Darkness and Near Work

Myopia and Its Progression in Third-year Law Students

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Purpose: To evaluate myopia prevalence, myopia progression, and various potential myopia risk factors in third-year law students.

Design: Cross-sectional study and survey.

Participants: One hundred seventy-nine third-year law students at the University of Pennsylvania.

Methods: We administered a questionnaire to assess the prevalence of myopia, myopia progression, and risk factors, including near work, family history, and daily light/dark exposure. We conducted a screening eye examination to ascertain myopia status. Myopia was defined as the mean spherical equivalent of the two eyes of ≤ -0.5 diopters; myopia progression was defined by the self-reported need for a stronger eyeglass prescription during law school.

Main Outcome Measures: (1) prevalence of myopia, (2) progression of myopia.

Results: Seventy-nine percent of the class participated (n = 179, two were excluded for amblyopia leaving 177 students). Fifty-eight percent were male, 75% were Caucasian, and the mean age was 27 years. Seventy-nine percent reported parental myopia. The mean amount of near work was 7.4 hours/day; mean sleep was 7.9 hours/day; mean darkness was 5.3 hours/day. Sixty-six percent of the students were myopic. Of 96 participants myopic before law school, myopia increased in 83 (86%) during law school. Among 75 students not myopic at the beginning of law school, 14 (19%) became myopic. The onset of myopia could not be determined for 6 patients. There were trends for higher myopia prevalence among those with a parental myopia history ($P = 0.14$) and for increased myopia progression among those reporting more daily near work ($P = 0.18$). Students with $\leq$5.6 hours of daily darkness were more likely to report myopia progression than those with $>$5.6 hours of darkness per day (95% vs. 80%, $P = 0.07$). To account for possible confounding effects of risk factors with myopia progression, logistic regression with categorization of the continuous exposure variables (hours of near work, sleep, and darkness) above or below median values weakened the near work association (odds ratio 1.8, 95% confidence interval 0.5–6.7, $P = 0.35$) but continued to identify darkness association with daily hours of darkness (odds ratio 4.8, 95% confidence interval 1.0 $\geq$ 23.3, $P < 0.05$). Among the 77 students with myopia onset before college, those with $\leq$5.6 hours of daily darkness were more likely to progress than those with more hours of daily darkness (97% vs. 76%, $P = 0.01$).

Conclusions: This study confirms high rates of myopia prevalence and myopia progression among law students. The strongest association, especially in those with myopia onset before college, was a relation of myopia progression during law school with less daily exposure to darkness, a potential risk factor previously identified in childhood myopia. The role of exposure to darkness in refractive development warrants additional study. *Ophthalmology 2002;109:1032–1038 © 2002 by the American Academy of Ophthalmology.*

The specific risk factors responsible for myopia and its increasing worldwide prevalence are uncertain, but available evidence suggests a multifactorial cause with interplay between environmental and genetic factors.[1] Higher level of education is one of the classic risk factors associated with myopia, and a high prevalence of myopia in the graduate school population has been established numerous times in school-based surveys.[2–10] In what we believe to be the initial study of US law students, myopia was found to be more prevalent among 100 randomly selected male graduate law and business school students than was previously reported for unselected males of similar age, and it was stated that “many show change in a minus direction” during their continued years of study at graduate school.[2] These impressions have been confirmed in another study that both surveyed 87 law students and followed prospectively 16 others for 6 months.[5]

To explore candidate risk factors for myopia and myopia

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progression among a population of highly educated young adults at presumed increased risk, we undertook a cross-sectional study of University of Pennsylvania law school students at the end of their third academic year. We assessed a number of classic risk factors. We specifically asked whether myopia onset occurred before or after college matriculation to distinguish juvenile-onset from early adult-onset myopia,[11] a stratification that may have etiologic significance. In addition, we recently proposed perturbations in the daily light-dark cycle as a novel,[12] although controversial,[13–15] risk factor for myopia development in young children. Accordingly, we also sought to learn whether any systematic daily pattern of light and dark might relate to refractive changes in this older population.

