A REVIEW OF OPHTHALMIC EXAMINATIONS CARRIED OUT AT A.F. CENTRAL MEDICAL ESTABLISHMENT*

By

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AN ANALYSIS OF THE VISUAL ACUITY AND THE REFRACTION

Summary

The distribution of the visual acuity of 2,266 cases examined at the Air Force Central Medical Establishment, New Delhi, from June 1956 to July 1959, are analysed and discussed. The incidence of the refraction of the 3,882 eyes refracted is demonstrated. The effect of 2% homatropine and cocaine upon the refraction was found to be negligible. The relation of the refraction to the visual acuity is demonstrated, and the correlations worked out are significant; the range of the refractive errors with the means and modes for each visual acuity level are determined, and the inaccuracy of laying down visual standards in terms of visual acuity alone, without specifying the refraction limits is made evident. The effects of lowering the visual standards are discussed. The distribution of the visual acuity and of the refraction in the accepted population and in serving pilots is analysed, and is shown to justify the maintenance of the present visual standards. The causes of the failures to correct to the 6/5 and 6/6 levels are also analysed.

Introduction

This paper will be restricted to an analysis only of the visual acuity and refraction, as determined in the ophthalmic examinations carried out at the Air Force Central Medical Establishment from June 1956 to July 1959. During this period 2,266 ophthalmic examinations were recorded; of these the refraction details of 1,941 cases or 3,882 eyes were available for analysis.

The Population under Review

The breakdown of the population reviewed is reproduced in Table I.

TABLE I

Classification of the ophthalmic examinations carried out at A.F.C.M.E.

Class No.	Class	Cases Examined	Cases Refracted	Range of Age
I	N.D.A. and direct entry candidates	649	566	15 to 21
II	Civil aviation aircrew	664	556	20 to 54
III	Candidates for ground duties branches	455	408	17 to 28
IV	Serving personnel for annual medical examination, disability, etc.	498	411	22 to 48
		2,266	1,941	

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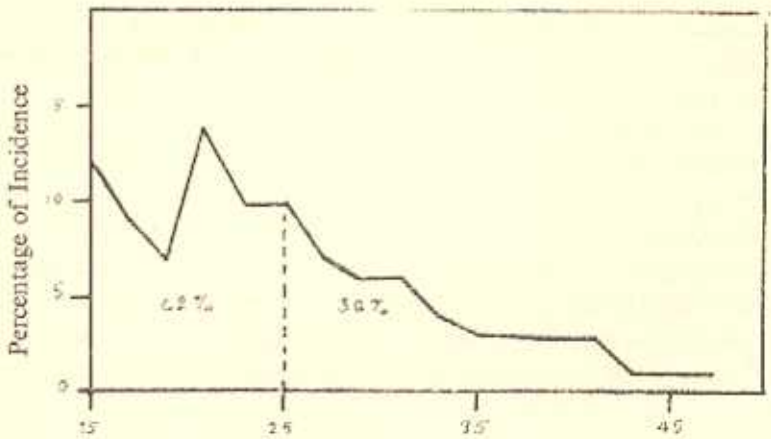
Class I represents candidates for the flying branches of the Air Force, either through the National Defence Academy, or by direct entry, the unaided visual requirement being 6/6, 6/9. Class II represents civilian aircrew, the majority being pilots who are required to conform to I. C. A. O. visual requirements of at least 6/18, 6/18 unaided vision, correctable to 6/9, 6/9. Class III includes candidates for the ground duty branches of the Air force, where the minimum vision accepted is 6/60, 6/60. Class IV represents serving personnel of all trades and branches. The over-all age incidence is given in Fig. 1.

FIG. 1



Age distribution of the cases reviewed

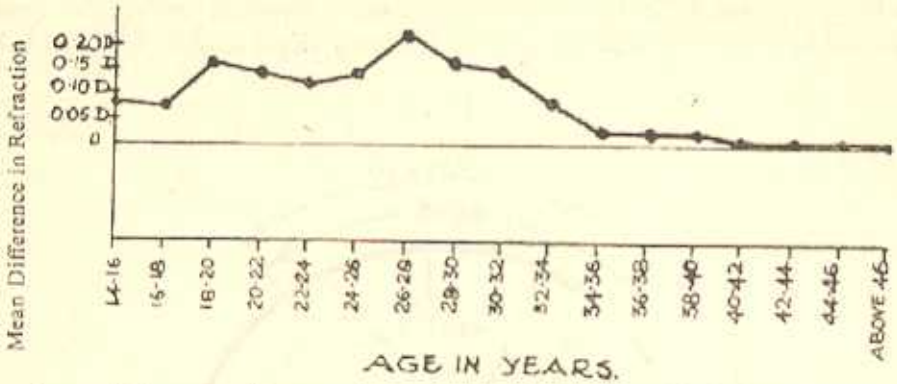
Technique

The visual acuity was determined in a dark room, at a test distance of 6 metres; Snellens test types were employed, the smallest line on the charts representing 6/5 vision. The types were illuminated by two 40 watt bulbs placed 15 inches from the plane of the chart in the manner described in the R. A. F. publication A. P. 130.

