-
According to this definition increased from 7.8% in 1990 to 14.7% in 2002 (P for trend < 0.0001) among the males and from 9.2% in 1990 to 18.3% in 2002 in the females (P for trend < 0.0001).

During the period of this study, a mild increase in the education level of the male candidates was observed. In 1990, 75% of the male candidates had 12 years of schooling or more compared with 85% in 2001. In contrast, no similar trend was detected in the females. In 1990, 91% of female candidates had 12 years of schooling compared with 93% in 2001.

The prevalence of myopia correlated positively with a higher level of education as expressed in school years (Fig. 2). For the male group with 8 and less years of education, the prevalences of mild, moderate, and high myopia were 4.7%, 1.7%, and 0.7%, correspondingly, whereas they increased to 16.0%, 7.7%, and 2.2%, correspondingly, in the male group with ≥12 years of education (P for trend < 0.001 for all three levels of myopia). In the female group with ≥8 years of education, prevalences of mild, moderate, and high myopia were 3.5%, 1.5%, and 0.4%, whereas they increased to 18.8%, 8.7%, and 2.4%, correspondingly, in the female group of with ≥12 years of schooling (P for trend < 0.001 for all three levels of myopia). Candidates with ≥12 years of education had almost twice the risk of having myopia than did candidates with <12 years of education. In males with ≥12 years of education, the risk ratio for the development of mild, moderate, or high myopia was 1.8 (95% CI: 1.77–1.85) and 1.87 (95% CI: 1.75–1.98), correspondingly, when compared with males with <12 years of education. In females, this risk calculation was 1.48 (95% CI: 1.44–1.52), 2.07 (95% CI: 1.96–2.18), and 2.21 (95% CI: 1.99–2.45) for mild, moderate, and high myopia, respectively.

An analysis of the entire study population revealed that female gender is a statistically significant risk factor for all three levels of myopia. The prevalences of mild, moderate, and high myopia among females were 18.24%, 8.30%, and 2.26%, correspondingly—significantly greater than the prevalences of myopia in males, which were 14.68%, 6.96%, and 1.99%, respectively (P < 0.001 for all three levels of myopia).

In a multivariate analysis, it was found that female gender, ≥12 years of education, and non-Israeli origin (either Western or Eastern origin, as defined in the Methods section) are independent risk factors for myopia. Although the year of recruit-
ment appeared to be a relatively low (but positive) risk factor per year, when it was considered on a continuous basis over 13 years, it became one of the most significant risk factors (Table 2).

**DISCUSSION**

To our knowledge, this article describes the largest population-based study estimating the prevalence of myopia in an unsampled population of young adults. We have found a 40% increase in the prevalence of myopia from 20.3% in 1990 to 28.3% in 2002 among Israeli young adults. The increase was most prominent in the subgroup of mild myopia and less prominent in the subgroup of high myopia. This difference can be explained by the assumption that the development of mild myopia may be associated with environmental factors, whereas high myopia may be more influenced by a genetic predisposition.

These findings confirm those in previous studies, which indicate an increase in the prevalence of myopia in this age group. In a 13-year period, the prevalence of myopia increased from 49.3% to 65.6% in Japanese students aged 17 years. In the Beaver Dam Eye Study, the prevalence of myopia was higher among young individuals than among older ones. However, when The Beaver Dam Eye Study was analyzed in comparison to earlier studies, it was concluded that the change in prevalence could be attributed to an intrinsic age-related decrease in an individual's amount of myopia, rather than a cohort effect of increasing prevalence over time. Yet, that study by Mutti and Zadnik dealt with subjects who were considerably older than the subjects in our surveys and referred to a period preceding ours—before the massive expansion of computers and Internet utilization in everyday life. This change, in our opinion, is an important factor in the increasing prevalence of myopia.

In a recently published paper summarizing the results of five surveys conducted over a period of 20 years in Taiwan between 1983 and 2000, an increase in the prevalence of myopia was also observed. In that study, the prevalence increased from 74% in 1983 to 84% in 2000 in children aged 16
to 18 years. Whereas the Taiwanese study was designed prospectively and sampled only a small fraction of the population, our study retrospectively analyzed data collected on an entire nonselected population. Another key difference between the two studies is the utilization of the objective cycloplegic refraction in the Taiwanese study, whereas in our study only the sphere of the noncycloplegic subjective refraction was used for analysis.

