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THE TRANSMISSION OF REFRACTIVE ERRORS WITHIN ESKIMO FAMILIES*

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ABSTRACT

A study was carried out on volunteer Eskimo families at Barrow, Alaska. The total population consisted of 508 subjects with complete information including a clinical examination as well as refractions with and without cycloplegics. Correlations between refractive errors of parents and children as well as between siblings are determined on 41 family units comprising 197 subjects. The correlations between parents and children were not significantly different from zero, whereas the correlations between siblings were high and significant. These results were interpreted to suggest that there is no major hereditary component involved in development of myopic refractions among the offspring while there is a strong environmental component operating to create the sibling correlations. These interpretations are supported by the fact that there is virtually no myopia among the grandparents or parents but approximately 58% of the offspring are myopic.

Two general types of approaches may be used to evaluate the relative importance of heredity and environment: the correlational approach and the experimental approach. The correlational approach has been most widely used in studies of human genetics and includes such methods as the study of human pedigrees, population genetics, consanguinity tests, the study of linkages and the study of twins. Although the correlational approach lends itself readily to the study of human genetics, the amount of information it can provide is limited to an indication of whether two or more variables are or are not related together with some indication of the degree of relationship. Since the correlational approach does not distinguish the nature of the relationship, the correlation found may be due to a relationship between the factors under study and one or more unknown but common variables rather than to a relationship between the factors themselves. Thus, the value of the correlational approach is essentially negative. If some correlation is found, there may or may not be a direct relationship between the factors, but, if no correlation is found, there is no relation-

ship between the factors. The nature of any correlation, which may be found, must be determined on the basis of other information since the correlational approach in itself does not provide such information.

The experimental approach, which includes such methods as co-twin control and foster-home placement, provides information concerning the nature of the relationship between variables as well as an indication of relationship and of degree. Thus, the experimental approach is superior to the correlational approach in the amount of information provided, and, in fact, is the most effective means of gathering knowledge currently available.

The experimental situation may be carried out under controlled laboratory conditions but it may also be carried out under field conditions which provide characteristics similar to those which would be provided in the laboratory if it were possible to do so. The situation among the Eskimos at Barrow, Alaska provides just such an opportunity to carry out field experimental studies.

This study of the transmission of refractive characteristics in families of Eskimos living at Barrow, Alaska grew out of a report by two of our investigators, Roy Box and Curtis Johnson, that older Eskimos show virtually no myopia while younger ones tended to show a relatively high incidence of myopia. Since older Eskimos had little or no schooling while younger Eskimos have compulsory schooling comparable to that required of children in the United States, it appeared possible to evaluate the effects of schooling on the development of refractive characteristics and, particularly, to determine the hereditary aspects of the transmission of refractive characteristics. If their findings are correct, it would be difficult to explain the incidence of myopia among children of parents and grandparents who do not exhibit myopia. Any genetic explanation is based upon the assumption that mutations occur in the parents which are then transmitted to the offspring. If neither of the grandparents nor the parents have myopia while the offspring have a significant amount of myopia a genetic explanation is hardly tenable.

Such findings could be due to the operation of some environmental circumstances which are different for the parents in comparison with the children. Thus, it should be possible to evaluate the contribution of both heredity and environment in the rather isolated and available population of Eskimos at Barrow, Alaska. In addition the environmental conditions under which the Eskimos live provide conditions similar to those obtained by Young and his co-workers on monkeys[1, 2].

The earliest school in Barrow, Alaska, was established by the U.S. Office of Education in 1890 and provided ungraded schooling to any Eskimo child desiring such education. This school remained small until 1932 when it was taken over by the Bureau of Indian Affairs. At this time, it had one teacher and approximately 22 children. By 1938, while still an ungraded school the school had increased to 64 children with three teachers. With the onset of the war, the building of a Dew line station near Barrow and oil exploration by the Navy, more and more Eskimos gathered into the Village of Barrow. Increased enrollment required the development of a graded school system, again with grades one through six. Any children wishing to have schooling beyond grade

six were sent to a boarding school which provided basically a vocational type of education. Following World War II, the establishment of the Naval Arctic Research Laboratory in 1947 just outside Barrow led to a further increase in employment opportunities, and more Eskimo families moved into the City of Barrow. This growth pattern can be seen by looking at the population statistics for the various decades from 1910[3]. In 1910 the population was 446, in 1920, 322; in 1930, 330; 1940, 363; 1950, 951; 1960, 1,314 and 1967, 2,000.