Retinoscopy was performed with the streak retinoscope in all cases. The subjects fitted with the trial frame were encouraged to read the test types at the test distance of 6 metres, through appropriate lenses till the point of neutralization was reached. The position of the principle meridians was subsequently verified by means of cross cylinders. In this manner a high degree of accuracy was ensured.

Cycloplegic refraction was also done in 694 eyes using 2% homatropine and cocaine drops. The retinoscopy was done before and after instillation, after an average interval of 45 minutes; the average mydriatic effect was indicated by an average increase of 3.3 mm in the apparent pupillary diameter. The mean cycloplegic effect of the homatropine and cocaine is represented in Fig. 2.

FIG. 2



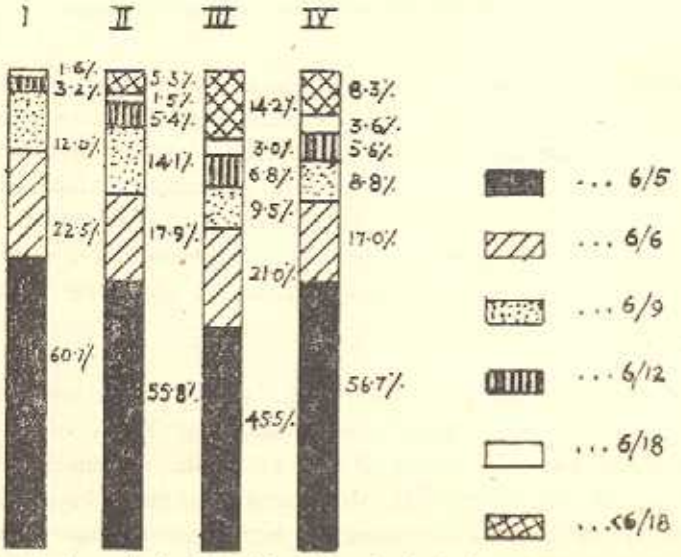
Curve of the mean differences between refractions before and after instillation of 2% homatropine and cocaine at various age groups

It will be seen that in this series the average mean cycloplegic effect of 2% homatropine and cocaine is to uncover only 0.14 D of hypermetropia in the age range from 15 to 32 years and thereafter is practically nil. This does not correspond with the widely held view that homatropine reveals +0.75 D of hypermetropia. It is probable that the technique of dynamic distance refraction used unmasks most of the physiological tone after the age of 15 years.

The Distribution of Visual Acuity

The distribution of the uncorrected visual acuity in each of the classes is depicted in Fig.3. Classes I and II represent candidates for service and civil flying and civil aircrew, and

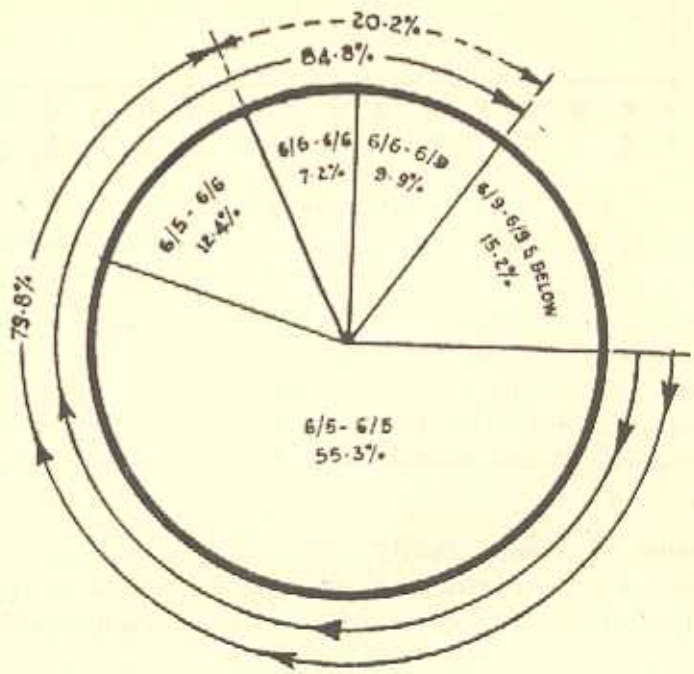
FIG. 3



Distribution of visual acuities in each of the four classes (3,882 eyes)

therefore contain a larger proportion of the higher visual acuities 6/5, 6/6 and 6/9. Classes III and IV, comprising 42% of the total cases reviewed, represent mainly the ground duty branches and have a greater representation of the lower visual acuities, 6/12 and below.

FIG. 4



Percentage distribution of the visual acuity groups

Fig. 4 represents summation of the acuity of all four classes. Since the smallest types on the chart represented 6/5 vision, this was the finest acuity that could be recorded. It will be seen that 55.3% of the total population reviewed had a visual acuity of 6/5, 6/5 ; a further 12.4% had a visual acuity of 6/5, 6/6. The conventional standard visual acuity is a visual acuity of 6/6, in which the minimum visual angle is one minute. In this analysis, 67.7% of the population under review have a binocular visual acuity of 6/5, the equivalent of a visual angle of 50 seconds, which therefore is more representative of normal vision than the conventional standard of 6/6.

