British Journal of Ophthalmology, 1978, **62**, 163–167

Refractive errors of retinitis pigmentosa patients

PAUL A. SIEVING AND GERALD A. FISHMAN

From the Department of Ophthalmology, University of Illinois Eye and Eye Infirmary, Chicago, Illinois, USA

SUMMARY A retinitis pigmentosa (RP) population (268 eyes) had predominantly myopic refractive errors. Whereas 12% of a normal population have myopic refractions, myopia was found in 75% of 268 eyes of RP patients and in 95% of 41 eyes of X-linked RP patients. The spherical errors describe a single-peaked, skewed distribution, with a mean of −1·86 dioptres that is significantly ($P < 0.001$) more myopic, by −2·93 D, than that of a normal population. The X-linked genetic group has a spherical mean of −5·51 D that is significantly ($P < 0.01$) more myopic than the non-X-linked RP population. This X-linked spherical error distribution may be composed of two separate sub-distributions. Astigmatic refractive errors greater than 0·5 D are found in 47% of this RP population, considerably in excess of the 19% of a normal population with such astigmatic errors.

During our investigation of patients with retinitis pigmentosa (RP) we became aware of the high incidence of myopic and cylindrical refractive errors. Although 3 previous reports (Usher, 1935; François and Verriest, 1962; Jain and Singh, 1967) from the ophthalmic literature refer to an increased incidence of myopia in patients with RP, none includes specific quantifiable data within each genetic type.

Methods

From a study population of 156 patients (311 eyes) with all genetic types of RP refractions were obtained for 285 eyes. Among these were 17 aphakic eyes, which were excluded from this study, leaving 268 eyes (86% of total) included in the present analysis. We obtained the majority of the data by manifest refractions. For a few patients the refraction was provided by the referring ophthalmologist.

The spherical refractive errors were expressed in spherical equivalents by adding one-half the cylindrical correction to the spherical correction. Cylindrical refractive errors were measured and analysed in positive dioptres.

Means and standard deviations were used to characterise the patient populations and were computed in the standard fashion. The means are given as mean $\pm$ SE, N, where N is the number of eyes. The confidence intervals of the means were calculated by using the SE. This is the range in which the mean lies for a specified probability (e.g., 99% confidence interval). The mean and SD were used to construct normal curves for the various patient groups. The differences between the means of the various patient groups were tested for statistical significance by the methods of unpaired observations and unequal variances in a modified Student *t*-test (Steel and Torrie, 1960). Unless otherwise noted, the levels of significance are stated for critical values of *t* in the 2-tailed test.

Five genetic groups of patients with RP were identified within the total study population. Standard criteria for genetic classification were used for the X-linked, autosomal recessive, and autosomal dominant groups. The 'isolated' classification indicates patients who appeared to be the only affected member within a pedigree. We recognise the probability that many of these latter patients have autosomal recessive inheritance. 'Genetic type uncertain' group included patients having at least 1 other affected family member but whose pedigrees were not conclusive for classification. For the majority of patients in the 'type uncertain' group a question exists as to whether they have an X-linked trait with partial expression in females or an autosomal dominant trait. The total group of RP patients were additionally separated according to age and placed into one of three groups.

Data on the refractive errors in the general population were taken from a study by Sorsby *et al.* (1960), who sampled 1033 male National Service recruits in Great Britain in 1957, ages 17 to 27 years. These authors included in their study a weighted addition of cases selected at random from a pool of

Address for reprints: Dr Gerald A. Fishman, University of Illinois Eye and Ear Infirmary, 1855 W. Taylor St, Chicago, Ill. 60612, USA

men rejected from service because of high refractive errors. This study approaches an unbiased series of the general male population. A similarly well controlled and unbiased series of a female population is unavailable.

The RP patients fulfilled criteria considered typical for the diagnosis of this disease, including complaints of night blindness, constricted peripheral fields, and abnormal electroretinogram recordings. The majority of the patients had bone-spicule pigmentation. Patients having associated systemic syndromes (e.g., Usher's syndrome) were not included in this study.

Results

Refractive errors for the 268 eyes of RP patients ranged from +4·50 to −16·25 D for the pure spherical element. The refractive errors show a single-peaked distribution approximating a bell-shaped curve, having a mean in the myopic range (−1·86 ±0·21 D, N=268) (Fig. 1). This mean is significantly (P<0·001) more myopic (−2·93 D) than the mean refractive error of the normal population (Sorsby *et al.*, 1960), also shown in Fig. 1.

