VARIATION AND REFRACTION

BY

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LEWES

MORE than 20 years ago Steiger developed his doctrine that myopia is not necessarily pathological in origin; but that a proportion of myopes arise simply as variations in growth. Unhappily, it has been assumed that if frequency distributions of refractive error be restricted to cases showing no pathological element then such distributions will follow the normal curve of error. This assumption having been repeated from author to author, it will be as well to deal with the matter of curve-fitting at the outset. In the first place the word "curve" should be reserved strictly for curves fitted by mathematical process. It has been—and still is—applied to frequency *polygons*, i.e., graphical records of actual distributions, which merely put into picture form the frequencies found by the observer for successive values of the character under observation. To give completeness to the picture the tops are joined by freehand; but, in point of fact, such graphs are but a succession of uprights. When, however, the tops are joined peaks appear exhibiting the "roughness" of the original material. Moreover, the peaks vary from sample to sample. Now although the original graphs possess no mathematical properties yet it is found that if the samples are summed and, in addition frequencies are obtained for intermediate values of the character; then the polygon becomes smoother and, with each gain in smoothness, approximates more and more closely to a *curve*. Finding the curve by increasing the data is a process not only exceedingly laborious but, in most instances, impracticable. The statistician has to do what he can with the material at his disposal and it becomes his business, therefore, to find a suitable formula which will represent the original statistics as nearly as possible. This formula is the fitted curve. It is *derived from all the original data*, it represents the whole series by a few numbers (the constants in the formula), it facilitates comparison with results obtained by other observers and enables the statistician to supply missing terms.

Now the binomial curve was so derived from the data yielded by experiments conducted in the simpler cases of artificial chance; such experiments (for example) as the throwing of dice or the tossing of coins. Theory predicted it and experiment verified it. We may, if we choose, regard the occurrence of refractions as so many throws of nature's dice, but it is quite unwarrantable to

assume that the dice are not loaded. There *are* biometric distributions which approximate to the binomial curve but they are far from common and it is an exaggeration to say (as Brown and Kronfeld say) that "many a phenomenon" in nature can be represented by the binomial curve. Nor is it true to say that deviations from this curve are regarded as "indications that the material is not homogeneous." Again, the statement that "in the majority of instances an asymmetrical frequency curve should be interpreted as including at least two biological types" is also without foundation. The upholders of the binomial doctrine have published frequency polygons of refractions with superposed binomial curves; these being drawn on so small a scale that the asymmetry of the polygon is not immediately apparent. Now to endeavour to determine symmetry by inspection is simply to demonstrate that the eye, like the heart, is deceitful above all things. An overwhelming majority of biometric distributions yield a moderately asymmetrical curve and refractions are no exception to this rule. The measure of this asymmetry is called the skewness. Clearly the more nearly this skewness approaches zero; the nearer the curve is to symmetry. I have fitted curves to six frequency distributions of refractive error from various sources, including three that have been published as exemplifying the binomial symmetry. They all fall into the asymmetrical category; the skewness of each being definite. Two of these, representing the highest and the lowest, are shown in the graph; the chief characteristics being given in the table. In order to facilitate comparison the number of observations in each case has been reduced to 100, thus allowing the successive ordinates to be given as percentages.

CURVES OF REFRACTION

	(1)	(2)	(3)	(4)	(5)	(6)
Observer.	Wibaut.	Sorsby	B of E.	Wibaut.	Scheerer	Brown
Material (age) -	New Born	4-8 years	4-15	Adolescent	Adult	Adult
Number - -	2398	672	2624	2920	12000	4431
Type - - -	I.	IV.	IV.	IV.	IV.	IV.
Mean (D) - -	+2.6	+2.26	+2.28	-0.3	+0.3	+0.7
Mode (D) - -	+1.25	+2.31	+2.63	+0.2	+0.21	+0.61
St. Deviation (D) -	1.47	1.23	1.75	1.64	1.13	1.97
Skewness - -	-0.92	+0.04	+0.3	+0.3	-0.08	-0.05
Modal Ordinate -	30.2	40.0	28.2	32.1	43.8	27.0
+6 etc.	4.6	0.9	2.2	—	—	1.0
+5	7.2	2.3	4.7	—	0.3	2.0
+4	12.8	9.5	13.7	0.2	0.7	4.7
+3	15.7	26.7	26.2	1.0	3.4	6.7
+2	27.5	33.5	26.0	6.4	14.1	17.0
+1	29.8	19.0	15.1	23.3	28.3	19.0
0	1.9	5.7	6.8	31.7	33.0	25.8
-1	0.3	1.6	2.9	20.3	8.4	11.9
-2	0.2	0.4	1.2	9.5	1.5	8.0
-3	—	0.3	0.6	4.1	0.2	2.1
-4	—	0.1	0.3	1.8	0.1	1.3
-5 etc.	—	—	0.3	1.7	—	0.5
	100.	100.	100.	100.	100.	100.