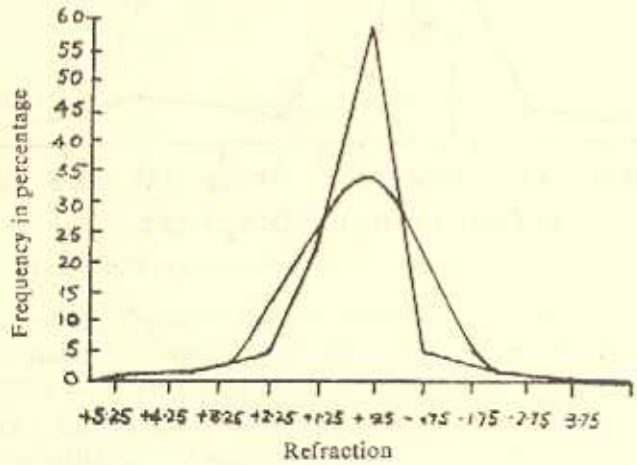
A total of 84.8% of the population come within our present visual requirement of 6/6, 6/9, — by retaining these standards, we ensure that 79.8% of the accepted population have an unaided binocular vision of 6/5, whilst the remainder all have an unaided binocular vision of 6/6. It is accepted the world over, that the highest visual acuity is a most definite requirement for the efficient flying of high performance aircraft. Our present standards meet the demands.

If, however, we lowered the standards to the ICAO requirements of 6/18 6/18, we would gain another 8.5% accepting a total of 93.3%, but this would necessitate mandatory wearing of correcting lenses in this 8.5% gained, a practice which has not yet been universally accepted as feasible for military flying.

The Incidence of the Refraction

The classical curve of the incidence of refraction compiled by Scheerer [7] and Betsch from a refraction of 12,000 eyes is reproduced in Fig. 5. This curve is compared with a

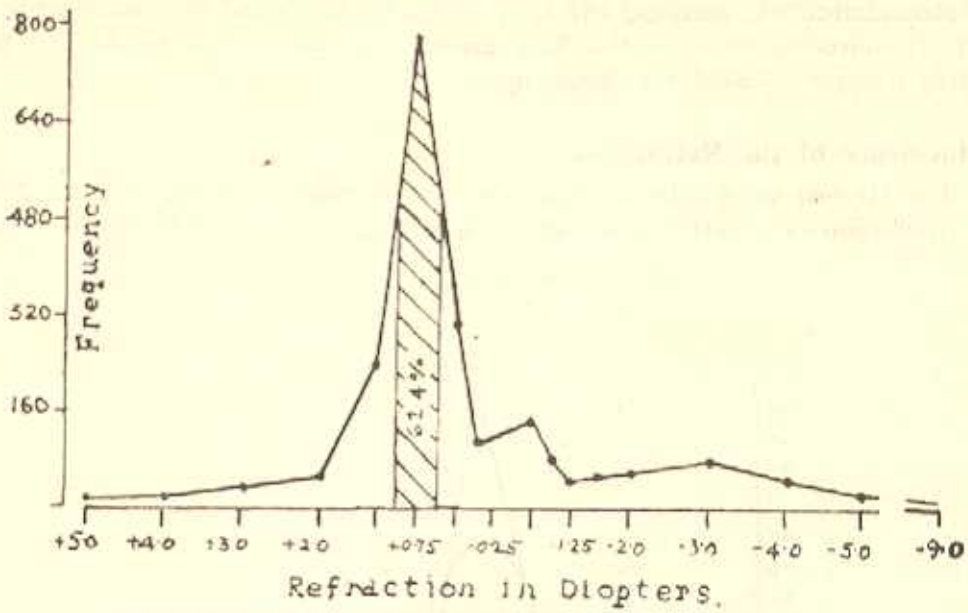
FIG. 5



Curve of the incidence of refractive errors compared with the theoretically derived binomial curve (after Scheerer and Betsch)

theoretically derived binomial curve. Its norm is at +0,5 D and is markedly in excess of the theoretical value. It has a skewness towards the myopic side; this skewness, however, is eliminated, when all cases showing abnormal changes in the fundus are excluded. The excessive central values around emmetropia results from the regulating process, seeking to reproduce the theoretically perfect eye, a process that has been termed emmetropization. Refraction curves taken at different age groups show a significant variation with age. Wibaut [10] (1925) analysing the data of 2,398 German newborn infants refracted under cycloplegia, obtained a curve with the mode at 2.0 D of hypermetropia. Sorsby's[11] (1934) curve of London children from 4 to 8 years showed a peak at 2,3 D of hypermetropia. Brown and Kronfeld[8] (1929) reviewing 10,000 American eyes of adolescents below 25 years, and adults above 25 years, found symmetrical curves with the peak at +1.0 D. The distribution of the refraction of the 3,882 eyes refracted in the series is reproduced in Fig. 6. In estimating the refraction, the cylindrical values have been taken into account, and have been combined with the sphere whenever they occurred. The curve shows

FIG. 6



Distribution of refractive errors in the series reviewed (3,882 eyes)

a peak at 0.75 D of hypermetropia ; refractions ranging from + 0.5 D to + 1.0 D comprise 62.4% of the total. On the myopic side, there are two slight rises ; the first from—0.25 D to —0.75 D is probably caused by the slightly increased frequency of — 0.25 D and —0.5 D cylinders, which at these levels have a more pronounced effect ; the second rise, from —2.5 D to—3.0 D, is probably due to the tendency of myopia to stabilize at these levels as observed by Cooper[5] (1951.)

