THE RELATION BETWEEN HEALTH AND INTELLIGENCE IN SCHOOL CHILDREN

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Introduction

The object of the inquiry reported upon in this paper was to determine whether there was any measurable association between the development of intelligence and the incidence of disease in school children.

The children selected were those attending elementary schools in the North Holland division of Lincolnshire. All children aged 9 and over in attendance at the selected schools were examined, the only criterion being the ability to read and write; five schools were of the isolated rural type taking children of all ages; five were schools taking only senior children, and one was a borough school containing children of all ages.

The number of children included in the inquiry was 959. As the information on every point investigated was not always available, the totals of the number of children, given in the separate tables, do not always correspond.

Intelligence test (5)

The intelligence test used was the "Northumberland Series", a group test published by Prof. Cyril Burt. The test was issued in the form of duplicated copies. This form of test was adopted in order that the information required could be collected rapidly in the summer months, when the maximum number of children was in attendance. Possibly group tests are not quite so satisfactory as individual oral tests, but Lawrence states (16) that "though a rough measure, they are a real measure of something which may provisionally be called intelligence. This is proved by the fact that entirely different ones given to the same set of children will provide results which correlate highly with each other." Precautions were taken to see that the proper procedure in testing was followed in each school.

Medical records

The records used for securing the medical histories were the medical cards completed for each child in the course of routine and special inspections at the schools. Uniformity of records was insured by selecting only those schools in which the author himself had carried out medical inspections in the past. Thus each child whose intelligence was tested had been seen by the author at least twice for medical inspection. The record of past illnesses was checked by sending out a special form for completion by the parents.

Records of height (to the nearest half inch) and weight (to the nearest pound) were taken at the time the intelligence tests were given.

PREVIOUS INVESTIGATIONS

The work of Shepherd Dawson (7) on the association between intelligence and disease though revealing negative results, except for diseases affecting the brain, gave definite indication for further inquiry. The children included in his investigation were hospital patients, and therefore could not necessarily be considered as a representative sample of the child population as a whole. Neither was there any reference to past ill health such as the common infectious diseases of childhood.

Several workers have associated health and intelligence (Lawrence (16), Habakkuk (15), Karl Pearson (20), Terman (25)). Terman's investigation relates only to superior children. Lawrence, Habakkuk and Pearson define health in terms such as good, average, or poor, and thus do not differentiate between good physique and the effects of ill health.

Dawson (7) gives a survey of some of the literature.

SOCIAL CONDITIONS

The Holland division of Lincolnshire is mainly agricultural, with an area of 268,992 acres, a population (census 1931) of 92,330, an estimated population at the date of inquiry of 93,590, and the number of persons per 100 acres 35 (census of 1931) (Booth, 1934).

The majority of children included in the investigation had parents engaged in agricultural work. The wages for this class of work were from 32*s.* 6*d.* to 42*s.* 6*d.* per week, depending on the type of employment. In this area the housewife frequently finds casual work on the land, and during the holidays the children also. Rentals on the whole are low. The cost of living as compared with the B.M.A. scale (4) is higher, but as a considerable number of the labourers have their own kitchen gardens, it is difficult to apply any scale in an endeavour to associate nutrition and income available per person. Unemployment is low except during the winter months. During this period any poverty has to be relieved by Public Assistance, as for agricultural workers there is no unemployment insurance.

Table I. *Intelligence*

I.Q. ...	Under 60	60–	70–	80–	90–	100–	110–	120–
Present series of Lincs. children:								
No.	39	83	161	257	190	116	56	57
%	4·1	8·7	16·8	26·8	19·8	12·1	5·8	5·9
	Total under 80%			29·5%				
Russell 1930 (24) 21%				19·4	27·7	17·4	9·7	4·7
Northumberland (Duff and Thompson, 1923) 7·3%				17·0	24·0	26·8	17·8	7·1

The mental age of each child was calculated from the marks obtained in the intelligence test by means of the published norms. In the subsequent analysis intelligence is expressed in the form of intelligence quotients,

$\frac{\text{Mental age}}{\text{Chronological age}} \times 100$. This enables children to be grouped according to their intelligence irrespective of age. Table I shows the comparison of the present series of children with children of some other areas who were given the "Northumberland Series" of tests. In the case of Russell for "An eastern county" (24) the children were given a preliminary trial test. No such preliminary trial test was given to the Holland children, and none of them had previous experience of any form of intelligence testing.