The population of spherical refractive errors from our total study group is described by a mean of −1·86 D and SD=3·39 D. The 99% confidence interval for the mean is from −1·33 to −2·39 D. Fig. 2, top, shows this population and the normal curve constructed from the same population parameters. Compared to its normal curve this RP population has an excess in the myopic peak, a paucity in the moderate myopic and mild to moderate hypermetropic ranges, and an excess in the high myopic tail. The hypermetropic tail is absent. The mode (peak) of this population is displaced by approximately 1·5 D from the mode of its normal curve. The population is skewed from a bell-shaped curve, having an excess in the myopic side of the peak compared to the hypermetropic side.

The spherical equivalent refractive errors from the X-linked population show a rectangular distribution having the bulk of values between 0 and −9·00 D, and a high myopic tail from −9·00 to −16·00 D (Fig. 2, centre). The mean is quite myopic (−5·51 ±0·63 D, N=41). In this population of 41 eyes, 39 have myopic refractive errors (−0·50 to −16·00 D). This X-linked population has 33 eyes (80% of its total) that are more myopic than the median spherical error (−0·5 D) of the total population (Fig. 2, top). Because of the flat distribution it is inappropriate to construct a normal curve for this population.

The non-X-linked population of 227 eyes (Fig. 2, bottom) has spherical refractive errors described by a mean of −1·20 ±0·19 D, N=227, and SD=2·79 D. The 99% confidence interval for the mean is −0·72 to −1·18 D. The normal curve constructed from these parameters describes its non-X-linked population fairly symmetrically, although the population is slightly skewed, having an excess in the myopic tail compared to the hypermetropic side of the peak. Compared to its normal curve, the non-X-linked group shows an excess in the myopic peak, a deficiency in the moderate myopic and mild to moderate hypermetropic regions, and an excess in the high myopic tail. The hypermetropic tail is absent.

The total RP population was separated into groups by age and genetic type. The mean spherical refractive errors, SD, and number of eyes were computed for each group (Table). These mean spherical refractions are displayed in the bar graph (Fig. 3). For each of the three age groups and the total the X-linked myopic mean is significantly higher (P<0·01) than the mean refraction of the corresponding non-X-linked population (Fig. 3,

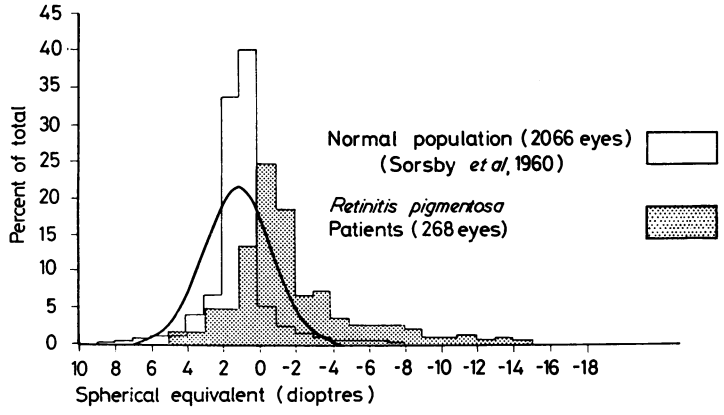

Fig. 1 *Spherical refractive errors of retinitis pigmentosa (RP) patients (mean = −1·86 dioptres) and normal population (Sorsby* et al., *1960) (mean = +1·007 D). Normal curve is shown for normal population. Note significant (P<0·001) myopic shift of mean of RP patients from normal population. Sorsby* et al. *(1960) used spherical equivalent refraction for eyes having 0·50 D or less of cylinder, and ocular refraction in least ametropic meridian for eyes with astigmatism greater than 0·50 D*

dashed line). In each age group the autosomal recessive and autosomal dominant types have the smallest myopic mean spherical equivalent refractions.

The population group 51 years and older has the smallest mean spherical equivalent refraction of the 3 age groups (Fig 3), for both the non-X-linked and the total RP means. In the non-X-linked population the mean spherical equivalent refractions for the group 51 years and older is significantly less ($P < 0.05$)