The incidence of the various types of refractive errors in other countries excluding presbyopia, is shown in Table II.

TABLE II

Incidence of various types of refractive errors in other countries (excluding presbyopia)*

Country	Reference	Percentage Errors			Percentage Emmetropia	Remarks
		Myopia	Hypermetropia	Mixed Astigmatism		
U. K.	... Harman[4] (1936)	31.7	65.6	2.7	...	30,000 cases (above 16 yrs.)
U. S. A.	... Jackson[7] (1932)	19.6	66.7	...	13.7	1,482 patients between 20—30 yrs.

Table – II Contd.

Country	Reference	Percentage Errors			Percentage Emmetropia	Remarks
		Myopia	Hyperme. tropia	Mixed Astigmatism		
BRAZIL	... Machado[9] (1942)	19.2	65.7	15.1	...	Children
AUSTRIA	... V. Ruess[14] (1881)	14.5	33.9	...	51.6	At Vienna
CHINA	... Rasmussen[16] (1936)	78.0	22.0	...	...	120,000 cases for visual correction
GERMANY	... Hess & Diedrichs[6]	26.8	38.2	...	35.0	Children

* (Estimated from figures quoted in Duke-Elder) *

The incidence of refractive errors, as estimated by different observers in different parts of India, together with the incidence as determined in the present series is tabulated in Table III.

TABLE III

Incidence of various types of refractive errors as estimated by different observers in different parts of India (excluding presbyopia)

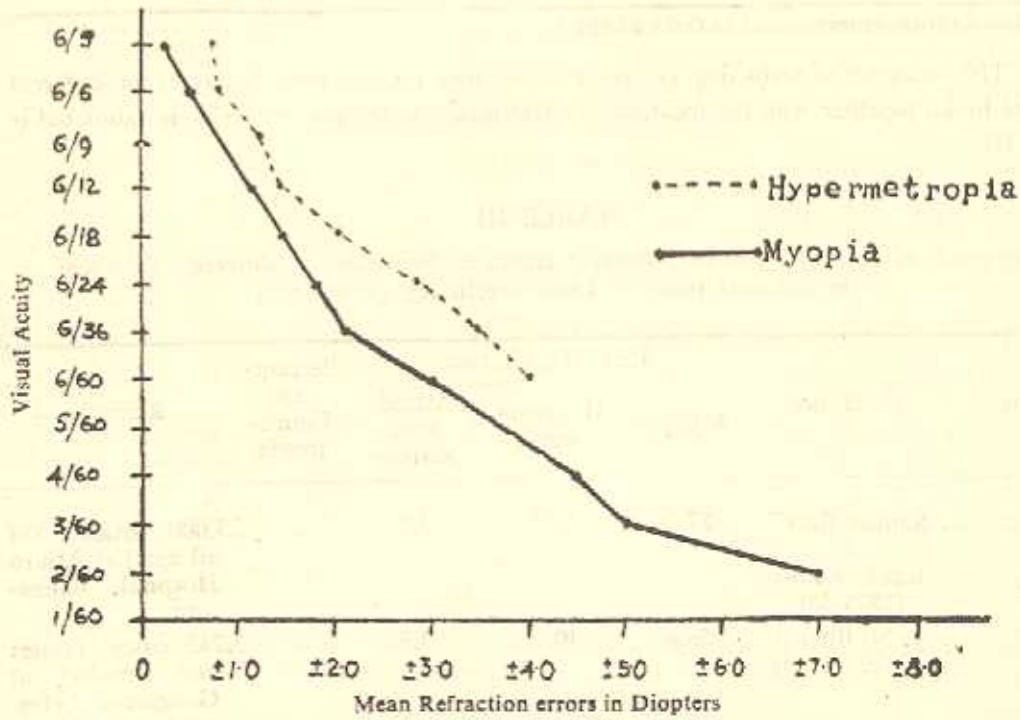
Region	Reference	Percentage Errors			Percentage Emmetropia	Remarks
		Myopia	Hyperme-tropia	Mixed Astigmatism		
Mysore	... Sunder Rao[15] & Krishna Rao (1925-35)	37.2	58.9	3.9	...	25,000 patients (of all ages) at Minto Hospital, Bangalore
Punjab	... T. N. Bhau[1] (1933-1938)	56.6	40.9	2.5	...	3,245 cases (males and females) at Gangaram Hospital, Lahore
Bengal	... Maj. V. P Patel,[9] (1950)	39.5	57.4	2.4	0.7	5,000 cases (from all strata of pop.) Bengal
All India	... Present paper under review	15.3	50.7	2.6	31.4	1,941 cases at A. F. C. M. E., New Delhi
		37.2	52.0	2.8	8.0	35,186

Since the population reviewed in the earlier series, comprise patients attending hospitals with complaints of defective vision, these series contain no or a very small percentage of emmetropia, and since myopia is more common a cause for defective vision, the myopia in these series is unduly accentuated. The series under review gives undue weightage to emmetropia and hypermetropia, since it covers a population the majority of whom had no visual complaints. These facts must be borne in mind when considering the results of the summation, which indicates that the predominant refraction state in India is hypermetropia occurring in approximately 52% of the population.