The school population, of course, follows a population increase and, consequently, the major increase in school population began between 1940 and 1950 as would be indicated by the increase in employment opportunities of Barrow during the 1940 decade. At the present time, the major employers in the area are the U.S. Public Health Service, the Bureau of Indian Affairs, The Naval Arctic Research Laboratory, the Federal Electric Company as operator of the Dew line and the Vanell Corporation as the supporter of the Naval Arctic Research Laboratory. Most of the employed Eskimo population work for one of these organizations or in commerce in Barrow itself. Barrow has four general stores, two hotels and two restaurants, two movie theaters and a bank, as well as an air line. At the present time, Barrow has a utility district which furnishes electricity and gas for the city. Electricity has been available for approximately seven years, although not all homes are equipped with electrical service. Those homes not so equipped use either Coleman Mantle Lamps or kerosene or oil lamps. A number of homes have been equipped with Coleman lamps for the last 20 to 25 years.

Thus, for the purposes of this study, it is possible to say that most of the families making up the present population have arrived in Barrow during the past 25 years and represent Eskimo groups which have moved to Barrow from more isolated communities along the northernmost coast of Alaska. The characteristics of Barrow are important for the nature of this study since it is an area which has continuous darkness for a considerable period of time and continuous daylight also for a considerable period of time. The sun is above the horizon continuously from the 10th of May to the 2nd of August and below the horizon continuously from the 18th of November to the 23rd of January. Thus, for a period of 19 weeks or approximately 4½ months there is less than six hours of possible daylight per day. The Barrow area tends to be quite foggy and therefore somewhat warm; the actual amount of daylight is much less than the possible amount of daylight. Highest temperature recorded in Barrow was 79° F. in July, 1927 and the lowest temperature was –56° in February, 1924. The average annual temperature is 10° F. with an average of 169 days per year with a maximum temperature of 0° F. or less.

Since the Eskimo houses are not equipped with electric meters, the utility bills its patrons in terms of the current usage of a forty-watt bulb during any month. For this reason most homes have only one such bulb per room. This amount of light is quite low and is comparable to the light level (4 footcandles) used in a monkey study by Young[4]. The long periods of darkness require use of the eyes for eight or more hours a day under these light levels. Additionally, since diversions other than television are restricted, children tend to spend

more time reading than do children in areas with some amount of daylight. With no family history of myopia, beginning reading groups, low levels of illumination during the earlier school years and at home, with long hours of reading under low levels of illumination, the Eskimo children parallel the monkey studies quite closely and provide field experimental conditions similar to those which would be set up in the laboratory if it were possible to do so.

The potentialities of such a study were so great that we secured the support of a number of sources such as the office of Naval Research Arctic Research Laboratory, The American Optometric Foundation, the National Institute of Neurological Diseases and Blindness, the Aero-Medical Research Laboratory of Holloman Air Force Base, Washington State University and Pacific University to assist in the support of such a study.

SUBJECTS

The population consisted of 570 Eskimos who volunteered as subjects and came as family units. This study is based on 197 subjects drawn from this group. It is possible to discuss the characteristics of the mother and father and their offspring as well as, in some cases, the characteristics of the grandparents. The population does not represent a random sample of the Eskimo population of Barrow, Alaska, since all subjects are volunteers. The parents were approached by two Eskimo women who worked with us during this study and asked to bring themselves and all available children six years of age and older to the Barrow Junior High School where they were tested on an assembly line basis by our group. A lower age limit of six was used since it is difficult to perform phakometry on children younger than this. Since volunteer subjects usually have different characteristics than non-volunteer subjects, no generalization can be made from this group to the total population at Barrow. However, since these represent family units, it is possible to trace the development of refractive characteristics within families and to look at the influence of varying environmental conditions upon the development of refractive characteristics. The basic characteristics of the population used in this study are presented in Table 1.

