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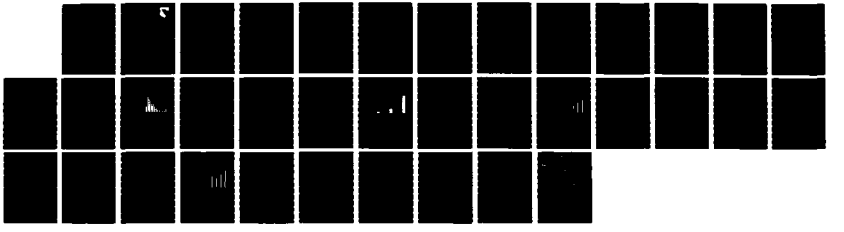

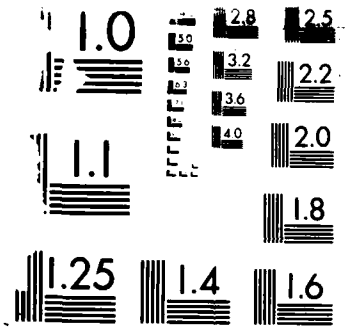

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REFRACTIVE ERROR CHANGE AT THE UNITED STATES AIR FORCE ACADEMY — CLASS OF 1985(U)

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A retrospective refractive error study was made at the USAF Academy (n = 497, 17-21 yrs old) for the 2.5 year period between entrance and third year exams. The entrance SPEQ refractive errors were 37.3%, 18.5%, and 44.2% hyperopes, emmetropes, and myopes, respectively. A significant ($p < 0.01$) mean SPEQ change of -0.18, -0.21, and -0.57 D occurred for the hyperopic, emmetropic, and myopic eyes, respectively. Myopia progression, derived from eyes showing a myopic shift, was -0.42, -0.52, and -0.75 D for the hyperopic, emmetropic, and myopic eyes, respectively. A myopic shift sufficient to cause a change in pilot status (> -0.25 D) occurred in a high percentage of each refractive error type, and was 47.7% of hyperopes, 41.3% of emmetropes, and 74.0% of myopes, and a clinically significant myopic shift of > -0.50 D was seen in 21.3%, 25.0%, and 55.1% of each type, respectively. This report supplies detailed information on the incidence and rate of myopia progression at the USAF Academy.

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Block 11. REFRACTIVE ERROR CHANGE AT THE UNITED STATES AIR FORCE ACADEMY - CLASS OF 1985(U)

SUMMARY

A retrospective study was conducted at the USAF Academy to determine the incidence and change in refractive error over a 2.5 year period between the entrance and third academic year exams. For 497 cadets, aged 17-21 years, the percentage of eyes in each refractive error, by spherical equivalent (SPEQ), at the Academy entrance exam was 37.3%, 18.5%, and 44.2% hyperopes, emmetropes, and myopes, respectively. A significant ($p < 0.001$) mean SPEQ change of -0.18 D, -0.21 D, and -0.57 D occurred for the hyperopic, emmetropic, and myopic eyes, respectively; over this period. The myopia progression was derived from those eyes showing a myopic shift, and was -0.42 D, -0.52 D, and -0.75 D for the hyperopic, emmetropic, and myopic eyes, respectively. A myopic shift sufficient to cause a change in pilot qualification ($\geq$ -0.25 D) occurred in a high percentage of each refractive error type, with 47.7% of hyperopes, 41.3% of emmetropes, and 74.0% of myopes having a myopic shift. There was a high incidence of myopic shift in all refractive error ranges, with a higher rate and incidence of myopic increase in the higher refractive errors, whether hyperopic or myopic; indicating 17 to 21 year old individuals are not as safe from a myopic change as previously thought. Many cadets underwent a rather large change towards myopia, and many were no longer qualified for UPT at graduation. The high incidence and rate of myopia progression at the USAF Academy is a problem that deserves continued attention. Additional studies using automated equipment are needed, and a program aimed at reducing the myopic shifts to increase the number of cadets eligible for UPT should be considered.

PREFACE

This study was conducted by the Crew Systems Effectiveness Branch of the Human Engineering Division, Armstrong Aerospace Medical Research Laboratory (AAMRL), Wright-Patterson AFB, Ohio, under Work Unit 7184-18-03.

The data was collected at the USAF Academy by former Captain Thomas R. Connon, O.D. of this branch and by Mary Ann Barbato and Martha Hausmann of the Human Factors Division, Systems Research Laboratory. The excellent figures were produced by Carol Brown of SRL Graphics Support. The data analysis and report was prepared by Major Melvin R. O'Neal, O.D., Ph.D., who is solely responsible for its content.

A special acknowledgement is reserved for Charles Bates, Director, Human Engineering Division, and Colonel Louis V. Genco, O.D., former Chief, Crew Systems Effectiveness Branch, for their considerable interest and enthusiastic support of this project.

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INTRODUCTION

The United States Air Force Academy (USAFA) is a primary source for potential pilots entering Undergraduate Pilot Training (UPT), with a goal of 70% of the graduating class eligible for UPT. Unfortunately, each year the goal of many cadets to become pilots is unattainable as they lose their UPT eligibility due to a myopic shift in their refractive error. In addition, a substantial number of cadets enter the Academy without the need for glasses and graduate needing an optical correction to see clearly, and must request a vision waiver to enter UPT. Knowledge of the refractive error changes that may occur during the Academy years would give the USAFA information on the anticipated graduating versus entering refractive error, and assist individuals in making an informed career decision prior to attending the Academy.

The medical standards for entering Undergraduate Pilot Training (Flying Class I Physical) are described in Air Force Regulation 160-43, Chapter 4, "Medical Standards For Enlistment, Commission, and Flying". The vision requirements are: at least 20/20 uncorrected acuity in each eye, refractive error in any meridian of less than -0.25 D of myopia or +1.75 D of hyperopia, and astigmatism of less than 0.75 D. Those individuals who meet the Flying Class I standards are classified as pilot qualified. Pilot waiver classification for visual acuity and refractive error are currently being granted to UPT candidates selected from the United States Air Force Academy, Reserve Officer Training Corp, Officer Training School, and Extended Active Duty. The acuity waiver is uncorrected visual acuity of 20/50 in each eye, with a refractive error waiver of up to -1.25 D of myopia in any meridian, +2.50 D of hyperopia in any meridian, or astigmatism requiring up to 1.50 D of cylindrical correction.

Prior to entering the Academy, cadets in the Class of 1985 obtained a physical exam from their own physician or government medical facility. The results were forwarded to the Department of Defense Medical Examination and Review Board (DODMERB) where they were classified as either Pilot Qualified

(PQ) or Pilot Waiver (PW). Cadets received a graduation physical during the beginning of the third academic year to certify their physical classification prior to entering the Pilot Indoctrination Program. Cadets also received a supplemental physical just before graduation to recertify their classification. It is after these two later physicals that many of the cadets suffered a change in classification or were no longer able to meet the pilot vision standards due to a myopic shift in their refractive error.

An overall myopic shift in refractive error in the population is known to occur throughout the education years.[1,2] Of particular concern to the military is the change towards myopia that occurs during the college years. Refractive error changes for the 17 to 21 year old age group have been reported;[3,4] however, these studies were conducted years ago on a general population and and may not apply to today's college individuals. A more recent study[5] assessed refractive error changes in graduate students; however, it involved an older age group. Refractive error change at the USAF Academy has never been reported, and previous studies at military academies have primarily addressed changes in visual acuity[6-8] and lack specific refractive error data.