It is difficult to assign any figure for the effect of a previous test or practice. Chapman (6) gives between 15 and 43 per cent. improvement as a result of coaching. Even if an allowance up to 10 per cent. for the advantage of a trial test is made, the figures in the present series show an excess of children in the lower intelligence grades as compared with those figures published by Russell (24) and Duff and Thompson (9). However, this does not in any way affect the present investigation.

The upper limits of intelligence have not been defined. The highest score published in the table of norms (5) was 282, corresponding to a mental age of 16. To obtain the mental age for higher scores would necessitate the extrapolation of a skew curve. The information so obtained would have been of no material assistance to the present investigation.

Table II. *Height and weight. Comparison with Isle of Ely*

Age group years	Number measured		Mean height in in.		Mean weight in lb.	
	Holland	Ely	Holland	Ely	Holland	Ely
Boys:						
9–	69	164	52·0	51·3	66·0	62·4
10–	67	148	52·3	52·8	68·8	66·7
11–	101	166	54·7	54·9	73·7	74·1
12–	111	165	58·0	57·1	80·6	83·4
13–14	119	140	58·2	58·8	90·1	91·3
Girls:						
9–	77	121	51·0	51·0	63·0	60·3
10–	77	131	53·4	53·0	71·4	66·6
11–	96	146	55·5	55·4	77·0	75·1
12–	118	155	58·1	57·9	86·6	85·9
13–14	121	109	59·8	59·4	94·0	92·1

Table II shows the average heights and weights of the children under investigation as compared with those of children of the Isle of Ely. The latter were chosen for comparison for two reasons; firstly because the figures are of recent date (17), and accurately recorded; and secondly because the Isle of Ely is mainly agricultural, and is the southern boundary of the Holland division. It may be noted here that the Ely figures are generally regarded as showing a high standard of physique. The Holland figures being in close agreement, these children are probably rather above the average of physique for rural children.

METHOD OF TABULATING AND ANALYSIS OF SUCCEEDING TABLES

In all subsequent tables, except Table V, the children are divided into four main intelligence quotient groups; *i.e.* below 80, 80–89, 90–99, 100 per cent. and over.

If defects or diseases are found to be recorded more frequently at one or other end of the intelligence scale with a corresponding increase or decrease in the other groups, an association is suggested. To determine whether such observed differences are likely to have arisen merely by chance the figures have been submitted to statistical analysis.

In testing for association between intelligence and the other factors involved in the investigation, *e.g.* the incidence of a specific disease, the method of χ^2 has been adopted [χ^2 being the sum of the values (observed number − expected number)^2 ÷ expected number. The observed numbers are those given in each of the tables that follow; for example (Table X), of children in the intelligence group under 80 per cent. there were 96 who had suffered from measles before school age and 187 who had not. The expected numbers were calculated from the marginal totals of the table on the assumption that the two variables, intelligence and the specific disease, were independent]. The value of χ^2 is a measure of the discrepancy between observation and expectation on the hypothesis of independence. With relatively small numbers a certain amount of discrepancy will invariably arise merely by chance, and to test whether the discrepancy observed is more than might be reasonably ascribed to that, a probability P is obtained from the value of χ^2 by means of published tables (Fisher (11)). The smaller the value of P the less is the probability that the discrepancy between observation and expectation is due merely to chance. A conventional level of "significance" is usually taken at P equals 0·05, *i.e.* with $P=0{\cdot}05$ the observed value of χ^2, measuring the difference between observation and expectation (or a larger one), would only arise by chance once in 20 times. Therefore when P, in the tables that follow, is less than 0·05 an association between intelligence and the other variable concerned is suggested; when P is greater than 0·05 no significant association is apparent in the observations available. The exact value of P is, it will be observed, largely immaterial, and adopting the 0·05 level it would be sufficient merely to show whether P was above or below that value. Actually in the tables that follow the value of P is given more closely; where association is suggested the value of P is given as less than 0·01, between 0·01, and 0·02, or between 0·02 and 0·05. Where no association is apparent P is given as greater than 0·05, or greater than 0·1, 0·2, 0·3, etc.; greater than 0·05 implies a value between 0·05 and 0·1, greater than 0·1 a value between 0·1 and 0·2, and so on.