PROCEDURE

The examination group consisted of five optometrists, two ophthalmologists, one refracting optician, two psychologists and four optometry students, although at any one time the four students, three optometrists, one ophthalmologist, the refracting optician and two psychologists worked as the examining team. Each subject's height, weight were determined and he was given color vision and near and far visual acuity tests. Corneal curvatures were measured with a Bausch and Lomb keratometer and a subjective and manifest refraction was taken by one of the optometrists. Where necessary a prescription was written for the patient. Following his refractive examination the subject was given a cycloplegic, either one per cent cyclogyl or one per cent mydriacil or a combination of these depending upon the age of the subject and darkness of the iris. Generally, all subjects below age 21 were given either three drops of cyclogyl in each eye spaced ten minutes or two drops of cyclogyl ten minutes apart followed by one or two drops of mydriacil ten minutes apart. Those subjects 50 and over were given three drops of mydriacil ten minutes apart, while those

TABLE 1
DISTRIBUTION OF RIGHT EYE REFRACTIVE CHARACTERISTICS IN TOTAL ESKIMO POPULATION BY FIVE YEAR AGE GROUPS

Age Group	N	Mean (Dio.)	SD	Myopes		Range
				Number	Per Cent	
6-10	93	1.51	1.40	6	6.4	−2.19 to +9.34
11-15	86	−0.46	2.31	44	51.2	−6.02 to +5.32
16-20	63	−0.79	2.65	37	58.7	−5.16 to +7.69
21-25	41	−2.07	2.23	36	87.8	−7.09 to +4.77
26-30	37	+0.03	1.93	16	43.2	−4.49 to +4.33
31-35	28	+0.72	1.41	7	25.0	−3.82 to +4.22
36-40	29	+1.08	1.67	6	20.7	−0.99 to +5.38
41-45	33	+1.61	1.19	1	3.0	−1.95 to +4.48
46-50	20	+1.79	0.97	1	5.0	−0.25 to +4.20
51-55	24	+2.26	1.10	0	0.0	+0.50 to +5.60
56-60	21	+2.23	1.26	0	0.0	+0.76 to +4.20
61-65	16	+2.25	1.38	0	0.0	+0.75 to +5.89
66-70	9	+2.68	1.14	0	0.0	+1.27 to +4.76
71-88	8	+2.94	1.81	0	0.0	0.25 to +6.44
6-25	283	−0.12	2.47	123	43.4	−7.09 to +9.34
26 & Above	225	+1.45	1.68	31	13.8	−4.49 to +6.44
Total	508	+0.58	2.29	154	30.3	−7.09 to +9.34

subjects between 21 and 49 were usually given two drops of cyclogyl followed by one drop of mydriacil. Approximately 40 minutes after the first administration of the cycloplegic the subject was examined with a slit lamp and a ophthalmoscope. If the subject was over 40, tensions were taken with a Schiotz tonometer. Following this examination, the subject was again refracted by the refracting optician and phakometric measurements were taken on the subject. The subject was then examined using the ultrasound equipment described elsewhere[5]. The examination was completed when tensions were taken with the Durham gas tonometer and the Posner Tonomat tonometer. The patient's eye and hand preference was determined by the use of a sighting tube. The complete examination required slightly over one hour per subject because of the waiting time for the action of the cycloplegic.

RESULTS

The distribution of right eye refractive characteristics in the total population by 5-year age groups is presented in Table 1. The total of 508 right eyes represents the number remaining of the original 570 subjects when those with various types of right eye disabilities such as loss of eye, removal of lens and corneal opacities are removed together with all children below six years of age who are included in the population. For comparison purposes, Table 1 is summarized in terms of those individuals 25 and below and those individuals 26 and above. These comparisons pertain to the distribution of the family groups included in Table 2 in which the range of ages for the parents was 26 to 77 whereas the age ranges for children was 6 to 22. This comparison permits us to relate the characteristics of the sample to the characteristics of the original population. When these comparisons are made, we note that the sample parents show a mean refractive error approximately ¼ of a diopter more plus than that shown by the total population of similar age, whereas the children show a mean refractive error almost ½ a diopter more plus than the total population of similar age. The standard deviations of the sample are close to the standard devia-

tions of the population for both parents and children. The range for the parents falls well within the range of the older population and is not significantly less than that of the population. The range for the children, however, is considerably less than that for the population. All of these values are based on the right eye only and upon the cycloplegic refraction only. All refractive errors have been converted to vertical equivalent spheres. Myopia is defined as a refractive error of −0.25 D or more minus on the equivalent sphere measure.