The USAFA is an ideal place to assess changes in refractive error for a large number of individuals of approximately the same age, and for whom the environment is relatively equal. For instance, all cadets attend about the same number of classes, do a similar amount of studies under identical conditions, are required to participate in leisure and sports activities, and to a large extent eat the same food. The difficulty of the program is evidenced by the high rate of withdrawal, with only two-thirds of the entering class graduating (about 1,000 of the initial 1,500 cadets). Determining the change in refractive error at the USAFA would give some insight into expected changes for college students participating in intense educational programs, and would give the USAFA vital information on myopia progression within the Academy cadet population. This information would allow prospective cadets to be informed of the anticipated refractive error change that may occur and affect their pilot eligibility.

It was clear that a current and concise study on refractive error at the Academy was needed. The purpose of this study was to investigate the initial refractive error distribution and both the prevalence and rate of progression of myopia within the cadet population at the United States Air Force Academy for the Class of 1985. This report provides detailed refractive error changes for each type and level of initial refractive error. The refractive error change was both statistically and clinically significant over the period for this study. The progression towards myopia appears to be substantially higher than previously reported for the 17 to 21 year old age group that attends the USAF Academy.

METHODS

This was a retrospective study of the physical examination records of cadets graduating in the Class of 1985 at the United States Air Force Academy. Of the total class population of 944 cadets, 843 (89.3%) were men and 101 (10.7%) were women. The mean age of the cadets upon entering the Academy was 18.5 years (range 17 to 21 years). Approximately 30% of the class entered at age 17 years and 60% at age 18 years, with the remaining 10% at either 19, 20, or 21 years.

All of the medical records of the Class of 1985 in the medical records room (672 records) on data collection day were screened. The missing records were absent due to use by various hospital sections or personnel departments and it is possible a small number may have been missing due to reasons related to their vision examinations. Of the 672 records screened, 122 were omitted from the analysis due to incomplete entries or cadet wear of contact lenses at any time. An additional 53 records were eliminated due to use of near glasses at any time; which included 16, 43, and 47 emmetropes, hyperopes, and myopes, respectively. Thus, data from 497 records were included in the analysis. Data collected for each cadet were recorded by social security number only; thus the distribution of each age group and sex is unavailable, although it is probably similar to that for the entire class.

Those data collected were the refractions for each eye from both the entrance and third academic year vision examinations, separated by a period of approximately 2.5 years. The entrance exam was performed by the individual's private eye care specialist and may not have been cycloplegic, while the exam given at the beginning of the third academic year was a cycloplegic exam performed by one of the military optometrists stationed at the Academy. Although the initial exam was not performed by a military optometrist, it is probable that most of the refractions would not have differed substantially, however, some variation cannot be excluded.

During the examinations by military optometrists, cycloplegic refractions were accomplished approximately 30 minutes after instilling one or two drops of 1% cyclopentolate in each eye. Refraction end point was the most plus sphero-cylindrical correction to best visual acuity. The results of the tests where recorded on Standard Form 600 (Chronological Record of Medical Care), from which the refraction data were obtained.

The refractions were converted to their spherical equivalents by algebraically adding 1/2 of the cylindrical power to the sphere power. For example, -0.75 sphere with -0.50 cylinder is a -1.00 spherical equivalent (SPEQ) refractive error. The net change in refraction for the 2.5 year period was determined for each eye by subtracting the entrance SPEQ from the third academic year SPEQ refractive error. The data for each eye was entered into a computer for analysis; and although a mean data point for both eyes may be more correct, only unmatched, computerized individual eye data is now available.

Statistical Analysis:

The two eyes of the same individual would be expected to undergo a similar refractive error change, and must be considered during statistical analysis.[9] To reduce the effect of this positive correlation, all statistical calculations were made using a reduced n value of one half the number of eyes. This conservative statistical approach was continued further by making all t-tests two-tailed (i.e., two-sided), since eyes can change towards hyperopia or myopia. A value of $p < 0.05$ was considered statistically significant, with p values to 0.001 also reported.

RESULTS

Refractive Error Distribution:

The number (%) of eyes in selected ranges of each type of spherical equivalent (SPEQ) refractive error at the Academy entrance exam is given in Table 1, with the relative frequency distribution shown in Figure 1. Of the 994 total eyes, 371 (37.3%) were hyperopic, 184 (18.5%) were emmetropic (taken to be +0.12 to -0.12 D), and (439) 44.2% were myopic. The peak of the distribution was slightly hyperopic, +0.50 D, but the distribution was clearly skewed towards myopia. The percentage of eyes in the +0.37 to -0.37 D SPEQ range about emmetropia was 43.1%, while 20.8% were more hyperopic, and 36.1% were clinically myopic ($\geq$ -0.50 D).

The SPEQ refractive error distribution at the third academic year exam (i.e., 2.5 years after the entrance exam) is also given in Table 1 and shown in Figure 1. At the third year exam, 29.9%, 16.4%, and 53.7% of the eyes were now hyperopic, emmetropic, and myopic, respectively. The main difference between the entrance and third year exams was a 20.0% decrease (n = 74) in hyperopic eyes and a 21.6% increase (n = 95) in myopic eyes, with over one-half (53.7%) of the eyes now myopic. The refractive error distribution appears more skewed towards higher myopia, with only 37.1% of the total eyes now within the +0.37 to -0.37 D SPEQ range, and 45.9%, of the eyes now clinically myopic. Figure 2 is a relative cumulative frequency distribution of the entrance and third year SPEQ refractive error distributions and shows the general shift towards myopia for all of the refractive error ranges.

TABLE 1. DISTRIBUTION OF SPHERICAL EQUIVALENT (SPEQ) REFRACTIVE ERRORS AT ENTRANCE AND THIRD YEAR EXAMS

SPEQ Refractive Error (D)	Number of Eyes (%) Entrance n	(%)	Third Year n	(%)
(All Hyperopes)	371	(37.3 %)	297	(29.9 %)
>	4	(0.4)	5	(0.5)
+1.12 to +1.50	17	(1.7)	10	(1.0)
+0.62 to +1.00	101	(10.2)	79	(7.9)
+0.25 to +0.50	249	(25.1)	203	(20.5)
+0.12 to -0.12 (Em)	184	(18.5)	163	(16.4)
-0.25 to -0.50	130	(13.1)	108	(11.0)
-0.62 to -1.00	85	(8.6)	113	(11.4)
-1.12 to -1.50	60	(6.0)	83	(8.4)
-1.62 to -2.00	40	(4.0)	48	(4.8)
-2.12 to -3.00	45	(4.5)	72	(7.2)
-3.12 to -4.00	34	(3.4)	40	(4.0)
-4.12 to -5.00	18	(1.8)	29	(2.9)
>	27	(2.7)	41	(4.1)
(All Myopes)	439	(44.2)	534	(53.7)
(All Eyes)	994	(100%)	994	(100%)