In one or two tables certain groups have been amalgamated in calculating χ^2 to avoid the error that may arise when small numbers are involved.

In the general absence of positive associations in this investigation there has clearly been no case for endeavouring to go beyond χ^2—which measures the *presence* or *absence* of association—by the calculation of measures of the *degree* of association. Where, in a few tables, association is suggested by χ^2 the percentage figures of the table concerned show the direction of the association and, broadly, its degree.

Table III. *Age composition of I.Q. groups*

Age	9·0–	10·0–	11·0–	12·0–	13·0–	Mean age
I.Q. under 80%	14%	14%	20%	27%	25%	11 yr. 10 mo.
I.Q. 80–89%	14%	14%	24%	22%	27%	12 yr.
I.Q. 90–99%	13%	12%	17%	26%	31%	12 yr.
I.Q. 100% and over	21%	21%	19%	21%	18%	11 yr. 5 mo.
Total	146	146	197	230	240	
I.Q. 69% and under	10·7%	14·8%	19·7%	31·1%	23·8%	

Total 122. % of total children 12·7

Table III shows the age constitution of the I.Q. groups. The "100 per cent. and over" group is of a slightly younger average age, but this does not seem to have had any material effect on the general results reached. It was considered necessary to introduce this table, as it might be thought that if any marked difference in age distribution existed, the groups might not be deemed comparable when considering the incidence of disease.

The "No. of children observed", recorded in the tables for infectious disease occurring "During school life", are those children who have entered school without previously having suffered the disease in question.

Nutrition

Two methods were employed for assessing nutrition: (1) clinical examination; (2) the weight/height ratio.

(1) *Clinical examination.* In the course of routine medical inspection of school children the Medical Officer records his impressions of the child's nutrition. For the purpose of this enquiry the findings were grouped into two broad categories, normal and subnormal. As each child had experienced at least two inspections the results were further subdivided into those who had been recorded as subnormal once only, and those recorded subnormal on two or more occasions.

Table IV. *Nutrition. By inspection*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	276	255	190	229	950
Subnormal at one inspection	59	47	30	45	181
Incidence %	21·4	18·4	15·8	19·7	19·1
Subnormal at two or more inspections	31	27	13	10	81
Incidence %	11·2	10·6	6·8	4·4	8·5

Intelligence and nutrition unsatisfactory on one or more occasions (both groups): $\chi^2 = 12{\cdot}96$; $P =$ less than 0·05.

Intelligence and nutrition unsatisfactory on two or more occasions (lower group only): $\chi^2 = 9{\cdot}77$; $P =$ less than 0·02.

Table IV shows the results. It will be seen that subnormal nutrition is associated more frequently with the lower intelligence grades in both subdivisions, and the statistical test shows that the association is unlikely to have arisen by chance. In the group of lowest intelligence, 11·2 per cent. had been recorded as subnormal two or more times and this level declines to 4·4 per cent. for children of highest intelligence.