TABLE 2

AGE AND REFRACTIVE ERROR CHARACTERISTICS OF ESKIMO POPULATION INCLUDED IN CORRELATIONAL STUDY

		AGE (YEARS)			REFRACTIVE ERROR (DIOPTER)		
Group	N	Mean	SD	Range	Mean	SD	Range
Fathers	41	47.98	10.71	32 to 77	+1.85	1.30	−0.70 to +5.89
Mothers	41	42.71	9.22	26 to 61	+1.54	1.75	−4.49 to +5.38
Sons	59	12.37	4.17	6 to 21	+0.25	2.25	−4.72 to +7.04
Daughters	56	12.45	4.88	6 to 22	+0.41	2.48	−4.69 to 7.01
Parents	82	45.34	10.33	26 to 77	+1.69	1.55	−4.49 to +5.89
Children	115	12.41	4.53	6 to 22	+0.33	2.37	−4.72 to 7.01

Table 2 presents the means, standard deviations and ranges of age and refractive errors of the fathers, mothers, and children involved in this sample. It may be noted that the Eskimo fathers are approximately five years older than their wives whereas the average age of the sons and daughters is nearly identical. The refractive errors show similar patterns for the parents as well as a similar pattern for the children, but the average refractive error of the parents is 1⅓ diopter more hypermetropic than the average refractive error of the children.

The pertinent correlation coefficients between the refractive errors of the parents and of their children are presented in Table 3 together with the first order partial correlations between the refractive errors of the fathers and their sons and daughters and between the refractive errors of the mothers and their sons and daughters and for the father with the sons and daughters combined as well as the mothers with the sons and daughters combined. The significance levels of the correlation coefficients are also indicated in Table 3.

The correlations between the siblings are presented in Table 4 again with an indication of the significance levels of the correlation coefficients. All correlations coefficients are based on the right eye findings only.

DISCUSSION

An examination of Table 1 indicates a significant difference between the proportion of myopes occurring from age 41 and above and those occurring age 40 and below. If this breakdown is considered, there are 131 right eyes 41 years and above and only 1½ % or 2 of these show any myopia at all and one of these shows a ¼ of a diopter of myopia. Of the subjects age 40 and below, 152 or 44.7% of the population of 377 subjects show myopia. Since it is unusual for myopia to develop before 11 years of age, as indicated by Table 1, if only the population between 11 and 40, inclusive, is considered, 146 out of 284 subjects or 51.4% show at least a ¼ diopter of myopia in the right eye.

TABLE 3

First Order Partial Correlations Between Right Eye Refractive Errors of Eskimo Parents and Children Together with Zero Order Correlation Coefficients Required to Partial Out Age Effects.

Groups	N	Partial r	r_{12}	r_{13}	r_{14}	r_{23}	r_{24}	r_{34}
Father–Sons	59	0.22	0.01	0.26†	0.20	−0.37‡	−0.52‡	0.26†
Father–Daughters	56	0.11	0.05	0.48‡	0.17	−0.28‡	−0.49‡	0.81‡
Father–Children	115	0.19†	0.04	0.37‡	0.21†	−0.32‡	−0.50‡	0.56‡
Mother–Sons	59	0.16	0.13	0.00	0.03	0.00	−0.49‡	0.34‡
Mother–Daughters	56	0.08	0.01	0.00	0.12	−0.44†	−0.49‡	0.58‡
Mother–Children	115	0.12	0.07	0.00	0.08	−0.42†	−0.49‡	0.46‡

Partial r = Correlation between refractive errors with age held constant.

r_{12} = Zero order correlation between parent refractive error and children refractive error.

r_{13} = Zero order correlation between parent refractive error and parent age.

r_{14} = Zero order correlation between parents refractive error and child age.

r_{23} = Zero order correlation between child refractive error and parent age.

r_{24} = Zero order correlation between child refractive error and child age.

r_{34} = Zero order correlation between parent age and child age.