Patients and Methods

Over a 6-week period beginning in March 2000, we invited all students completing their third and final academic year at the University of Pennsylvania School of Law to participate in this study. The Institutional Review Board at the University of Pennsylvania approved the study, and all participating students provided informed consent.

The students were asked to complete a questionnaire designed to assess the prevalence of myopia, myopia progression, and possible risk factors. These included classical risk factors such as age, amount of near work, race, medical and ophthalmic history, and parental myopia history. To assess ambient light exposure, we asked: (1) whether their bedrooms were lit with artificial light during sleep; (2) their customary times of going to sleep and waking up, both during the school year and during summer breaks; and (3) their geographic locations during summer breaks to identify any extended time spent in regions with patterns of natural light exposure markedly different from Philadelphia. The subjects were asked when they started to wear corrective lenses, the reason why they wore corrective lenses, if they experienced a lens prescription change during law school, and whether any new lens prescription during law school was stronger or weaker. The subjects also were asked to provide their current eyeglass or contact lens prescription.

Examination Procedures

In addition to the questionnaire, all subjects were invited to participate in a screening eye examination at the law school that included visual acuity, autorefraction, and measurement of eyeglass prescription with a lensometer. Best-corrected visual acuity was assessed with Early Treatment of Diabetic Retinopathy Study charts using a testing procedure adapted from the Amblyopia Treatment Study[16] (illumination at the chart's surface was at least 10 candelas/m^2). Chart 1 was used for the right eye and Chart 2 for the left eye. Refraction was measured bilaterally with a Nikon Retinomax autorefractor (Nikon Corporation, Kawasaki, Kanagawa, Japan) without cycloplegia.

Analysis

Myopia was defined on a per student basis as the mean spherical equivalent refraction (MSE) of both eyes of ≤ -0.5 diopters (D) at the end of law school. Myopia progression was defined as a self-reported need for a stronger myopic spectacle prescription during law school.

Students were classified as having myopia at the end of law school if the results from the questionnaire and examination indicated an MSE of ≤ -0.5 D. Some students, however, either did not bring their corrective lenses to the screening eye examination or did not attend the examination. To enroll as many students as possible with an accurate diagnosis of the presence or absence of myopia, the following hierarchy of conditions was used to define myopia: (1) use of corrective lenses and an MSE ≤ -0.5 D as documented by a contact lens prescription or lensometer reading (n = 98); (2) use of corrective lenses and an MSE of ≤ -0.5 D as measured by the autorefractor (n = 8); (3) use of corrective lenses attributed to nearsightedness by the student and no other information available on refractive error or visual acuity (n = 8); and (4) no reported use of corrective lenses, but reduced uncorrected visual acuity (20/40 or worse) in at least one eye and an MSE ≤ -0.5 D as measured by the autorefractor (n = 2). The assumption of condition 3, that students could be classified accurately as myopic based on self-reporting without independent confirmation of refractive error, is justified, because of the students who reported nearsightedness as the reason for the use of corrective lenses and also had measurements from their lenses, all 95 had an MSE ≤ -0.5 D. Students who did not wear corrective lenses with an MSE of $\leq$ 0.5 D of myopia and who did not have reduced uncorrected visual acuity attributable to myopia were classified as not having myopia.

Hours of near work, hours of sleep, and hours of darkness were calculated on weekdays and weekends during the school years and summer breaks, and weighted averages were calculated using 8.5 months for the school year and 3.5 months for the summer break. Regarding the darkness determinations, we calculated a weighted average of daily hours of dark based on student reported dark exposures during the course of the year. Most of the students reported sleeping at night without artificial lighting in their bedrooms throughout the entire year. For these, the period of darkness was calculated to start at the time of going to sleep, presumably when artificial lighting is turned off, and to end at the time of first light exposure in the day. The time of first light exposure was the earlier of either: (1) sunrise, assuming that some natural sunlight enters through bedroom windows; or (2) the time of awakening, assuming that students will turn on artificial lighting if awakening in the dark. Only six students reported using artificial lighting in their bedrooms while sleeping during school and breaks, and these were categorized as experiencing zero hours of darkness per day. For those students who spent summer breaks at markedly different latitudes from Philadelphia, dark exposures during school breaks were correspondingly adjusted to local sunrise times.