Table V. *Standards of weight at given heights. Comparison with Board of Education figures*

Height in in. midpoint of group	Mean weight in lb. for each height group	Standard deviation of weight	Weight/height Holland	Weight/height Board of Education
Boys (total = 1107):				
43	42·0	4·1	0·98	0·99
45	46·1	3·3	1·02	1·03
47	50·0	4·6	1·06	1·10
49	55·6	6·0	1·14	1·14
51	60·2	5·7	1·18	1·19
53	65·3	6·6	1·23	1·25
55	72·0	6·1	1·31	1·32
57	79·8	8·0	1·40	—
59	86·3	7·1	1·46	—
Girls (total = 1216):				
43	40·8	3·5	0·93	0·94
45	45·0	4·1	1·00	0·98
47	49·2	5·6	1·05	1·04
49	53·3	4·4	1·09	1·08
51	58·8	6·0	1·15	1·17
53	65·0	7·6	1·23	1·21
55	73·6	11·6	1·34	—
57	77·8	8·4	1·35	1·39
59	85·9	13·5	1·46	1·50

Table VI. *Nutrition. Based on weight/height ratio*

I.Q. ...	Under 80%	80–89%	90–99%	100%	Total
No. of children observed	249	224	160	199	832
20% or more below normal	5	0	0	1	6
Incidence %	2·0	0	0	0·5	0·7
10–19% below normal	22	18	14	11	65
Incidence %	8·8	8·0	8·8	5·5	7·8
Normal to 9% below normal	70	60	40	62	232
Incidence %	28·1	26·8	25·0	31·2	27·9
1–10% above normal	91	79	62	77	309
Incidence %	36·5	35·3	38·8	38·7	37·1
11–20% above normal	47	49	31	33	160
Incidence %	18·9	21·9	19·4	16·6	19·2
Over 20% above normal	14	18	13	15	60
Incidence %	5·6	8·0	8·1	7·5	7·2

$\chi^2 = 7{\cdot}82$; P = greater than 0·7.

(In calculating χ^2, the group more than 20% below normal and 10–19% below normal were combined, as the expected values in the lowest group were less than 5 in each case.)

Taking three groups:	10% or more Below normal	Within 10% Normal	10% or more Above normal

$\chi^2 = 6{\cdot}70$; P = greater than 0·3.

(2) *The weight/height ratio.* There were several reasons for adopting the weight/height ratio for the purpose of determining the association of nutrition with intelligence. Height and intelligence have already been shown to be

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associated (Root (23), Habakkuk (15), and Dawson (7)); therefore the use of height alone as an estimate of nutrition would be fallacious. As height and weight are so closely associated the same objection might arise in using an average weight scale. The weight/height ratio was not open to this objection. Findlay and Paton (10) have shown that this ratio is correlated with nutrition assessed by inspection, the coefficients for children of 5 years and under being: $0{\cdot}6489 \pm 0{\cdot}0159$ for boys and $0{\cdot}6469 \pm 0{\cdot}0186$ for girls. Benedict and Talbot (1) state that "it is clear that as an index of the best proportional distribution of flesh to skeleton the relationship of height and weight is the most satisfactory."

Averages of weight at units of height were prepared in 1933—Table V—from the records of 2323 children distributed over the whole of the Administrative County of Holland. The table shows how closely the ratios compare with those published by the Board of Education (18). The weights of the children in this investigation were thus compared with averages of their brothers and sisters.

Table VI shows the grouping of the weight/height ratio with intelligence. No association of any statistical significance is demonstrated, and a broader grouping does not alter this result.

Number in family

In collecting the information with regard to number in family, it was decided to record the total possible number in family; that is, to include any children born who had subsequently died. Parents were also included, but not grandparents, or any more distant relatives.

Thus the figures are a record of the fertility of any particular family. Table VII shows that there is a definite association; the lower the intelligence the greater on the average the number in family. In the intelligence group under 80 per cent. the average number in family was 7·1 and this value falls to 5·9 in the intelligence group 100 per cent. and over. Previous investigations, Dayton (8) for example, have reported similar findings.