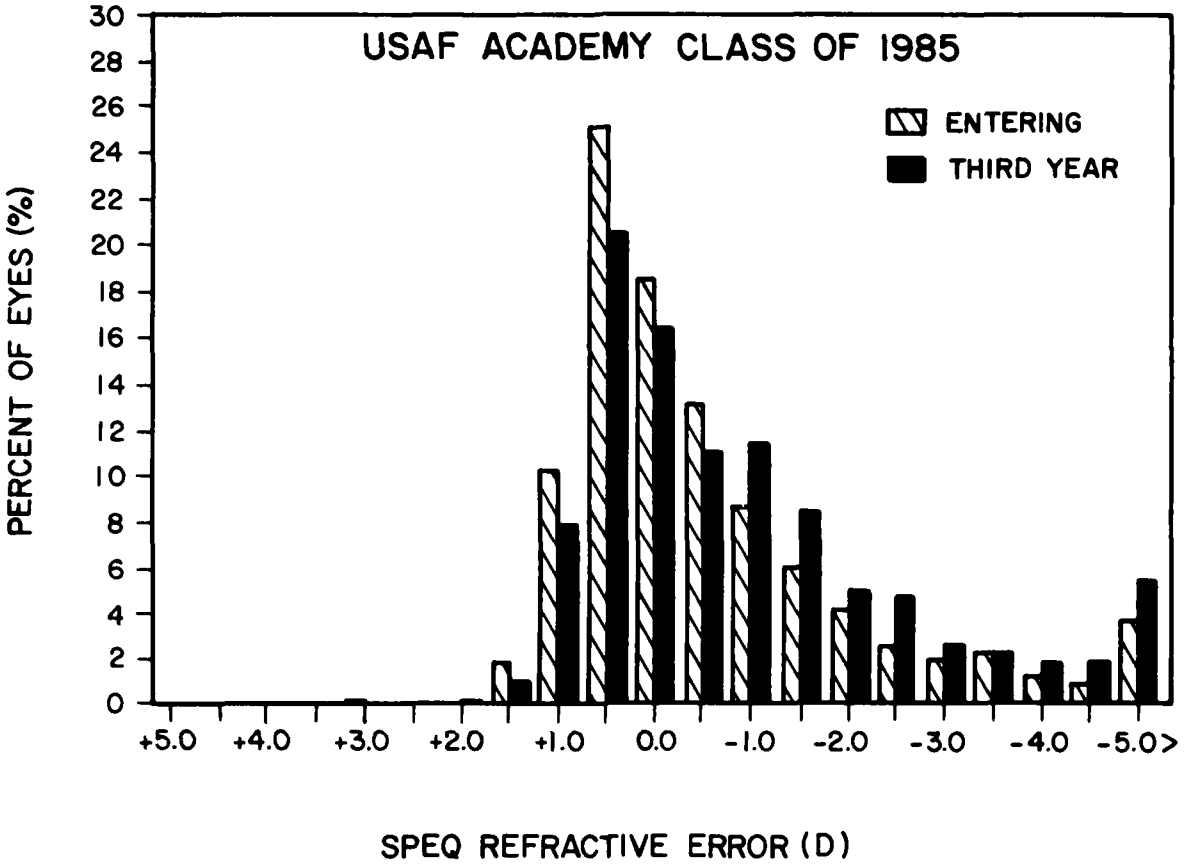

Figure 1. Distribution of spherical equivalent (SPEQ) refractive errors upon Academy entrance and at the third academic year exam (2.5 years later) for 994 eyes from the USAF Academy Class of 1985.

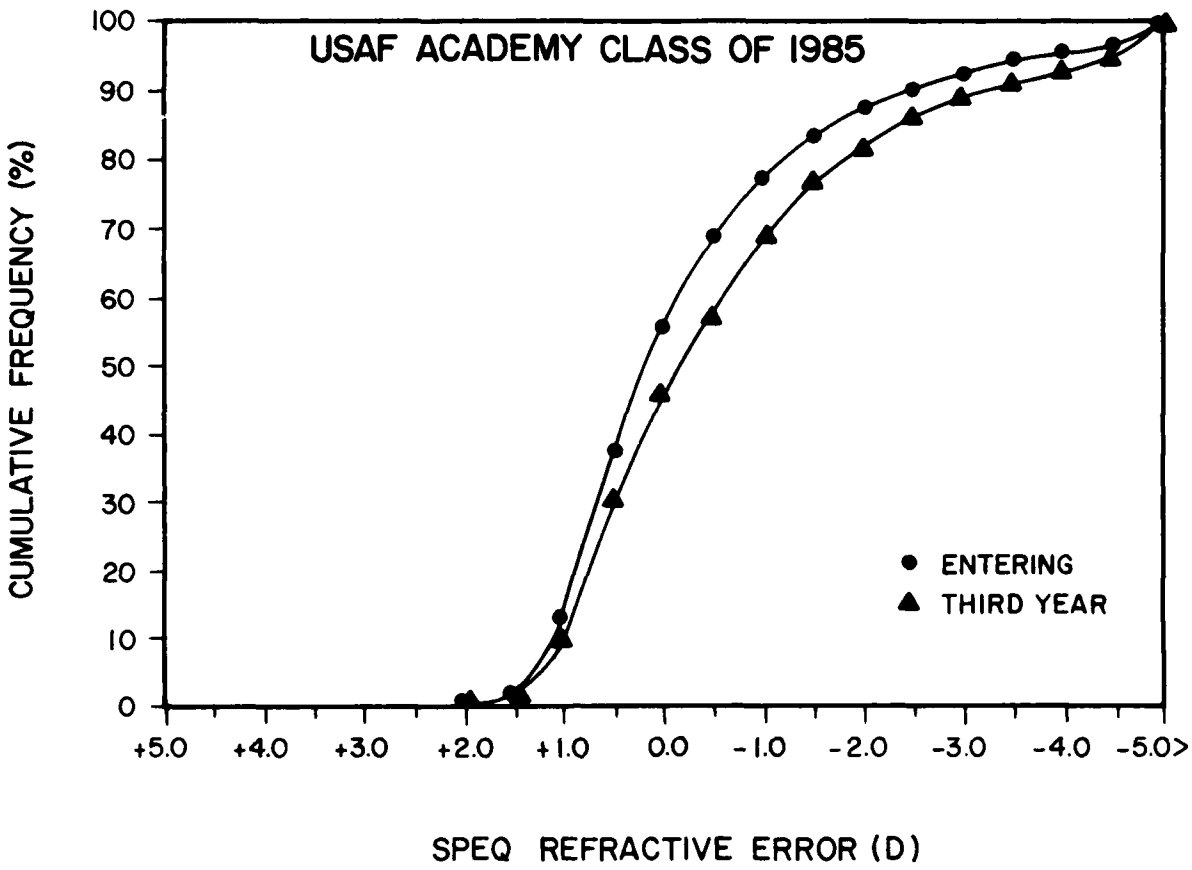

Figure 2. Cumulative frequency distribution of spherical equivalent (SPEQ) refractive errors upon Academy entrance and at the third academic year exam (2.5 years later) for 994 eyes from the USAF Academy Class of 1985.

Mean Refractive Error:

The mean SPEQ refractive error at the entrance and third year exams is given in Table 2. At Academy entrance, the mean SPEQ was +0.54 D for the hyperopic eyes, -1.71 D for the myopic eyes, and -0.55 D for all eyes combined. The mean SPEQ refractive error for the total eyes was significantly more myopic to -0.90 D by the third year exam ($t = 3.32$, $dF = 992$, $p < 0.001$)

TABLE 2. MEAN SPHERICAL EQUIVALENT (SPEQ) REFRACTIVE ERROR AT TIME OF ENTRANCE (MEAN AGE, 18.5 YRS) AND THIRD YEAR (MEAN AGE, 21.0 YRS) EXAMINATIONS

Type of SPEQ Refractive Error	Mean SPEQ Refractive Error (D) Entrance Mean ± SD	(n)	Third Year Mean ± SD	(n)
Hyperopes	+0.54 ± 0.39	(371)	+0.55 ± 0.42	(297)
Myopes	-1.71 ± 1.63	(439)	-1.97 ± 1.79	(534)
All Eyes	-0.55 ± 1.52	(994)	-0.90 ± 1.79	(994)

Refractive Error Change:

A refractive error change of 0.25 D is sufficient at the Academy to effect a change in pilot classification. The number and percent of eyes in each type of entering spherical equivalent (SPEQ) refractive error showing a hyperopic or myopic shift of $\geq$ 0.25 D or a lesser shift (shown as no shift) in SPEQ refractive error between the entrance and third academic year exams is given in Table 3 and shown in Figure 3. For the total eyes, 302 (30.4%) showed a lesser (no) shift and only 114 (11.5%) were found to have a hyperopic change, while 578 (58.1%) had a myopic shift of -0.25 D or more in refractive error. For each type of entering SPEQ refractive error, the greatest number of eyes had a myopic shift; with 177 (47.7%) of the hyperopic, 76 (41.3%) of the emmetropic, and 325 (74.0%) of the myopic eyes showing a -0.25 D or greater myopic shift in refractive error.