Now these curves, considering the nature of the original material, are, on the whole, reasonably good fits. Though the data do not possess homogeneity they are none the less comparable. Without entering too deeply into statistical refinement it may

be said here that the Pearsonian system of curves consists of three main types, all of which are bell-shaped curves and possess skewness. At their adjoining frontiers are the subsidiary transitional curves which do not concern us. The three main types are known as I, IV and VI, the two former being represented in this series; though five of the six are of the same type, namely, type IV. The only representative of type I (Wibaut's new-born distribution), deals with data formed by pooling the observations of four observers. This frequency distribution was submitted by Wibaut as an example of a binomial distribution! Actually it has the highest skewness of the whole series; a skewness that is 23 times as great as that yielded by Sorsby's data (No. 2 in the series), and in even this distribution the skewness is still sufficiently high for the normal curve of error to give an extremely poor fit.

The means of the series are interesting. They fall into two distinct categories showing clearly the development of myopia at puberty. The mean of +2.6 D. in Wibaut's "new-born" distribution accords with the mean of +3.0 D. given by the string of observers quoted by Sorsby in his Dublin (B.M.A.) paper last year. This curve also shows a marked preponderance of hyperopia (as we would expect) and though the myopic side is a trifling affair yet it serves to remind us that congenital myopia is a fact. I am indebted to Schurr for details of two cases; one, a child of two months having -4.0 D. in both eyes and the other, a child of one year with -4.5 D. (both eyes). Both cases were examined under atropine.

Below the means are given the modes; the mode in a curve being that value of the variate which is most in the fashion (*à la mode*), *i.e.*, it has the greatest frequency and, graphically, the tallest ordinate. The modal ordinates are given three lines below and indicate the relative heights of these six curves. The modes fall into two categories just as do the means.

The standard deviation measures the spread of the distribution *i.e.*, the greater the clustering around a few central values the lower becomes the standard deviation. In this series it does not vary greatly, though showing some increase with age.

In the lower half of the table are the ordinates. These show the myopic drift with age with the well-known spurt at puberty. The data for Wibaut's adolescent curve came from secondary school children; the material can hardly be regarded as "unselected" and, moreover, may contain a racial factor. A comparison of No. 5 (Scheerer) with No. 6 (Brown) is instructive. For the former the refractions were obtained *without* a mydriatic, and the latter *with* a mydriatic. It suggests that the emmetropic peak found *without* mydriasis is probably not real. This is a very

different peak from that found by Sorsby for non-Jewish children in London schools. A second sample from Jewish children of the same age-period gives a similar curve with lower hyperopic mean, a more definite skewness and a much flatter top. This second curve suggests a lower hyperopic reserve in Jewish children, presumably racial in origin. Both these curves show no variation with sex. They are given in full by Sorsby in his paper in the current L.C.C. School Medical Report.

Now the fact that the increase in myopia tends to pull out the right hand side of the curve and so increase asymmetry has led to the suggestion that the exclusion of pathological cases will allow the true, binomial character of refractive distribution to assert itself. One method followed has been to exclude all cases showing fundal changes. A second—quite arbitrary—method is that of Tron who throws out all cases over -6.0 D! Probably the best method of all would be to restrict the data to cases in which vision can be restored to normal with the appropriate correcting glass. If the distributions were based upon meridians, so that each case contributed four meridians and collective investigation were utilized a comparatively large sample could be obtained without undue labour.

The binomial belief appears to have developed from a misreading of the work of the great Quetelet. In Appendix I (p. 318) of Vol. I of Helmholtz' *Physiological Optics*; Gullstrand quotes Steiger's statement of the correlation existing between corneal refraction and the depth of the anterior chamber ("distance of pupil"). With this he couples the correlations alleged to exist between corneal refraction, circumference of head and stature by Bourgeois and Tscherning (*Ann. d'ocul.*, Vol. XCVI, 1886). These observations were carried out on 203 French cuirassiers. As the authors give the arrays in full I have been able to work out the correlation coefficients; only to find that corneal refraction is *uncorrelated* with either anatomical measurement.

Bourgeois and Tscherning (1886).

YOUNG ADULT MALES (203).