The Relation of the Refraction to the Visual Acuity

The effect of the refractive error upon the visual acuity is demonstrated in Fig. 7 by plotting the mean refractive error against the visual acuity. The correlation coefficient between visual acuity and hypermetropic errors works out to +0.89; and that between visual

FIG. 7



Graph showing the effect of refractive error upon visual acuity

acuity and myopic errors works out to +0.79. The hypermetropic errors are not restricted to absolute hypermetropia, but include facultative hypermetropia, which is corrected by an effort of accommodation, and which occurs in the younger age groups which comprise the majority of the population under review. Hypermetropia, therefore, shows a less effect on the visual acuity than myopia, having a larger mean value than myopia at the various visual acuity levels, and being less linear in its effect.

The limits of the refraction and the means and modes are depicted in Table IV. The effect of hypermetropia is somewhat irregular and the means and modes of the hypermetropic errors are greater than those of the myopic errors by amounts varying from 0.2 D to 1.5 D—this is due to the presence of the facultative moiety. Moreover, since this series includes only 14 cases of hypermetropia above 4.0 D the effect of the larger hypermetropic errors cannot be considered conclusive. The myopic errors have a more linear effect. The myopic limits ascend steeply from –0.5 D at the 6/5 level to –8.0 D at the 6/60 level, whilst the means and modes have a more gentle ascent. The modes, which represent the normal refraction at each visual acuity level, ascend by almost regular steps of–0.25D to 6/24, and then by steps of –0.5 D and –0.75 D to –3.0 D at the 6/60 level.