TABLE 3. EYES SHOWING A 0.25 D OR GREATER MYOPIC (-) OR HYPEROPIC (+) SHIFT OR NO SHIFT ($\leq$ 0.12 D) IN SPEQ REFRACTIVE ERROR

Entrance SPEQ Refractive Error Type (n)	Hyperopic (+) Shift n (%)	No Shift n (%)	Myopic (-) Shift n (%)
Hyperopes (371)	49 (13.2 %)	145 (39.1 %)	177 (47.7 %)
Emmetropes (184)	34 (18.5)	74 (40.2)	76 (41.3)
Myopes (439)	31 (7.1)	83 (18.9)	325 (74.0)
All Eyes (994)	114 (11.5)	302 (30.4)	578 (58.1)

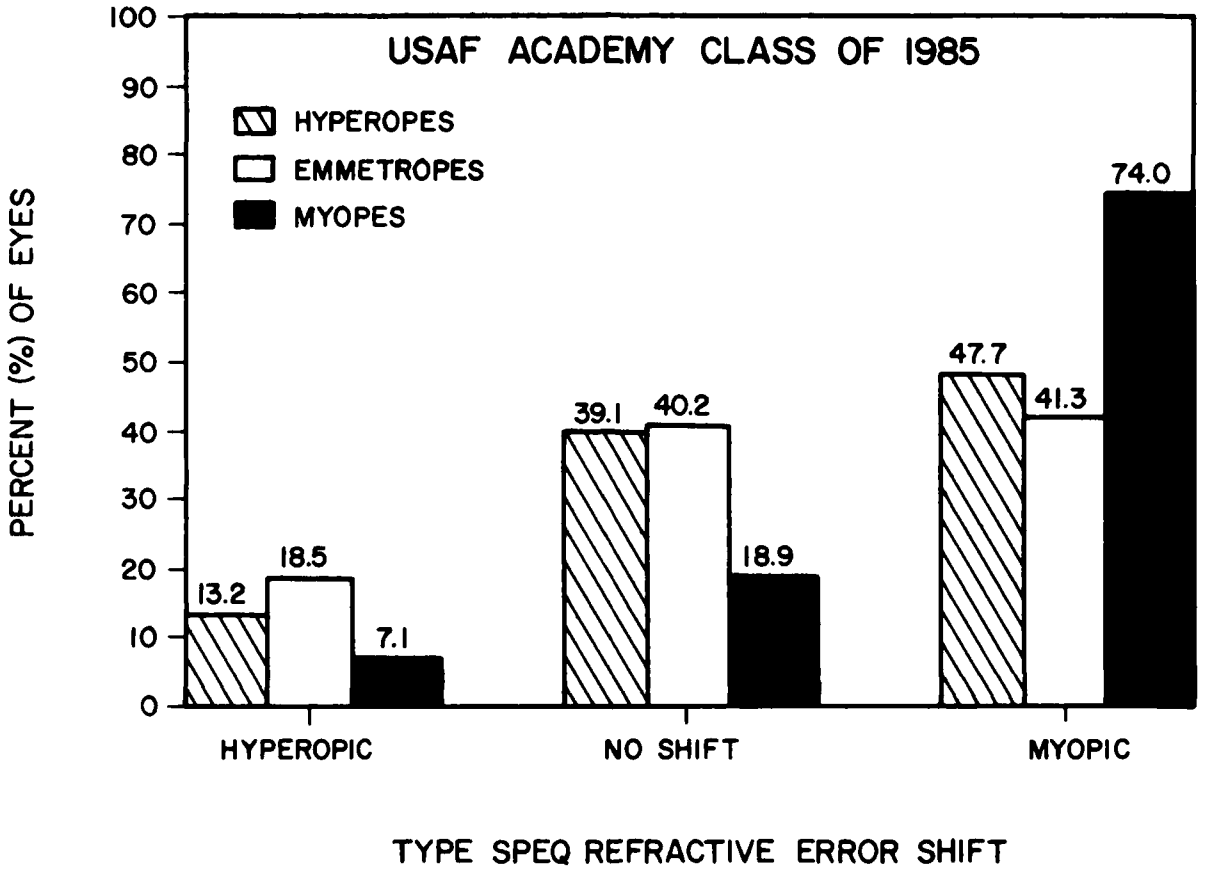

Figure 3. Percent of eyes in each type of entering spherical equivalent (SPEQ) refractive error showing a hyperopic or myopic shift of $\geq$ 0.25 D or a lesser (no) shift in SPEQ between the entrance and third academic year exams (2.5 year period) for 994 eyes from the USAF Academy Class of 1985.

Mean Refractive Error Change:

The mean change in SPEQ refractive error over the 2.5 year period between the entrance and third year exams is given in Table 4 and shown in Figure 4 for selected ranges of entering SPEQ refractive error. For each type of refractive error, there was a significant (paired t-tests, $p < 0.001$) mean SPEQ change towards myopia; with a change of -0.18 $\pm$ 0.37 D (range +0.75 to -1.75 D) for the hyperopic eyes ($t = 6.63$, $dF = 184$), -0.21 $\pm$ 0.47 D (range +0.87 to -1.75 D) for the emmetropic eyes ($t = 4.29$, $dF = 91$), -0.57 $\pm$ 0.62 D (range +1.50 to -3.00 D) for the myopic eyes ($t = 13.62$, $dF = 218$), and -0.35 $\pm$ 0.54 D for the total eyes ($t = 14.45$, $dF = 496$). Comparison of the amount of change between each refractive error type was significantly different for the entering myopes vs hyperopes ($t = 7.50$, $dF = 402$, $p < 0.001$) and myopes vs emmetropes ($t = 5.00$, $dF = 309$, $p < 0.001$), but was not significantly different between emmetropes and hyperopes ($t = 0.58$, $dF = 275$, $p > 0.50$).

The amount of the mean SPEQ change was increasingly myopic for higher refractive errors, whether hyperopic or myopic eyes. Comparisons of refractive error change between various entrance SPEQ ranges were significantly ($p < 0.05$) different for $\geq$ +1.00 vs +0.50 D ($t = 2.23$, $dF = 101$), -0.25 vs -0.50 D ($t = 2.07$, $dF = 88$), and -0.50 vs -3.00 D ($t = 2.46$, $dF = 92$); however, the change was not significantly different for $\geq$ +1.00 D vs emmetropes ($t = 1.27$, $dF = 107$, $p > 0.20$). These data indicate a greater refractive error change (myopic) occurs on average in the higher versus lower refractive errors, particularly for entering myopic eyes, even for the ages involved in this study.

The annual rate of mean change in SPEQ refractive error for the age range covered in this study (17-21 years old) is also given in Table 4 and was -0.07 D, -0.08 D, -0.23 D, and -0.14 D per year for the hyperopic, emmetropic, myopic, and total eyes, respectively.