For the demographic and behavioral characteristics of the study participants, a descriptive analysis was performed examining grouped frequency distributions, means, and standard deviations. The associations of potential predictors (age, gender, race, family history of myopia, prematurity, hours of near work, hours of sleep, and hours of darkness) with myopia and with myopia progression were examined with the chi-square tests for independence, using tests for trend for ordered categories. Logistic regression was used to provide estimates of odds ratios and to adjust for the effects of potential confounding factors. Differences were considered statistically significant if $P < 0.05$. For the myopia progression analyses, the study population was restricted to the 96 myopic students who reported wearing glasses before law school. Hours of near work, hours of sleep, and hours of darkness were categorized with quartiles as cut points. Correlations among these three risk factors were also examined. As a further subanalysis, the association of myopia progression with hours of near work, hours of sleep, or hours of darkness was determined for those students who reported myopia onset before college.

Table 1. Demographic Characteristics of Third-year Law Students (n = 177)

Characteristic	Number of Students (%)
Age (yrs)	
21–25	70 (39.6)
26–30	92 (52.0)
31–35	10 (5.6)
36–45	5 (2.8)
Gender	
Male	103 (58.2)
Female	74 (41.8)
Race	
Caucasian	133 (75.1)
African American	17 (9.6)
Asian	10 (5.7)
Hispanic	9 (5.1)
Other	8 (4.5)
Prematurity	
Yes	8 (4.5)
No	169 (95.5)
Parental history of myopia	
Both parents myopic	78 (44.1)
One parent myopic	62 (35.0)
Neither myopic	37 (20.9)

Results

One hundred seventy-nine (79%) of the 226 third-year University of Pennsylvania Law School students who resided in the Philadelphia area during the period of the study elected to participate in the study. Two of these students were excluded from the analysis because of unilateral amblyopia.

Baseline characteristics of the 177 enrolled subjects are reported in Table 1. Fifty-eight percent were male, 75% were Caucasian, and the mean age was 27 years (range, 23–44 years). A high prevalence of myopia was noted among parents, with 79% of students reporting myopia in one or both parents. The mean amount of near work was 7.4 (range, 3.0–13.8; median, 7.3) hours/day. The mean amount of sleep was 7.9 (range, 5.8–9.7; median, 7.9) hours/day. The mean amount of darkness was 5.3 (range, 0.0–8.1; median, 5.6) hours/day. Hours of sleep positively correlated with hours of darkness ($r = 0.27$, $P < 0.01$) and negatively correlated with hours of near work ($r = -0.16$, $P < 0.05$). However, hours of darkness did not correlate with hours of near work ($r = -0.11$, $P = 0.16$).

Among the 177 students, 116 (65.5%) were myopic by the end of law school (Table 2). The median refractive error among the 108 students classified as myopic based on lensometry or autorefraction was −3.00 D (interquartile range, −5.00, −1.69). Of the 96 participants who were myopic before law school, myopia increased in 83 (86%) during law school. Even those myopes older than 30 years of age shared similar high rates of myopia progression (71%) with their classmates. Among the 75 students who were not myopic at the beginning of law school, 14 (19%) became myopic during law school. The onset of myopia could not be determined for six students.

Females and males showed similar prevalence rates of myopia at the end of law school (65% and 66%, respectively; Table 2). However, a higher percentage of females had become myopic before college (79% vs. 57%) and had progression of myopia during law school (91% vs. 83%), although neither of these gender differences reached statistical significance (Table 2). The prevalence of myopia at the beginning of law school and the incidence of progression within the categories of the potential risk factors are displayed in Table 3. Prevalence of myopia was relatively uniform within most of the categories; however, there was a trend for increased prevalence in students with two myopic parents ($P = 0.14$). Notably, though, even students who reported having no parents with a history of myopia had a high prevalence of myopia (22 of 37, or 60%). Incidence of progression increased with more hours of near work per day ($P = 0.18$) and with fewer hours of darkness per day ($P = 0.07$).