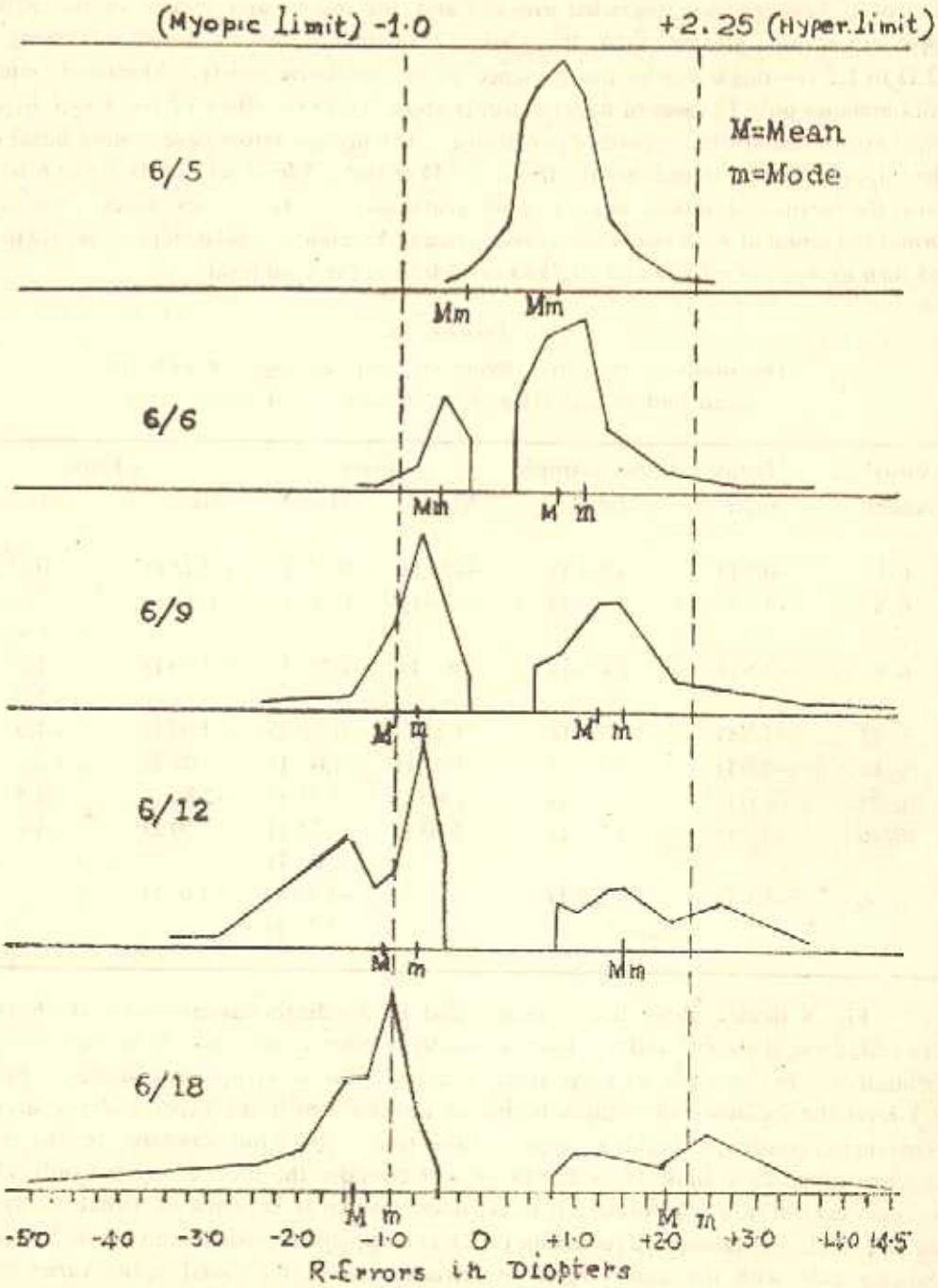
TABLE IV

The limits of refractive errors encountered together with the mean and modal refractions at each visual acuity level

Visual Acuity	Myopic limit	Hypermetropic limit	–Error		+Error	
			Mean	Mode	Mean	Mode
6/5	–0.5 D	+2.5 D	–0.25 D	–0.25 D	+0.75 D	+0.75 D
6/6	–1.5 D	+3.5 D	–0.50 D	–0.50 D	+0.80 D	+0.75 D +1.0 D
6/9	–2.5 D	+4.5 D	–1.0 D	–0.75 D	+1.24 D	+1.25 D +1.5 D
6/12	–3.5 D	+3.5 D	–1.15 D	–0.75 D	+1.43 D	+1.5 D
6/18	–5.0 D	+4.5 D	–1.42 D	–1.0 D	+2.05 D	+2.5 D
6/24	–6.0 D	+4.0 D	–1.80 D	–1.25 D	+2.82 D	+2.5 D
6/36	–7.5 D	+5.5 D	–2.10 D	–1.75 D –2.0 D	+3.50 D	+4.0 D
6/60	–8.0 D	+5.5 D	–3.0 D	–2.75 D –3.0 D	+4.0 D	

Fig. 8 depicts these limits, means and modes diagramatically up to the 6/18 level. The refraction at the 6/5 and 6/6 levels is mostly hypermetropic and all the hypermetropia is facultative. The myopia at these levels is mostly due to myopic astigmatism. From the 6/9 level the incidence of myopia begins to increase whilst the hypermetropia decreases; absolute hypermetropia begins to appear at this level. Since our standards restrict manifest hypermetropia to a limit of +2.25 D we will consider the effect of myopia only. It now becomes evident how inaccurate it is to lay down standards in terms of visual acuity below the 6/9 level. For example, a refraction of–2.0 D is capable of visual acuity from 6/9 to 6/18, showing that with the same degree of refractive error, the visual acuity varies with the individual's ability to interpret the blurred image presented on his retina, which is dependent upon the state of fatigue, general health, motivation, conditions of examination and other

FIG. 8



Graphs showing the distribution of refractive errors, with means and modes for each visual acuity level from 6/5 to 6/18.

factors. Let us now consider the effect of lowering our visual standards in terms of refraction. If we lowered our visual acuity requirement to 6/18 then the modal values of the highest myopia admitted will be raised from the present 6/9 value of -0.75 D to-1.0 D, but we will be liable to accept myopes up to -5.0 D, which is not desirable at the adolescent age of entry with two or three years of training ahead, during which a further increase in myopia is possible. If, however, we expressed our lowered standards in terms of refraction, and limited myopia to a total sphero-cylindrical value of -1.0 D, we would in effect be lowering our standard to 6/18, 6/18, whilst at the same time we would be excluding the extremes of myopia met with at the lower accepted levels. In this manner we would gain another, 6% and would accept 91% of the population under review. It would be necessary, however, to add a proviso that ophthalmoscopy under cycloplegia does not reveal,

a) macular changes in the form of a fine degree of pigmentation associated with a fall in the corrected visual acuity,

b) any degree of anterior choroiditis,

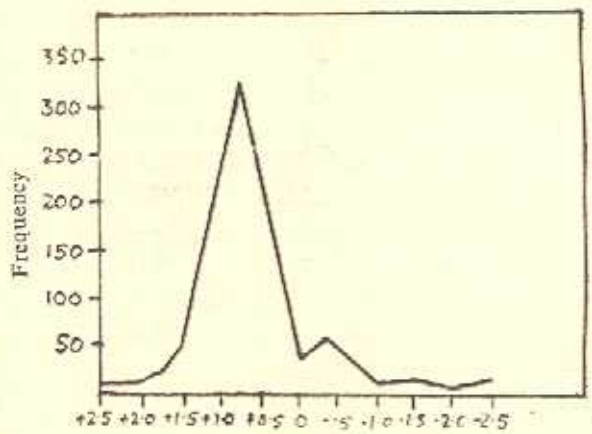
c) any vitreous opacities,

as all these are indicative of the so-called pathological or progressive myopia. It will also have to be made obligatory for aircrew with unaided binocular vision of 6/9 and below, to wear correcting lenses to meet the demands of present day military aviation.