TABLE 4. MEAN CHANGE AND ANNUAL RATE OF CHANGE IN SPHERICAL EQUIVALENT (SPEQ) REFRACTIVE ERROR OVER 2.5 YR PERIOD BETWEEN ENTRANCE AND THIRD YEAR EXAMS

Entrance SPEQ Refractive Error (D)	Change In SPEQ (D) Mean ± SD	(n)	Rate (D/yr)
(All Hyperopes)	-0.18 ± 0.37	(371)	-0.07 D/yr
≥ +1.00	-0.37 ± 0.51	(35)	-0.15
+0.50 to +0.87	-0.15 ± 0.34	(172)	-0.06
+0.25 to +0.37	-0.17 ± 0.35	(164)	-0.07
+0.12 to -0.12 (Em)	-0.21 ± 0.47	(184)	-0.08
-0.25 to -0.37	-0.28 ± 0.51	(80)	-0.11
-0.50 to -0.87	-0.49 ± 0.45	(112)	-0.20
-1.00 to -2.87	-0.65 ± 0.65	(159)	-0.26
≥ -3.00	-0.80 ± 0.75	(88)	-0.32
(All Myopes)	-0.57 ± 0.62	(439)	-0.23
(All Eyes)	-0.35 ± 0.54	(994)	-0.14

(All changes significant at $p < 0.001$, paired t-tests, $dF = n/2 - 1$.)

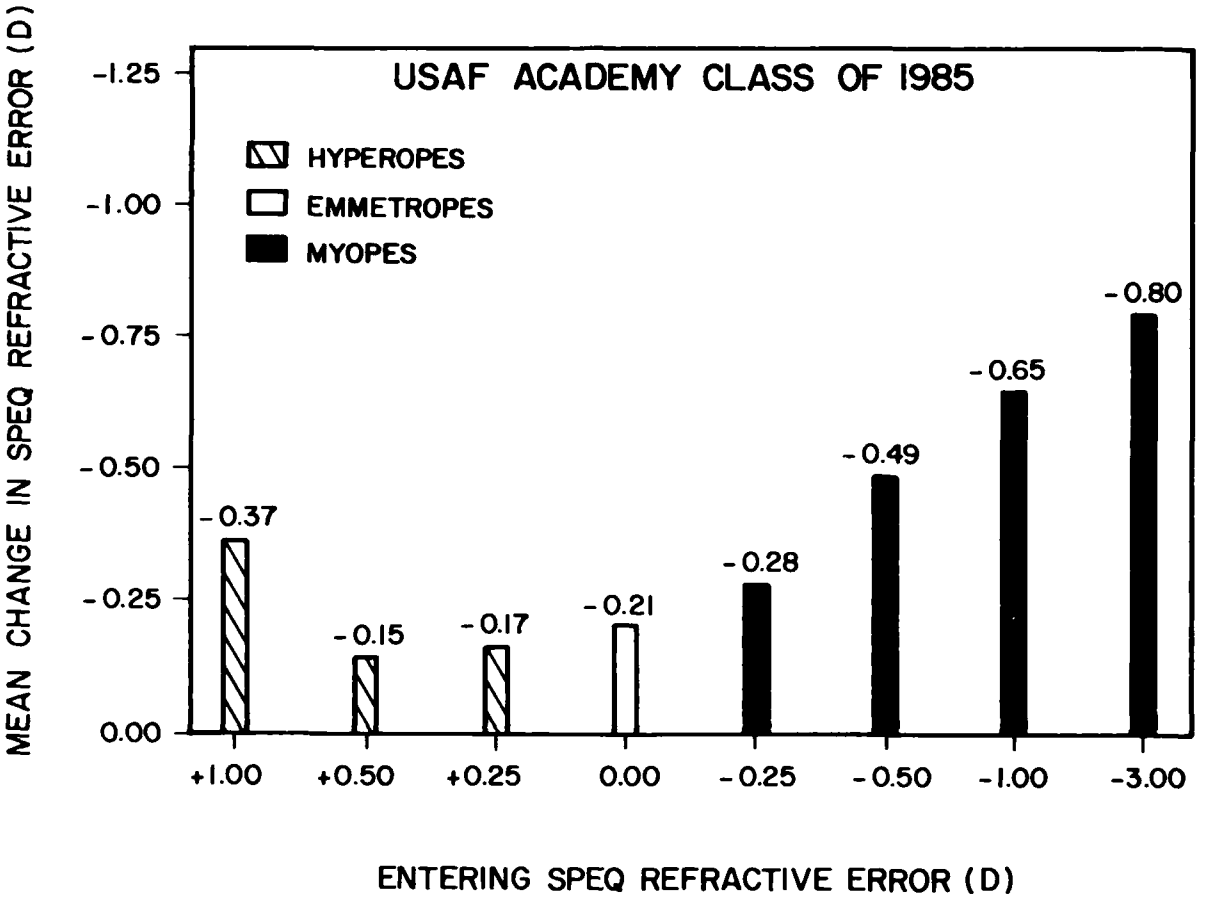

Figure 4. Mean change in spherical equivalent (SPEQ) refractive error between the entrance and third academic year exams (2.5 year period) for 994 eyes from the USAF Academy Class of 1985. The ranges of entering SPEQ refractive error (diopters) are $\geq$ +1.00, +0.50 to +0.87, +0.25 to +0.37, +0.12 to -0.12, -0.25 to -0.37, -0.50 to -0.87, -1.00 to -2.87, and $\geq$ -3.00.

Myopia Progression:

The amount of myopia progression was derived from those eyes showing any amount of myopic shift in SPEQ refractive error. The percentage of eyes in selected ranges of entering SPEQ refractive error that showed a myopic shift greater than or equal to selected amounts at the third academic year exam is given in Table 5 and shown in Figure 5. A clinically significant myopic shift (requiring initial wear or change in glasses) of -0.50 D or greater was found for a fair percentage of the hyperopic (21.3%) and emmetropic (25.0%) eyes, and a large percentage of the myopic eyes (55.1%). A greater percentage of eyes showed a myopic shift, particularly for the larger shifts, in the higher degrees of both hyperopic and myopic refractive errors than occurred in the lower refractive error range about emmetropia; suggesting some prediliction for higher refractive errors to undergo larger refractive error shifts.

For those eyes showing any amount of myopic shift, the cumulative frequency of eyes with shift greater than or equal to selected amounts for each type of refractive error is given in Table 6. Figure 6 is the usual graphical display for this type of frequency, which is constructed based on the cumulative frequency of eyes with shifts "less than" the amounts shown. A clinically significant myopic shift of -0.50 D or greater occurred in 37.8% of the hyperopic, 46.5% of the emmetropic, 68.0% of the myopic, and 55.3% of the total eyes that showed a myopic shift. Indeed, a fair percentage of myopic (27.5%) and emmetropic (20.2%) eyes had a large myopic shift of -1.00 D or more; further indicating that, for this sample, refractive error can frequently become much more myopic even at 17-21 years of age.