Table 2. Refractive Status and Myopia Progression in the Study Participants (n = 177)

	Number of Males (%)	Number of Females (%)	Totals (%)
Refractive status at end of law school			
Myopia	68 (66.0)	48 (64.9)	116 (65.5)
Nonmyopia	35 (34.0)	26 (35.1)	61 (34.5)
Time of myopia onset			
Before college	39 (57.4)	38 (79.2)	77 (66.4)
During college	13 (19.1)	6 (12.5)	19 (16.4)
During law school	11 (16.2)	3 (6.3)	14 (12.1)
Unknown	5 (7.4)	1 (2.1)	6 (5.2)
Myopia progression during law school*			
Yes	43 (82.7)	40 (90.9)	83 (86.5)
No	9 (17.3)	4 (9.1)	13 (13.5)

*Among students who were myopic at entry into law school.

The results in Table 3 do not account for the possibly confounding effects of other risk factors with myopia progression. Logistic regression analysis was used with categorization of the continuous exposure variables (hours of near work, sleep, and darkness) into groups with values above or below the median value. When the effects of hours of near work and hours of darkness were considered simultaneously, the near work association with myopia progression weakened (odds ratio, 1.8; 95% confidence interval, 0.5–6.7; $P = 0.35$), but the association of daily hours of darkness with myopia progression persisted (odds ratio, 4.8; 95% confidence interval, 1.0–23.3; $P < 0.05$). Additional analyses adjusting for gender, family history of myopia, and hours of sleep, as well as analyses excluding students older than 30 years of age did not appreciably alter the results.

For the students who reported myopia onset before college (n = 77), hours of darkness was significantly associated with myopia progression: those with ≤5.6 hours of daily darkness were more likely to have progressed than those with more hours of daily darkness (97% vs. 76%; $P = 0.01$). There was no relation of myopia progression and near work among these students ($P = 0.75$).

Discussion

Among surveys of refractive error among law students, this report includes the largest number of subjects from an individual school and corresponds to a high 79% participation rate of senior law students at the University of Pennsylvania. All data were collected over a 6-week interval at the end of the academic year, providing contemporaneous sampling. Within the constraint of not using cycloplegia in order to obtain this high participation rate during the academic year, we believe that we have obtained a valid refractive classification of the presence or absence of myo-

Table 3. Potential Risk Factors for Law Student Myopia and Myopia Progression

	Myopia* (n = 177)			**Myopia Progression† (n = 96)**		
Potential Risk Factors	*Total Student Numbers*	*Students with Myopia (%)*	*P*-value	*Total Student Numbers*	*Students with Progression (%)*	*P* Value
Age						
21–25	70	46 (65.7)	0.78	35	31 (88.6)	0.46
26–30	92	61 (66.3)		54	47 (87.0)	
31–35	10	6 (60.0)		4	3 (75.0)	
36–45	5	3 (60.0)		3	2 (66.7)	
Gender						
Male	103	68 (66.0)	0.87	52	43 (82.7)	0.24
Female	74	48 (64.9)		44	40 (90.9)	
Race						
Caucasian	133	83 (62.4)	0.45	68	58 (85.3)	0.79
African American	17	14 (82.4)		11	9 (81.8)	
Asian	10	8 (80.0)		8	7 (87.5)	
Hispanic	9	6 (66.7)		4	4 (100.0)	
Other	8	5 (62.5)		5	5 (100.0)	
Prematurity						
Yes	8	6 (75.0)	0.56	6	6 (100.0)	1.00
No	169	110 (65.1)		90	77 (85.6)	
Parental history of myopia						
Both myopic	78	56 (71.8)	0.14	46	39 (84.8)	0.94
One myopic	62	38 (61.3)		32	29 (90.6)	
Neither myopic	37	22 (59.5)		18	15 (83.3)	
Hours of near work/day						
≤ 6.00	44	29 (65.9)	0.37	23	18 (78.3)	0.18
6.01–7.30	45	34 (75.6)		29	25 (86.2)	
7.31–8.90	43	25 (58.1)		21	19 (90.5)	
≥8.91	45	28 (62.2)		23	21 (91.3)	
Hours of sleep/day						
≤7.30	41	28 (68.3)	0.84	26	23 (88.5)	0.72
7.31–7.90	44	26 (59.1)		24	19 (79.2)	
7.91–8.40	52	35 (67.3)		27	24 (88.9)	
≥8.41	40	27 (67.5)		19	17 (89.5)	
Hours in darkness/day						
≤4.70	44	26 (59.1)	0.60	20	19 (95.0)	0.07
4.71–5.60	43	30 (69.8)		22	21 (95.5)	
5.61–6.40	50	34 (68.0)		32	25 (78.1)	
≥6.41	40	26 (65.0)		22	18 (81.8)	

*Includes all participants.