The Distribution of the Refraction in the Accepted Population

The distribution of the refraction of the eyes of the candidates in Class I, who were accepted for flying training in accordance with our present standards, and of serving G.D. officers is outlined in Fig. 9.

FIG. 9



Distribution of refractive errors in accepted candidates and in serving aircrew

This curve approximates to the over-all curve in Fig. 6 with the ends cut off; it shows that 80% of these accepted candidates and serving aircrew have a refraction ranging from +0.5 D to +1.5 D. This is a very big advantage from the point of view

of the requirements of military aviation, since such a refractive state is ideally suited for search under conditions of an empty visual field. The myopia, ranging from —0. 6 D to —1. 5 D, that is found to occur under such conditions, reducing the pick up range to half, is neutralised by this hypermetropia; the far point remains at infinity; and the pick up range is unaffected. (Whiteside [16,17,18].)

The Distribution of Visual Acuity and Refraction in Serving Pilots

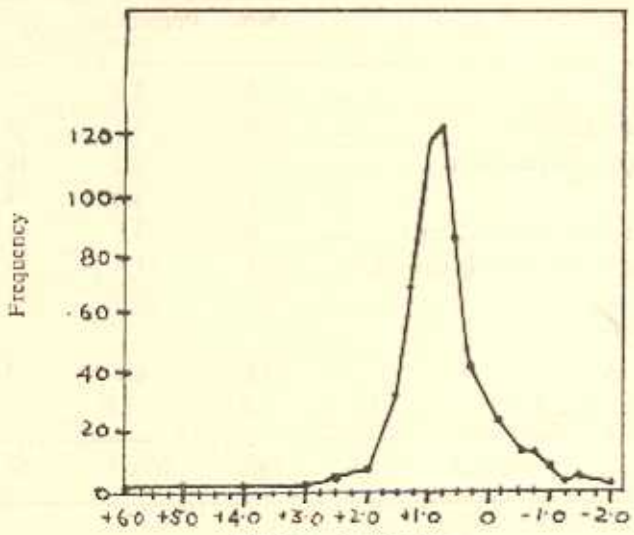
Table V shows the distribution of the visual acuity in 106 Air Force pilots and 204 civil pilots. Of the Air Force pilots, 70% had 6/5 vision in each eye; 84.1% had binocular vision of 6/5, and 94.5% binocular vision of 6/6. There were three cases with unaided binocular vision of less than 6/12; these cases reflect an unduly large proportion of the 106 Air Force pilots reviewed, since they were specially referred to A.F.C.M.E. for below standard vision. Deterioration below the initial entry standard of 6/6, 6/9 occurs in 6 cases or 5.6% of the serving pilots reviewed.

TABLE V

Visual Acuity	A. F. Pilots		Civil Pilots		Total	
	Frequency	Cumulative %	Frequency	Cumulative %	Frequency	Cumulative %
6/5–6/5	74	70.0	130	63.7	204	65.8
6/5–6/6	13	82.2	24	75.4	37	77.7
6/5–6/9	2	84.1	4	77.4	6	79.7
6/5–6/12	—	—	3	78.9	3	80.7
6/5–6/18	—	—	1	79.4	1	81.0
6/6–6/6	7	90.7	15	86.7	22	88.1
6/6–6/9	4	94.5	6	89.6	10	91.3
6/6–6/12	—	—	4	91.6	4	92.6
6/6–6/18	—	—	2	92.6	2	93.2
6/9–6/9	1	95.4	4	94.6	5	95.1
6/9–6/12	2	97.3	5	97.0	7	97.3
6/12–6/12	—	—	1	97.5	1	97.6
6/12–6/18	1	98.2	1	98.0	2	98.2
6/12–6/24	—	—	1	98.5	1	98.5
6/12–6/36	—	—	1	99.0	1	98.8
6/18–6/18	1	99.1	—	—	1	99.1
6/24–6/24	—	—	1	99.5	1	99.4
6/36–6/36	—	—	1	100.0	1	99.7
6/36–6/60	1	100.0	—	—	1	100.0
	106		204		310	

Among the 204 civil pilots, 63.7% had unaided 6/5 vision in each eye; 79.4% were 6/5 binocularly and 92.6% had 6/6 binocular vision. There was only 1% with unaided binocular of less than 6/12 necessitating the mandatory wearing of glasses. The percentage below the initial Air Force entry standard was 12.3%; and there were 4 cases or 2.0% below the initial ICAO standard of 6/18. The combined distribution of the refraction is given in fig. 10.

FIG. 10



Distribution of refractive errors in serving Air Force and Civil Pilots.