TABLE 5. PERCENTAGE (%) OF EYES IN SELECTED SPEQ RANGES WITH MYOPIC SHIFT GREATER THAN OR EQUAL TO SELECTED AMOUNTS

Entrance SPEQ Refractive Error (D)	(n)	Percent (%) of Eyes With Myopic Shift Greater Than or Equal To: -0.25	-0.37	-0.50	-0.75	-1.00	-1.50	-2.00
(All Hyperopes)	(371)	47.7%	29.1%	21.3%	8.9%	2.4%	1.3%	0 %
≥ +1.00	(35)	65.7	48.6	37.1	20.0	8.6	8.6	0
+0.50 to +0.87	(172)	44.8	29.7	20.9	5.8	0.6	0.6	0
+0.25 to +0.37	(164)	47.0	24.4	18.3	9.8	3.0	0.6	0
+0.12 to -0.12	(184)	41.3	29.3	25.0	14.7	10.9	1.6	0
-0.25 to -0.37	(80)	52.5	45.0	36.3	21.3	10.0	2.5	1.3
-0.50 to -0.87	(112)	82.1	59.8	49.1	23.2	11.6	5.4	0.9
-1.00 to -2.87	(159)	76.1	65.4	61.6	47.2	28.9	12.0	3.8
≥ -3.00	(88)	79.5	72.7	68.2	50.0	35.2	22.7	9.1
(All Myopes)	(439)	74.0	61.7	55.1	36.9	22.3	10.7	3.6
(All Eyes)	(994)	58.1	43.6	36.9	22.3	12.8	5.5	1.6

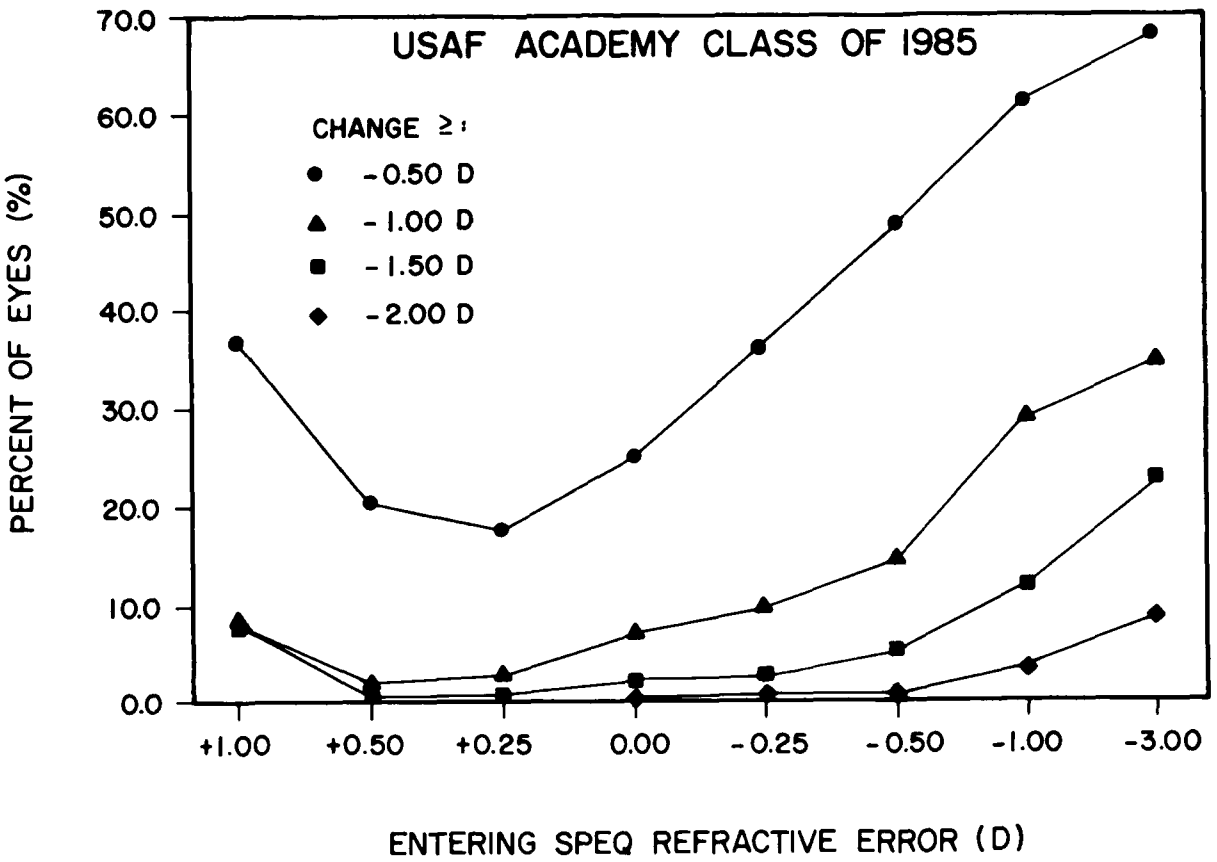

Figure 5. Percentage (%) of eyes in selected ranges of entering spherical equivalent (SPEQ) refractive error with a myopic shift in SPEQ greater than or equal to selected amounts for 994 eyes from the USAF Academy Class of 1985. The ranges of entering SPEQ refractive error (diopters) are $\geq$ +1.00, +0.50 to +0.87, +0.25 to +0.37, +0.12 to -0.12, 0.25 to -0.37, -0.50 to -0.87, -1.00 to -2.87, and $\geq$ -3.00.

TABLE 6. CUMULATIVE FREQUENCY OF EYES SHOWING A MYOPIC SHIFT GREATER THAN OR EQUAL TO SELECTED AMOUNTS FOR THOSE EYES SHOWING ANY AMOUNT OF MYOPIC SHIFT IN EACH TYPE OF REFRACTIVE ERROR

Amount SPEQ Myopic Shift (D)	Type of Entrance SPEQ Refractive Error							
	Hyperopes		Emmetropes		Myopes		All Eyes	
	%	(n)	%	(n)	%	(n)	%	(n)
-0.12	100%	(209)	100%	(99)	100%	(356)	100%	(664)
-0.25	84.7	(177)	76.8	(76)	91.3	(325)	87.0	(578)
-0.37	51.7	(108)	54.5	(54)	76.1	(271)	65.2	(433)
-0.50	37.8	(79)	46.5	(46)	68.0	(242)	55.3	(367)
-0.75	15.8	(33)	27.3	(27)	45.5	(162)	33.4	(222)
-1.00	4.3	(9)	20.2	(20)	27.5	(98)	19.1	(127)
-1.25	2.9	(6)	8.1	(8)	18.0	(64)	11.7	(78)
-1.50	1.9	(4)	3.0	(3)	12.1	(43)	7.5	(50)
-1.75	1.0	(2)	2.0	(2)	6.5	(23)	4.1	(27)
$\geq$ -2.00	0	0	0	0	4.2	(15)	2.3	(15)