†Includes only students with myopia at entry into law school.

pia by adopting a hierarchical scheme combining history with corrective lens prescriptions, lensometer readings, standardized visual acuity measurements, and autorefraction. Although myopia progression and risk factor exposures were assessed by questionnaire, the high academic standing of the students and the emphasis on recent behavior during law school each limit some of the potential sources of recall bias inherent in such surveys.

Considering the largely Caucasian American and African American racial background of the respondents, the overall myopia rate of 66% at the end of law school is very high. This finding certainly confirms prior impressions of high rates of myopia among US law students. Although the number of subjects is limited by the class size, and the applicability of these results to the overall graduate student population must be qualified, this prevalence rate is higher than the approximate 50% rate most typically found in US and European medical students,[4,7–9] another graduate student group extensively surveyed with subjects of somewhat comparable racial background to the students here. A 75% prevalence of myopia was reported in a US optometry student population,[3] but the possibility that students with vision problems might preferentially select optometric careers limits generalization to other US graduate student populations. Certainly, the myopia prevalence among Penn law seniors exceeds the 30% to 40% prevalence rates that are thought to typify young adults in US society as a whole.[17]

Because the University of Pennsylvania law student population consists mostly of young adults, two other descriptive features of the refractive data are remarkable. Although many of the students reported having myopia at the start of law school, approximately 19% of nonmyopic students entering law school first developed myopia by their third year. In addition, some 87% of students with myopia at entry into law school reported getting worse. From available reports that included axial length measurements, myopia progression among young adults seems to result from axial growth of the eye,[2,18,19] as in childhood myopia. Evidently, some quality of the law school experience adversely influences the eye's optical components, but, as with childhood myopia, the mechanisms precipitating myopia or its progression in young adults are obscure.

Parental history is commonly asserted to be an explanatory factor for myopia, even though it is usually impossible to distinguish the influences of shared genes from shared environment for this multifactorial disorder. Here, there was a weak trend ($P = 0.14$, Table 3) for myopic senior law students to have at least one myopic parent, but 21% of myopic students still reported no parental history of myopia. In our subjects, there was no association of parental myopia history with myopia progression in law school. Whether positive parental history of myopia reflects genetic or environmental influences, it thus provides no clear insight into myopia pathogenesis for this subject population.

Among other conventional risk factors, advanced educational level repeatedly correlates with increased myopia prevalence, and the population of this study ranks among the most highly educated young adults in the United States. What is unclear in the literature is whether education per se constitutes a risk factor for myopia or whether education is merely a surrogate for some other factor, most commonly suggested to be extensive use of the eyes for near activities, such as reading. Generally, however, it has been easier to establish correlations between myopia prevalence and educational attainment than objective indices of near work, raising the issue of whether these two conventional risk factors correspond to somewhat different environmental exposures.[20]

Although all law students presumably have high demands for study and reading, there was sufficient variability in reported near work hours/day to permit analysis of its relation with myopia and myopia progression. Here, only a weak trend related myopia progression with reported near work ($P = 0.18$). Given the extensive literature on the near work hypothesis for the cause of myopia, it is unclear why the nearwork/myopia association was not stronger here, just as in the many other clinical studies that have had difficulty correlating myopia with reported nearwork. Among potential explanations, the high reading demands of law school may cause all students to read above a critical nearwork threshold for myopia causality. Alternatively, qualities of nearwork not commonly assessed, such as reading with or without distance correction, may influence myopia progression,[3] or self-reported hours of recent nearwork may not appropriately measure the physiologic stimulus for lifelong myopia pathogenesis. Recently, daily hours of sleep have been correlated with myopia in young children.[21] Even though daily hours of sleep negatively correlated with hours of nearwork among our subjects, hours of sleep itself did not correlate with myopia or myopia progression, suggesting that hours of sleep is not a myopia risk factor in this older population.