†Significantly different from zero at 5% level.
‡Significantly different from zero at 1% level.

TABLE 4

First Order Partial Correlations Between Right Eye Refractive Errors of Eskimo Siblings Together with Zero Order Correlation Coefficients Required to Partial Out Age Effects.

Groups	N	Partial r	r_{12}	r_{13}	r_{14}	r_{23}	r_{24}	r_{34}
Brother–Brother	52	+0.32	+0.38†	−0.53‡	−0.42†	−0.11	−0.33	+0.42
Sister–Sister	36	+0.72‡	+0.67‡	−0.33†	−0.45‡	−0.49‡	−0.66‡	+0.53‡
Brother–Sister	100	+0.45‡	+0.42‡	−0.42‡	−0.07	−0.15	−0.62‡	+0.03

Partial r = Correlation between refractive errors with age held constant.

r_{12} = Zero order correlation between different siblings' refractive errors.

r_{13} = Zero order correlation between first sibling refractive error and first sibling age.

r_{14} = Zero order correlation between sibling refractive error and second sibling age.

r_{23} = Zero order correlation between second sibling refractive error and first sibling age.

r_{24} = Zero order correlation between second sibling refractive error and second sibling age.

r_{34} = Zero order correlation between first sibling age and second sibling age.

†Significantly different from zero at 5% level.
‡Significantly different from zero at 1% level.

The amount of myopia demonstrated by individuals below age 40 in the Eskimo population far exceeds that usually demonstrated in any type of American or European population[6]. Further, the amount of myopia demonstrated by persons 41 years and above also falls far short of the amount usually demonstrated by American-European populations and is more nearly comparable to that found among African natives by Holm[7].

The only extensive study of the visual characteristics of Eskimos in terms of refractive errors was that by Skeller[8] and, unfortunately, Skeller does not clearly indicate the nature of his procedures for obtaining adequate cycloplegia, although he did use homatropine cycloplegic. This leads to some rather peculiar results in that he found nine out of 60 children between two and four years of age with myopia of or in excess of ¼ diopter and 29 of 176 children between five and nine years of age with myopia a ¼ of a diopter or greater. This is an extremely high proportion of low grade myopia to be found in a population

of this age range and makes the interpretation of his presented results rather difficult. He had no subjects at any age level between two and 69 showing more than 1¼ diopters of myopia, although there were four persons out of 1,123 who showed this amount.

Parent age and child age presented as r_{34} in Table 3 indicate that, generally speaking, there is a fairly high correlation between the ages of the parents and the age of the children in a positive direction so that the older parents tend to have older children and younger parents younger children. If this relationship is applied to Table 1, we would assume that most of the children in the 6 to 10-year-old group are the children of the parents in the 26 to 30 or possibly 26 to 35-year-old groups. Of the family groups presented in Table 2, one mother was 15 at the time of birth of her first child, one 19 and the rest of the mothers were 20 or more years of age at the birth of their first child. The average age of the mother at the birth of her first child was approximately 22 years. Since all of the children were six or older, the mothers of the youngest children in the study would be about 28 years of age and would have been born about 1940 and would have entered school in about 1946. As has been pointed out, the first major improvement of the school system in Barrow occurred between approximately 1947 to 1950. The school system has been expanding rapidly since that time so that it now has two grade schools and a junior high school. Most of the children examined in the study have attended school during the compulsory education phase and during the time when the schools were in their expansion stage, whereas most of the parents over 35 years of age have had schooling only under the ungraded school conditions for the maximum of six grades in most cases. Thus the parents may be said to have relatively little schooling while the children have had American style schooling. A few of the younger parents fall in the transitional phase between voluntary, ungraded schooling and the graded, compulsory schooling now available in Barrow. One of the major changes, then, in the environmental situation is the introduction of schooling to the younger individuals or those born since approximately 1940.