(1) <i>Circumference of Head</i>	Mean.	55.67 cms.	S.D. 1.36 cms.
(2) <i>Corneal Refraction</i>	-	„ 43.1 D.	S.D. 1.33 D.
(3) <i>Stature</i>	-	„ 172.2 cms.	S.D. 2.39 cms.
(4) <i>Correlations</i>	-	$r_{12} = -.113 (\pm .048).$	
		$r_{13} = +.282 (\pm .045).$	
		$r_{23} = -.095 (\pm .048).$	

The second of these between head-circumference (1) and stature (3) is the only significant correlation. Following upon the tables giving the arrays of measurement is a reference to Quetelet's well-

known demonstration that stature in man, when investigated on the large scale, yields a binomial distribution; whereupon the authors proceed to assert that the law is applicable to the different parts of the human body and even to phenomena "tout à fait irréguliers" such as errors in marksmanship (some shots certainly do go astray!). The reader is then invited to observe how "the results of our researches are in accord with Quetelet's law." The demonstration consists of freehand polygons with superposed binomial curves; whereas statistical analysis yields;

(1) Corneal Refraction	-	Type I. curve.	Skewness	+ '14.
(2) Circumference of Head	"	I. "	"	+ '04.
(3) Stature	-	" I.	"	+ '16.

The normal curve of error *might* give a reasonable fit with the second of these measurements but not with the other two. Curiously enough the authors themselves noticed the departure from symmetry but apparently were too intent on demonstrating the binomial quality to draw the obvious conclusion. They remark that the distributions are "oblique" in the same direction. They attribute the stature skewness to the selective nature of the material and the smallness of the sample, and console themselves by saying that the tallest and the largest-headed men have the largest radii of corneal curvature "though the association is weak." Actually, there is no association at all and, moreover, there may be complete independence between the various components that go to make up refraction. Steiger has suggested that the *modal* adult eye is emmetropic as a result of "emmetropization," that is to say, that in the process of growth the hyperopic bias of the child eye is lost and the resultant effect is emmetropia. He has been supported by Tron who has shown that there is no standard length for the emmetropic eye. Apparently an axial length less than 20.5 mm. renders hyperopia inevitable; whilst a length of more than 25.5 mm. just as certainly indicates myopia; but a length between 21.6 and 23.9 may be any of the three. Now if the elements of which refraction is compounded are not perfectly correlated the several individual skewnesses may cancel out and leave a binomial distribution. But from the curves obtained it looks as though fairly high correlations between these factors may exist. There may, for example, be an association between marked curvature of the cornea and unequal curvatures of the same structure. My own cases (1,080 pairs) in children gave a coefficient of correlation between sphere and cylinder of +0.31 (± 0.02); the regression equation showing a rise of half a cylinder with unit increase of sphere. Apparently this association lessens with age, *i.e.*, hyperopia lessens and astigmatism remains constant. Brown's (adult) cases

give for hyperopic astigmatism a correlation coefficient of $+0.144$ (± 0.01) and for myopic astigmatism a coefficient of $+0.148$ (± 0.02); the cylindrical increase for unit spherical increase being reduced to 0.25 D. The modal value of the non-astigmatic eye found by Brown by arithmetical methods was $+1.25$ D. The mathematical method gives $+1.35$ D., the discrepancy being of no importance.

Errors of refraction considered as material for the study of variation may serve to draw attention to the unexplored field of clinical anthropometry.

COUNCIL OF BRITISH OPHTHALMOLOGISTS

Annual Report

THE Council presents its report for the year 1933-34. At its first meeting the following were elected as Officers:—*President*, Mr. Leslie Paton; *Vice-Presidents*, Mr. P. H. Adams, Mr. A. C. Hudson; *Hon. Treasurer*, Mr. M. S. Mayou; *Hon. Secretary*, Mr. M. L. Hepburn. The following were appointed to serve on the Executive Committee:—The President and Secretary (*ex-officio*) with Mr. Greeves, Mr. Levy, Mr. Mayou, Mr. Neame and Mr. Russ Wood.

The Council has to record with great regret the death of Mr. J. B. Lawford. He was Treasurer of the Council when it was originally founded, and later he became President for the years 1920-23. He showed in the affairs of the Council the same conscientious thoroughness and high idealism which characterized his work in all other branches of Ophthalmology, and many important public matters were dealt with during his presidency.

Mr. Juler and Mr. Mayou were again asked to represent the Council on the Ophthalmic Committee of the British Medical Association; and Mr. Paton was appointed as representative on the Prevention of Blindness Committee which was rendered vacant owing to the death of Mr. Fisher.

Regarding the work of the Council during the year, several subjects have occupied their attention.

As a result of the Council's persistent efforts, the London County Council has granted permission for the students of all the London Hospitals to attend St. Margaret's Hospital for instruction in the diagnosis, prevention, and treatment of ophthalmia neonatorum, and advantage has already been taken of this offer to the extent that 180 students have attended the Institution during the three months, October to December, 1933.