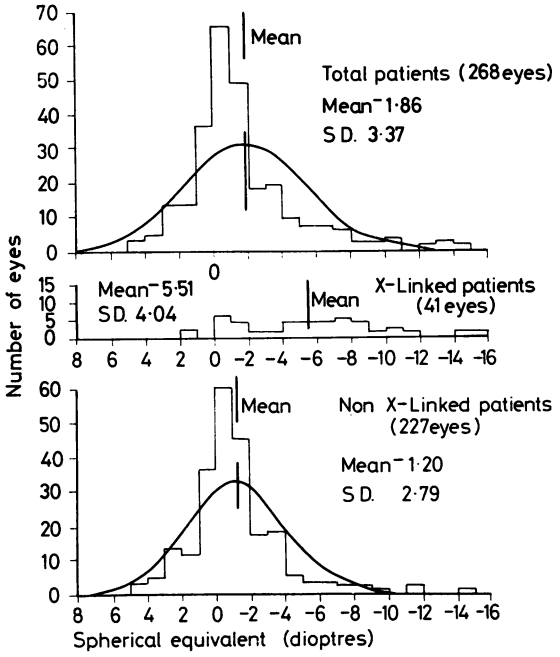

Fig. 2 *Spherical refractive errors of retinitis pigmentosa (RP) patients, showing mean and SD, for total RP study population* (top), *X-linked patients* (centre), *and non-X-linked* (bottom). *Normal curves are shown in top and bottom. Note rectangular distribution and highly myopic mean of X-linked patients. Normal curve of non-X-linked patients fits its data better than does the curve for total population*

Table *Spherical refractive data for retinitis pigmentosa patients**

Genetic type	*Ages, yr*			
	1–25	*26–50*	*51–75*	*All ages*
X-linked				
Mean	−4·25 D	−8·09 D	−5·33 D	−5·51 D
SD	4·03 D	3·82 D	0·69 D	4·04 D
No. of eyes	24	12	5	41
Autosomal recessive				
Mean	−0·61 D	−1·15 D	−0·19 D	−0·76 D
SD	2·50 D	2·43 D	1·09 D	2·21 D
No. of eyes	12	16	8	36
Autosomal dominant				
Mean	−0·14 D	−0·76 D	−0·21 D	−0·44 D
SD	2·25 D	1·85 D	2·30 D	2·08 D
No. of eyes	16	26	16	58
Isolated				
Mean	−2·00 D	−1·61 D	−1·30 D	−1·64 D
SD	4·11 D	2·11 D	1·31 D	2·65 D
No. of eyes	28	50	26	104
Type uncertain				
Mean	−1·59 D	−2·93 D	−0·20 D	−1·67 D
SD	5·79 D	3·25 D	3·89 D	4·43 D
No. of eyes	10	11	8	29
Total of all 5 types				
Mean	−2·04 D	−2·16 D	−1·06 D	−1·86 D
SD	4·07 D	3·22 D	2·39 D	3·39 D
No. of eyes	90	115	63	268
Non-X-linked				
Mean	−1·24 D	−1·47 D	−0·69 D	−1·20 D
SD	3·81 D	2·30 D	2·11 D	2·79 D
No. of eyes	66	103	58	227

*Dioptres indicated by D.

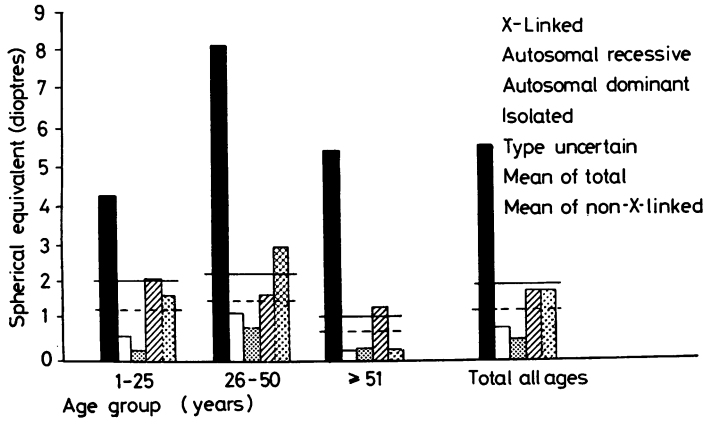

Fig. 3 *Mean spherical refractive errors for retinitis pigmentosa patients by genetic type and age group. Mean of total (all genetic types) is shown for each age group* (solid line). *Mean of non-X-linked population in each age group* (dashed line) *is less myopic than total mean for each group. X-linked mean in each age group* (solid bar) *is highly myopic*

than that for the 26- to 50-year group; it is also significantly less ($P < 0.05$, 1-tailed test) than the mean for the combined 1- to 50-year group.

The RP population shows considerable cylindrical refractive errors, extending from 0 to +5·00 D (Fig. 4). Cylindrical errors greater than 0·5 D are found in 74% of the RP patients. For a normal population only 19% have cylindrical refractive errors of this magnitude.