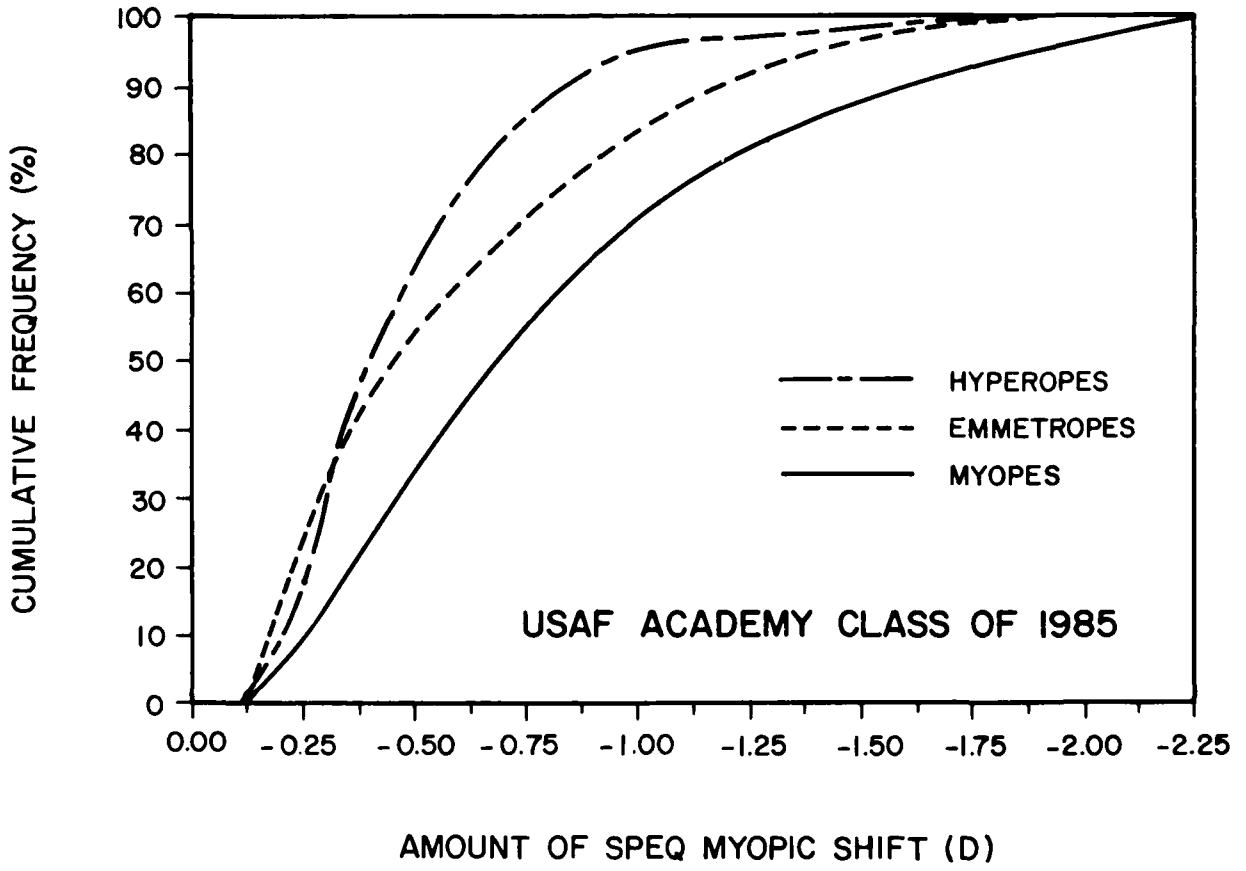

Figure 6. Cumulative frequency of eyes showing a myopic shift in spherical equivalent (SPEQ) refractive error less than selected amounts for those eyes showing any amount of myopic shift between the entrance and third academic year exams (2.5 year period) for each type of entering refractive error for 664 eyes from the USAF Academy Class of 1985.

Mean Myopia Progression:

For the eyes showing any amount of myopic shift, the mean myopic shift in SPEQ refractive error over the 2.5 year period between the entrance and third year exams is given in Table 7 and shown in Figure 7 for selected ranges of entering SPEQ refractive errors. The mean myopic shift was significant (paired t-tests, $p < 0.001$) for each type of refractive error; with a shift of -0.42 ± 0.29 D for the hyperopic eyes ($n = 209$), -0.52 ± 0.41 D for the emmetropic eyes ($n = 99$), -0.75 ± 0.55 D for the myopic eyes ($n = 356$), and -0.60 ± 0.48 D for the total 664 eyes showing a myopic shift. Comparison of the amount of myopic shift between each refractive error type was significantly different for the entering myopes vs hyperopes ($t = 5.67$, $dF = 280$, $p < 0.001$) and myopes vs emmetropes ($t = 2.72$, $dF = 225$, $p < 0.01$), and was almost significantly different for the emmetropes vs hyperopes ($t = 1.73$, $dF = 151$, $p < 0.10$).

Comparisons of myopic shift between various entrance SPEQ ranges were significantly different for $\geq +1.00$ vs $+0.50$ D ($t = 2.10$, $dF = 58$, $p < 0.05$) and -0.50 vs -3.00 D ($t = 3.62$, $dF = 78$, $p < 0.001$); however, the shift was not significantly different for the $\geq +1.00$ vs $+0.25$ D ($t = 1.41$, $dF = 53$, $p > 0.20$). These data indicate that, when a myopic shift occurred in this sample population, it was on average about -0.50 D for the hyperopes, emmetropes, and low myopes ≤ -0.75 D and was approximately -0.90 D for the -1.00 D or greater myopes, suggesting that the the moderate and higher myopes have not yet stabilized even by 17 to 21 years of age.

The annual rate of myopic shift in SPEQ refractive error is also given in Table 7 and was -0.17 D, -0.21 D, -0.30 D, and -0.24 D per year for the hyperopic, emmetropic, myopic, and total eyes, respectively.

TABLE 7. MEAN MYOPIC SHIFT AND ANNUAL RATE OF MYOPIC SHIFT IN SPHERICAL EQUIVALENT (SPEQ) REFRACTIVE ERROR OVER 2.5 YR PERIOD BETWEEN ENTRANCE AND THIRD YEAR EXAMS FOR THOSE EYES SHOWING A MYOPIC CHANGE IN SPEQ REFRACTIVE ERROR

Entrance SPEQ Refractive Error (D)	Myopic Shift In SPEQ (D) Mean ± SD	(n)	Rate (D/yr)
(All Hyperopes)	-0.42 ± 0.29	(209)	-0.17 D/yr
≥ +1.00	-0.58 ± 0.46	(25)	-0.23
+0.50 to +0.87	-0.38 ± 0.24	(96)	-0.12
+0.25 to +0.37	-0.43 ± 0.28	(88)	-0.17
+0.12 to -0.12 (Em)	-0.52 ± 0.41	(99)	-0.21
-0.25 to -0.37	-0.62 ± 0.40	(46)	-0.25
-0.50 to -0.87	-0.58 ± 0.40	(100)	-0.23
-1.00 to -2.87	-0.79 ± 0.58	(137)	-0.32
≥ -3.00	-1.00 ± 0.63	(73)	-0.40
(All Myopes)	-0.75 ± 0.55	(356)	-0.30
(All Eyes)	-0.60 ± 0.48	(664)	-0.24

(All shifts significant at $p < 0.001$, paired t-tests, $dF = n/2 - 1$.)