The combined mean refractive error is + 0.68 D and the mode + 0.75 D; 96.8% of the total eyes examined were within the range from + 2.0 D to - 1.0 D. The total range being + 6.0 D to - 2.0 D. Of the 11 cases with less than 6/12 vision in one or the other eye, two were hypermetropic, both civil pilots of the age groups, wherein absolute hypermetropia becomes evident; one was aged 48 years with an average refraction of + 2.0 D Sph. and unaided vision of 6/24; and the other was 54 years of age with an average refraction of +6.0 D Sph and an unaided visual acuity of 6/36. Two cases were simple myopes, the maximum error being —1.25 D. Two others were predominantly astigmatic with cylindrical errors ranging from + 1.0 D cyl. to — 1.75 D cyl. The others were cases of compound or mixed astigmatism.

Correction of Refractive Errors

Of the total of 3,882 eyes refracted, 196 eyes or 5.05% of this total did not correct to 6/5. Of these eyes 140 were capable of correction to 6/6, the remainder correcting below 6/6 was only 1.43% of the total. The breakdown of these eyes is shown in Table VI.

TABLE VI

Number of eyes examined = 3,882
Number of eyes which could not be corrected to 6/5 = 196 (or 5.05% of the total)
Number of eyes which could not be corrected to 6/6 = 56 (or 1.43% of the total)

Errors		Eyes not corrected to 6/5		Eyes not corrected to 6/6	
		No.	Percentage	No.	Percentage
1. i) Myopia	...	6	3.1	—	—
ii) Simple myopic astigmatism	...	9	4.5	2	3.6
iii) Compound myopic astigmatism	...	58	29.5	19	33.9
2. i) Hypermetropia	...	8	4.0	4	7.2
ii) Simple hypermetropic astigmatism	...	6	3.1	—	—
iii) Compound hypermetropic astigmatism	...	62	31.6	18	32.1
3. Mixed astigmatism	...	27	14.0	8	14.2
4. Macular changes					
i) Eclipse burns	...	12	6.1	3	5.4
ii) Degenerative changes	...	8	4.1	2	3.6
Total	...	196	100.0	56	100.0

Changes were found in the maculae of 20 eyes or 10.2% to account for their failure to correct; of these 6.1% had eclipse burns, whilst the remaining 4.1% showed degenerative changes in the form of colloid bodies or fine pigmentary deposits. The distribution of the refraction of the remaining eyes shows that predominant refractive states are those in which both focal lines do not fall on the retina, *i.e.*, compound myopic astigmatism, compound hypermetropic astigmatism and mixed astigmatism, accounting for 75.1% of the eyes. Of the remainder 3.1% had simple myopia, and 4.0% had simple hypermetropia, 4.5% simple myopic astigmatism, and 3.1% had simple hypermetropic astigmatism. It is interesting to note that all the simple myopia and simple hypermetropic astigmatism could be corrected to the 6/6 level — whilst the incidence of the other refractive errors maintained almost the same proportions in the eyes corrected to the 6/6 level and in those to levels below 6/6.

Conclusion

The above analysis reveals the following:

1) The mean cycloplegic effect of 2% homatropine and cocaine was to reveal +0.14 D of hypermetropia between the ages of 15 and 32 years and thereafter was nil. This was probably brought about by the unmasking of nearly all the physiological ciliary tone by the technique of dynamic distant refraction employed.

2) Visual acuity of 6/5 is more representative of normal vision than a visual acuity of 6/6.

3) The distribution of the refraction in this series shows a norm at + 0.75 D ; a rise between – 0.25 D and – 0.75 D due to the effect of the small myopic astigmatic errors at these levels, and a second rise between – 2.5 D and – 3.0 D indicating a tendency for myopia to settle at this level. The summation of the incidence of refractive errors in this series with the finding of other Indian observers shows that the tendency of refraction in India is towards hypermetropia, the incidence of which is 52%.

4) The present I.A.F. visual requirement of 6/6, 6/9 vision correctable to 6/6, 6/6 is very near the ideal. It accepts 84.8% of the population reviewed. Manifest hypermetropia is limited to + 2.25 D. The modal value of the myopia that may be admitted in the 6/9 eye is 0.75 D. Binocular vision of 6/5 is ensured in 79.8% of the population accepted, and 80% have a refraction that is ideally suited for search in an empty visual field. Deterioration below the initial entry standard occurred in 5.6% of the serving pilots is reviewed. This was unduly large since some of these pilots were specially referred to A.F.C.M.E. for below standard vision. The maximum myopia encountered in serving pilots was — 1.25 D.

5) If, however, a lowering of visual standards is enforced by circumstances beyond our control, then the lower limits should be expressed in terms of the refraction and not of visual acuity ; myopia should be limited to total sphero-cylindrical value of –1.0 D, with the proviso, that examination of the retina under cycloplegia reveals no changes in the macula, anterior choroid and in the vitreous ; the limit of + 2.25 D of manifest hypermetropia should be retained. In this manner a gain of 6% would be effected and 91% of the population will be accepted.

6) Compound astigmatic errors were predominant in the 196 eyes, which failed to correct to 6/5, occurring in 75.1% of these eyes. Macular changes occurred in 10.2%, of which 6.1% were caused by eclipse burns.

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