The astigmatic errors for X-linked and non-X-linked groups are shown in Fig. 5. Of the 41 X-linked eyes 80% have cylindrical errors greater than 0·5 D. For the non-X-linked group of 227 eyes this figure is 73%. Astigmatic errors of high cylinder (> 2·5 D) appear slightly more frequently for the X-linked group than for the non-X-linked group.

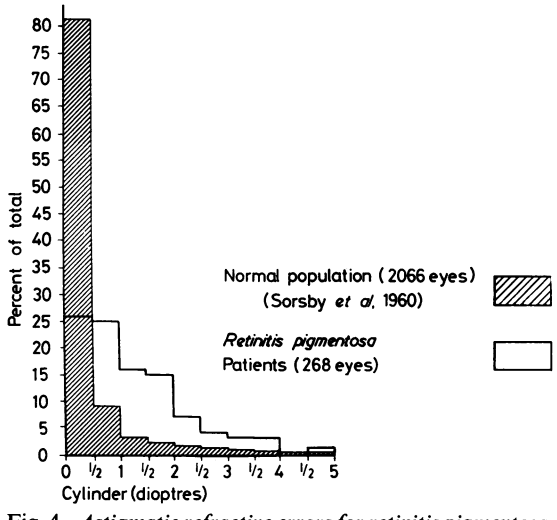

Fig. 4 *Astigmatic refractive errors for retinitis pigmentosa patients and for normal population (Sorsby* et al., *1960). Data for the normal population were adjusted to allow plotting by 0·5 dioptre steps*

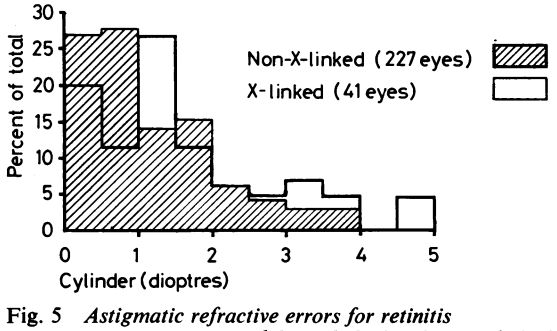

Fig. 5 *Astigmatic refractive errors for retinitis pigmentosa patients grouped by X-linked and non-X-linked type, showing graph of relative numbers* (%)

Discussion

The outstanding features of this analysis of the RP study population are (1) the significant myopic shift of the mean spherical refractive errors from the mean of a normal population; (2) the more highly myopic mean of the spherical errors in the X-linked group than in the other RP genetic groups; and (3) the much greater prevalence of astigmatic refractive errors than in a normal population.

Comparing the spherical errors of RP and normal populations, one finds similar distribution shapes but a significant ($P < 0.001$) difference in the means by nearly −3 D. These 2 populations, compared to their respective normal curves (Figs. 1 and 2, top), show an excess in the peak and deficiencies on both sides of the peak. Both have a longer myopic than hypermetropic tail, a feature that is exaggerated in the RP population. It appears that the entire RP population has a −3 D myopic component added almost uniformly to an otherwise normal spherical refractive error distribution shape. This possibility appears more evident for the non-X-linked RP distribution (Fig. 2, bottom) than for the highly myopic, rectangular distribution of the X-linked group (Fig. 2, centre).

We note that Sorsby *et al.* (1960) derived their 'normal distribution' differently from that used for our RP population study (see legend, Fig. 1). For the 81% of their population having cylinders less than or equal to 0·5 D they used the same 'spherical equivalent' as in the RP analysis. For the remaining 19% of their population with cylinders greater than 0·5 D they used the least ametropic meridian, a technique that understates the true spherical refractive error of the eye. Sorsby *et al.* (1960) found that astigmatic values of greater than 0·5 D were concentrated around the central spherical values and were proportionately more frequent with hypermetropic than myopic refractions. Thus, if their spherical errors were converted entirely to spherical equivalent values, the mean of these data would be slightly more hypermetropic than is presented here. This data conversion would increase the width and lower the peak of the distribution, causing it to approximate more closely to the shape (but not the mean) of the RP distribution.

The X-linked group is, on the average, more highly myopic than the remainder of the RP population. Of the 41 eyes in the X-linked group 80% (33 eyes) are more myopic than the median refractive error of the remaining RP population. The X-linked group contributes to the myopic skew of the total RP population. The high degree of myopia in the X-linked type extends into the youngest group of patients examined. Among the 7

youngest patients (14 eyes) aged 5 to 15 years, 4 eyes have spherical error of approximately -1·00 D and the remaining 10 eyes have spherical errors ranging from -5·00 to -11·00 D.