Although the change in school requirements represents probably the major change, there have been other changes also occurring in Barrow Eskimo life. Most of the families are equipped with mechanical devices such as mechanical sleds, trucks and boats rather than with the dog sled and kayaks usually associated with Eskimos. In addition, those males and relatively few females who are working for government agencies tend to eat at least one meal a day at their place of employment. These meals are essentially composed of American type food prepared by American chefs and are comparable to the type of meals available in Navy messes. While the employed Eskimos are eating caribou, whale and other mammal foods available in the area, as well as the American style food, the wives and children of these employees are still eating essentially the basic Eskimo diet since the cost of American style foods is prohibitively high in Barrow, Alaska. All consumable goods in Barrow must be brought in by air from Fairbanks, Alaska, a distance of approximately 660 miles. Since most of the myopic changes are occurring in the offspring rather than in the parents, it

is unlikely that diet plays any major role in the development of refractive characteristics of this population.

Allowing for the type of living conditions enjoyed by the Barrow Eskimo, it would appear that most of the parents who are in the age group 30 and above are not myopic. Actually only 16 out of 191 or 8.4% show any myopia in this age group, while their 227 offspring include 133 myopes for a total of 58.6% of the population being myopic. Among the older age group or the first generation, age 56 and above, all 54 people show no myopia at all. Thus, in a general way, it would appear that neither the grandparents nor the parents have myopia and yet the children have an exceptionally high proportion of myopia, the main variable operating being the introduction of American style compulsory schooling and the lack of outside entertainment which leads to a considerable amount of reading among the school children.

In Table 3 the correlations between the parents and offspring support the concept that heredity plays little or no role in the development of myopia among this Eskimo population. Of all of the correlations between the refractive errors of the parents and their children either zero order or the partial rs in which the age relationships have been removed, only one correlation approaches significance at the 5% level of confidence. These correlations indicate that the refractive characteristics of the parents are not followed as far as the children's refractive characteristics are concerned.

Some of the zero order correlations in Table 3 are of interest in their own rights. For example, while there is no correlation between the parents' refractive error and the parents' age for mothers, there is a significant positive correlation between age and the refractive errors for the fathers; thus, the older the father is the more hypermetropic the father tends to be. As might be expected from the way myopia develops, there is a highly significant correlation between the refractive errors of the child and the age of the child in a negative direction; the older the child, the more myopic the child. These correlational values do not support an hereditary basis for myopia, since, as Pearson[9] has pointed out, the correlation coefficients would have to be in the magnitude of 0.40 to 0.50 to provide evidence of a significant hereditary or genetic effect in myopia.

The intersibling correlations for brother, sisters, and mixed sibs are presented in Table 4. These correlations are uniformly fairly high and significantly different from zero and indicate that something about the situation faced by these children tends to make them more alike within the family group than we find among children in other family groups. If we had obtained insignificant correlations between siblings, we could conclude that there is no hereditary component and no environmental component operating to effect differentially the refractive characteristics within the family group as compared with other family groups. The fact that high and significant correlations occur, however, indicates that some variable or variables are operating to influence brothers and sisters. Since the parent-offspring correlations do not indicate a significant hereditary component, it is possible that the sibling correlations are due to the operation of an environmental component such as reading and that the differences between families may be related to the attitudes exhibited by parents toward

schooling. The differences could also be related to the personality characteristics of individuals within families and of family groups.

If the parents value education as a means of improving the situation and stress it, the children in that family will be pressured to perform adequately in the school situation and to engage in as much reading as possible. If, on the other hand, the parents are not basically oriented toward education, the children will tend to meet the requirements of school attendance, but will not actually spend a great deal of time in reading or in doing homework. Under these conditions, we might expect that the children within some families would tend to become more myopic than children within other families and that there would be a fairly high intercorrelation between sibs within family units.

As was discussed earlier, when high correlations between parents and offspring or between siblings are obtained, they indicate that some variable is operating but the nature of the variable cannot be determined from the correlation coefficients. The nature of the variable or variables must be determined from other evidence. Such evidence, as is currently available in the Barrow situation, indicates that environmental factors play a greater role in the development of myopia among Eskimos than do hereditary factors.

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