We are aware of the fact that noncycloplegic refraction is less accurate and results in a slight overestimation of myopia, especially in younger ages, due to pseudoaccommodation. Nonetheless, it has been established that it becomes less of a problem in older ages: above 11 years. Although our results may slightly overestimate myopia throughout the 13 surveys, it has little bearing on the main outcome, which is the trend of increasing prevalence over time. Furthermore, the use of the manifest refraction performed after the objective noncycloplegic one, reinforces the validity of the first. Defining the minimum criteria for myopia as $-0.5$ D helps eliminate many emmetropes experiencing pseudoaccommodation during autorefraction. The fact that using a stricter definition for mild myopia did not influence the main outcome of this study reinforces the results. However, it produces a significant decrease in the number of myopic subjects in this group, perhaps in part because, as myopia got more severe, fewer subjects had it—inside every subgroup, as well as between the subgroups. Another possible explanation is the elimination of even more emmetropes experiencing higher amounts of pseudoaccommodation during the examination.

The female gender and years of education were found to be independent risk factors for the development of myopia. As observed in this study, a higher prevalence of myopia was also detected in Finnish female students and in the general female population of the United States compared with the male population. The prevalence of myopia among Greek female students was found to be 46%, whereas among male students it was only 29.7%. However, the prevalence of myopia among Orthodox Jews was found to be 17% more frequent in males than in females. Given that our study excluded Orthodox Jews, the results presented are more comparable to those observed in non-Jewish populations.

Other studies have also found that the educational level correlates with the development of myopia in a linear fashion. It has also been hypothesized that myopia’s prevalence in different age groups is proportional to the amount of education of each group. This may explain the high prevalence of myopia in medical students in Norway (54.1%) and the low prevalence in a rural Indian population (2.8%), which has a high rate of illiteracy.

In the multivariate analysis that neutralized factors such as years of education, origin, and gender, an annual increase in the prevalence of myopia was still observed. What is the cause, then, of this increase? A characteristic feature of the past 10 years is the expanding use of computers for many purposes. The utilization of computers in everyday life has been a significant factor in the prevalence of myopia among children. In 1992, 22.8% of Israeli nationals owned a personal computer, as opposed to 49.8% in 2001. The relation between near work and myopia has been demonstrated in many settings. It was even shown to reverse the female-to-male positive ratio of myopia prevalence, as shown by Zilberman et al. in his study of Orthodox Jews. This reversal is attributable to a more demanding and continuous amount of near work that males experience during their studies, although they spend the same number of years in school as females.

Our study raises the need for a different universal measure to assess the accumulating lifelong amount of near work executed by an individual. This indicator must reflect factors other than school years or formal education (e.g., the expanding recreational and educational use of computers and the growing utilization of the Internet, pocket personal computers, and hand-held electronic games). It is reasonable to assume that among young adults with $\geq 12$ years of education, all other types of near work has increased during the past decade.

In conclusion, this study confirms previous observations that the prevalence of myopia has increased during the past decade. This 40% increase in prevalence in only a decade in Israel warrants further in-depth research.

**References**


**Table 2. A Multivariate Analysis of the Risk of Having Myopia**

<table>
<thead>
<tr>
<th>Level of Myopia</th>
<th>Any</th>
<th>Mild ($-0.50$ to $-3.00$)</th>
<th>Moderate ($-3.25$ to $-6.00$)</th>
<th>High (More Than $-6.00$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>OR</td>
<td>95% CI</td>
<td>OR</td>
<td>95% CI</td>
</tr>
<tr>
<td>Gender (females vs. males)</td>
<td>1.24</td>
<td>1.21–1.27</td>
<td>1.27</td>
<td>1.24–1.31</td>
</tr>
<tr>
<td>Years of Education ($\geq 12$ vs. $&lt; 12$)</td>
<td>1.90</td>
<td>1.85–1.95</td>
<td>1.75</td>
<td>1.69–1.81</td>
</tr>
<tr>
<td>Origin</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>East vs. Israel</td>
<td>1.23</td>
<td>1.17–1.29</td>
<td>1.25</td>
<td>1.18–1.32</td>
</tr>
<tr>
<td>West vs. Israel</td>
<td>1.28</td>
<td>1.22–1.34</td>
<td>1.27</td>
<td>1.20–1.34</td>
</tr>
<tr>
<td>Year of recruitment (continuous)</td>
<td>1.05</td>
<td>1.046–1.054</td>
<td>1.05</td>
<td>1.045–1.055</td>
</tr>
</tbody>
</table>

Data were analyzed according to gender, years of education, origin, and year of recruitment (between 1990 and 2002).