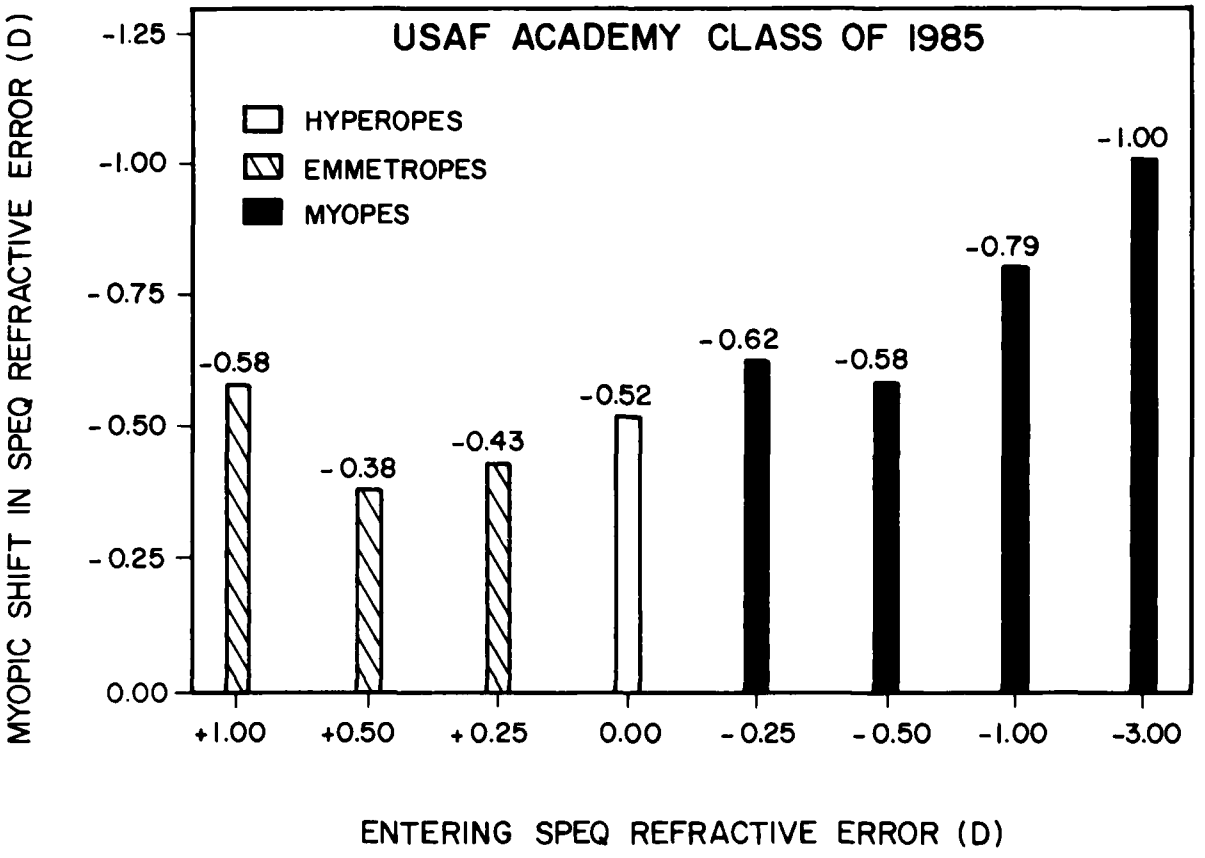

Figure 7. Mean myopic shift in spherical equivalent (SPEQ) refractive error for those eyes showing any amount of myopic shift between the entrance and third academic year exams (2.5 year period) for 664 eyes from the USAF Academy Class of 1985. The ranges of entering SPEQ refractive error (diopters) are $\geq$ +1.00, +0.50 to +0.87, +0.25 to +0.37, +0.12 to -0.12, 0.25 to -0.37, -0.50 to -0.87, -1.00 to -2.87, and $\geq$ -3.00.

DISCUSSION

The mean change in refractive error was substantially (about 50%) higher than previously reported for the 17 to 21 year old age group. From Brown,[4] a -0.10 D/year increase in myopia was calculated for this age group, while the present study found the overall rate to be -0.14 D/year; however, the initial refractive errors may have differed for these two studies. In a recent study at the Naval Academy, Shotwell[10] reported a group of control subjects with an initial refractive error of -0.37 to +0.75 D had an average change towards myopia of -0.25 D over a four year period. For this same initial refractive error range, the present study found a similar, yet still slightly higher, change of -0.08 D/year over a 2.5 year period, for a projected average change of -0.33 D for four years.

The degree of refractive error change was found to be related to the type and level of initial refractive error. The rate of increase in myopia was similar (-0.07 D/year) for the emmetropes and low hyperopes, but was double (-0.15 D/year) this rate for the +1.00 D or greater hyperopes, triple (-0.20 D/year) for the low myopes, 4 times higher (-0.26 D/year) for the moderate myopes, and 5 times higher (-0.32 D/year) for the higher myopes. Clearly, higher refractive errors, whether hyperopic or myopic, showed a higher rate of myopic increase than for the emmetropic and low hyperopic eyes. These results appear to be contrary to the generally accepted view that by this age level the higher myopes would already have completed most of their change.

By using Table 5, one can obtain a relatively good estimate of the probability that a certain amount of refractive error change may occur over a 2.5 year period during college for any type and level of initial refractive error. For instance, a clinically significant myopic shift of -0.50 D occurred in about 25% of the entering emmetropic and hyperopic eyes, but occurred twice as common (55%) in myopic eyes. Even for a rather high myopic shift of -1.00 D, 10% of the emmetropic eyes and 22% of the

myopic eyes showed this degree of change. The percentage of eyes within each selected SPEQ ranges showing a myopic shift was much greater for the higher hyperopes and myopes; suggesting some prediliction for higher refractive errors to undergo a larger myopic shift.

When eyes do undergo a myopic shift, it is informative to have some idea of how often a shift of a certain amount or more will occur. Figure 6 is a typical "less than" type of frequency distribution of the amount of myopia increase for only those eyes showing a myopic shift, and can be used to calculate this occurrence for all three types of refractive error. For example, a myopic shift of less than -0.50 D (i.e., -0.37 D or less) was found for about 30% of the myopic shifts in entering myopic eyes; giving a clinically significant shift of -0.50 D or greater for approximately 70% of the myopic shifts that occurred in myopes. These occurrences can also be obtain directly from Table 6, and indicate that when a myopic shift occurs, it will necessitate the issue of glasses or a change in prescription a fair percentage of the time over a 2.5 year period during college.

The mean change does not, however, give the complete description of the refractive error changes that would most affect pilot qualification at the USAF Academy. For this, the amount of myopia progression, as derived from those eyes showing any amount of myopic shift, must be evaluated. In addition, the more general assumption that eyes showing a hyperopic shift were overminused initially may also have some merit. The rate of myopia progression was found to be approximately twice that of the mean rate for the lower and hyperopic refractive errors and slightly higher for the higher refractive errors.

The difference between the mean and myopic progression rates may be due to a larger variability in the validity of the initial lower and hyperopic refractive errors, whereas the initial higher myopic refractive errors may have been much closer to the actual amount. Cycloplegia can cause either a hyperopic or myopic shift in refraction[11]; and since a number of the initial exams may not have been cycloplegic, a variability in the results

may have occurred. Due to this possible variability, the findings need to be verified by a non-retrospective study that compares the same type of refractive data obtained using the same equipment for both examinations.

This report allows a more detailed assessment of the refractive error changes for the 17 to 21 year old age group while attending a military academy, than was previously available. Contrary to what was previously thought, individuals in this age group are not relatively safe from a refractive error change towards myopia; and those with higher amounts of myopia can expect their refractive error to increase. This report presents detailed refractive error results that allows the Academy practitioner and others to advise individuals in this age group about the probability, and possible amount, of refractive error change while attending the USAF Academy or while involved in any intensive educational program.

RECOMMENDATIONS

This study was conducted using a retrospective review of records. The results indicate a substantial myopia progression occurs at the USAF Academy. The findings may have been affected somewhat by the variability in comparison of the two different types of refractions (i.e., non-cycloplegic vs cycloplegic) for some of the cadets. This may have decreased the difference between the two exams and the true amount of myopia progression may, in fact, be higher than reported here.

What is needed is a study to measure the refractive error of initial cadets upon arriving at the Academy and again during the usual third year physical exam. This study could be performed using automated equipment and would have minimal effect on the cadet's time; for instance, readings could be taken during the sports period. The data would be taken by research personnel supplied for the short data gathering periods needed. Optometry personnel stationed at the Academy are too busy to lend support, and it would be more appropriate if they remained separated from the study.

The high incidence and rate of myopia progression at the USAF Academy over the past few years recently prompted changes in cadet selection to reduce the number of entering myopes. It is expected this will increase the overall percentage of cadets eligible for pilot training; however, this needs verification by a follow-up study as described above. Each year highly qualified cadets will still be unable to become pilots due to their refractive error, and unfortunately a recent study by Shotwell at the US Naval Academy reported that the use of near reading glasses and bifocals did not retard the increase in myopia. Myopia progression at the USAF Academy is a problem that deserves continued attention.

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