The X-linked population may be composed of 2 subgroups of spherical refractive errors. In the distribution of Fig. 6 one can depict one subgroup from +2·00 to -4·00 D, with a mode at -0·5 D, and a second subgroup between -2·00 and -16·00 D, with a mode at -7·50 D. Between -2·00 and -4·00 D the high tail of the first group overlies the low tail of the second group. The first X-linked subgroup lies under the peak of the non-X-linked group and appears to have refractive characteristics similar to this group. The second X-linked subgroup lies under the myopic tail of the non-X-linked group and shows refractive characteristics more myopic than most of the RP population. Nearly 70% of the X-linked group appears to lie within the second subgroup. Due to the small number of X-linked patients in this study, any division of this population into these subgroupings must remain tentative at this point.

The RP population has astigmatic errors of greater than 0·5 D, considerably in excess of those found in the normal population. These errors are seen throughout the 5 genetic groups without any particular clumping of values in any one genetic type. The X-linked population shows only a slight excess of the higher astigmatic errors than does the non-X-linked population (Fig. 5). This excess must be interpreted with caution in view of the small number of X-linked eyes (N=41). For astigmatic errors in all 5 genetic groups there is no strongly positive correlation with the spherical refractive state. Patients with high myopic errors tend to have high astigmatic errors; hypermetropic spherical errors (+1·00 to +4·50 D) tend to have low astigmatic errors. However, eyes with spherical errors in the centre of the main distribution (+1·00 to -4·00 D) have a wide range of astigmatic errors (0·00 to 4·00 D).

The higher degree of myopia in the X-linked form of RP is of interest. A similar association of myopia and X-linked genetic inheritance with a stationary form of nyctalopia is already known (Carr, 1974). The explanation of the higher incidence of myopic and cylindrical refractive errors in RP patients of all genetic types is uncertain. Whether it is a specific finding for this retinal pathology is yet to be determined.

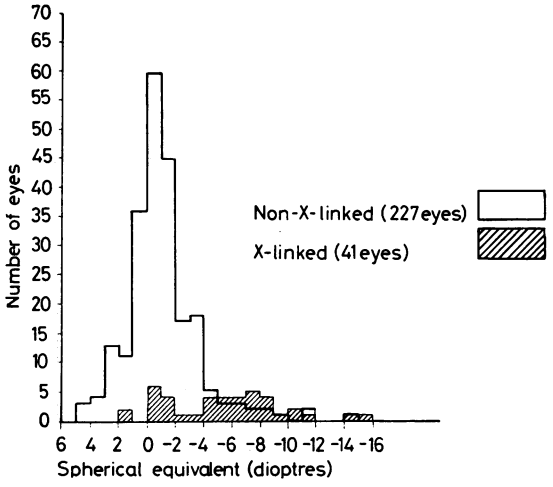

Fig. 6 *Spherical refractive errors for retinitis pigmentosa patients grouped by X-linked and non-X-linked types. X-linked group has higher myopic errors and may contain two subgroups, one under peak of non-X-linked population and second under myopic tail*

This investigation was supported in part by training grant EY 24–16 from the National Eye Institute, National Institutes of Health, and the National Retinitis Pigmentosa Foundation.

Morton F. Goldberg, MD, and Maxine Gere reviewed the manuscript and Leticia Escobar typed it.

References

Carr, R. E. (1974). Congenital stationary night blindness. *Transactions of the American Ophthalmological Society*, **72**, 448–487.

François, J., and Verriest, G. (1962). *Etude biometrique de la retinopathie pigmentaire. Annales d'Oculistique*, **195**, 937–951.

Jain, I. S., and Singh, K. (1967). A clinical study of primary retinitis pigmentosa. *Oriental Archives of Ophthalmology*, **5**, 99–104.

Sorsby, A., Sheridan, M., Leary, G. A., and Benjamin, B. (1960). Vision, visual acuity, and ocular refraction of young men. *British Medical Journal*, **1**, 1394–1398.

Steel, R. G. D., and Torrie, J. H. (1960). *Principles and Procedures of Statistics*, p. 81. McGraw-Hill: New York.

Usher, C. H. (1935). The Bowman lecture: VI. On a few hereditary eye affections. *Transactions of the Ophthalmological Society of the United Kingdom*, **55**, 176–183.