The strongest association in this population was a relation of increasing myopia progression during law school with less daily exposure to darkness, a potential risk factor previously identified in childhood myopia. The trend that we observed is strengthened after controlling for near work and/or parental myopia. Analysis of the subset of students who reported myopia onset before college suggests a relation of myopia progression and daily dark exposure in this particular group. These subjects both developed myopia before young adulthood, at least as defined by college matriculation, and have the longest personal histories of myopia; thus, either age at onset or duration could be a relevant pathophysiologic variable. Given the present uncertainties in the mechanisms of myopia pathogenesis, we believe that this particular age stratification is justified, because contemporary clinical myopia classifications typically distinguish juvenile-onset myopia from that developing in early adulthood[11] and reflect the notion that risk factors for myopia may differ by age.

That daily illumination patterns of light and dark might modulate human eye development is compatible with developmental mechanisms being revealed in the eyes of experimental animals, especially with the broad phylogenetic conservation of many of the mechanisms concerning refractive development.[22] In chicks[23–25] and probably mammals,[26] the normally developing eye elongates chiefly during the day and not at night; the principal growth alteration in chicks developing myopia is accelerated growth at night to levels comparable to that of the day.[23–25] Furthermore, the postnatal development of the chick eye is markedly influenced by the relative duration of the light and dark phases of daily illumination.[26–28] A recent investigation also found that some rhesus monkeys failed to emmetropize properly when reared without a conventional dark period (Smith et al [Invest Ophthalmol Vis Sci 41(Suppl)134, 2000]).

The neural mechanisms regulating postnatal eye growth localize largely to the retina, and available retinal pharmacology also is compatible with a potential influence of the light-dark cycle on refractive development. Among retinal neurons, much evidence implicates dopaminergic amacrine cells in eye growth control of both chicks and monkeys.[22,29,30] It is also proposed that dopamine in the chick participates in the so-called "retinal dark-light switch,"[31] a retinal circuit that entrains the endogenous circadian rhythms of retinal function with the daily light-dark cycle. Although circadian retinal rhythms of melatonin seem intact in myopia,[32] it is presently unknown how or if dopamine's roles in eye growth control and in circadian rhythms interrelate. Although the daily growth patterns in normal eyes seem to be regulated by an endogenous circadian oscillator,[28] it is also unknown whether the disordered day-night patterns of growth leading to myopia relate specifically to circadian or other possible light-dark effects.

How best to learn whether such basic laboratory findings apply to human refractive development is problematic. Human eye development extends over many years and is seemingly influenced by many environmental factors that are difficult to both control and assess. This study and a prior report each evaluated an "extreme" US myopia population: a group of severely affected young adults here and a group including many early-onset highly myopic children previously.[12] Studies in more "representative," although somewhat older US children, did not find the same relationship of myopia to reported light exposure that was observed in prior reports on young children.[13,14] Perhaps our approach of studying severely affected populations will prove more effective in isolating potential novel risk factors from the many confounding environmental or genetic variables, or perhaps only a subset of individuals are sensitive to light-dark effects that are obscured in more generalized samples.

Data from both this study and our report on young children[12] suggest that light exposure during sleep might alter refractive development. It is well established that visible light passes through human eyelids, although the transmission is both attenuated and enriched in long wavelengths.[33] Virtually all clinical work and most experimental work assessing the interaction of vision and refractive development address visual experiences under photopic conditions, such as reading. Our findings indicate a need to investigate potential developmental effects of dim light exposure.

Neither this study nor our prior study in young children can establish whether the relevant clinical parameter is light exposure, dark exposure, a feature of the light-dark cycle per se, or some subtle effect on circadian rhythms, but each study buttresses the notion that the basic research on the influence of the daily light-dark cycle on refractive development of experimental animals has potential relevance to human refractive development. The greatest challenge for future clinical research in this area is study design, given the difficulties of controlling and assessing light-dark exposures, the inherent limitations of questionnaire-based data, the potential confounding influences, and the extended periods during which human refractive errors develop.

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