Table VII. *Number in family*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	271	252	186	222	931
Average no. in family	7·1	6·9	6·5	5·9	6·7
No. of children in families of:					
5 persons and under	85	97	69	113	364
6–9 persons	139	106	96	94	435
10 persons and over	47	49	21	15	132

$\chi^2 = 33{\cdot}19$; P = less than 0·01.

Table VIII. *Incidence of bad family history*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
Total no. of children	283	257	190	229	959
Children with bad family history	36	15	15	17	83
Incidence %	12·7	5·8	7·9	7·4	8·7

$\chi^2 = 9{\cdot}16$; P = between 0·05 and 0·02.

Table IX. *Children sleeping alone or sharing a bed*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
Total no.	281	257	190	226	954
Sleeping alone %	26·7	30·7	35·2	35·0	31·4
Sleeping with 1, %	60·1	54·5	54·7	51·8	55·5
Sleeping with 2, %	11·0	11·7	8·4	11·5	10·8
Sleeping with 3, %	2·1	3·1	1·6	1·8	2·2

$\chi^2=7{\cdot}72$; $N=6$; $P=$approximately 0·26.

The last two rows were grouped for this calculation.

Grouping, "Alone" and "Not alone": $\chi^2=5{\cdot}47$; $P=$greater than 0·1.

BAD FAMILY HISTORY

Head teachers are asked to enter on the Medical Record cards any information known to them in respect of family history. No direct questioning of children or parents is permitted so that the records are not as complete in this respect as might be desired. The histories noted were of insanity, mental deficiency, epilepsy, and tuberculosis, the last predominating. Table VIII shows that children in the lowest intelligence group have bad family histories more frequently than children in the higher intelligence groups, and the difference in incidence is more than is likely to have arisen by chance.

SLEEPING

The evils attributed to overcrowding at night time are many. It was therefore considered desirable to see if any relation existed between this factor and intelligence. Children were questioned as to whether they slept alone or shared a bed. The results are recorded in Table IX. No association was found. The broader grouping of "Alone" and "Not alone" failed to demonstrate any significant association, though the figures suggest that a slightly larger proportion (about 35 per cent.) of the more intelligent children slept alone than of the less intelligent children (about 29 per cent.), as might perhaps be expected when the association between intelligence and size of family is remembered.

INFECTIOUS DISEASES

Tables X–XVI show the incidence of the common infectious diseases as they occur in the I.Q. groups chosen. Except with diphtheria (Table XIV), in which the numbers are insufficient for subdivision, the data have been divided into two classes, namely "Disease occurring before school life" and "Disease occurring during school life", a third table being included which is a combination of these two groups. Cyril Burt (5) has stated that: "All the elementary mental mechanisms essential to formal reasoning are present before the child leaves the Infant Department (*i.e.* mental age 7), if not somewhat before. Development consists primarily in an increase in the extent and variety of subject matter to which those mechanisms can be applied, and an increase and elaboration with which those mechanisms can operate." Thus, if infectious disease has any effect on the growth of intelligence, this influence would in all

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Table X. *Incidence of measles, before school age*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	96	119	73	99	387
Incidence %	33·9	46·3	38·4	43·2	40·3

$\chi^2=9{\cdot}72$; $P=$between 0·05 and 0·02.

Table X A. *Incidence of measles, during school life*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	187	138	117	130	572
No. of cases recorded	165	126	97	118	506
Incidence %	88·2	91·3	82·9	90·8	88·5

$\chi^2=5{\cdot}31$; $P=$greater than 0·1.

Table X B. *Measles, total incidence*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	261	245	170	217	893
Incidence %	92·2	95·3	89·5	94·8	93·1

$\chi^2=7{\cdot}19$; $P=$greater than 0·05.

Table XI. *Incidence of whooping cough, before school age*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	90	98	60	92	340
Incidence %	31·8	38·1	31·6	40·2	35·5

$\chi^2=5{\cdot}90$; $P=$greater than 0·1.

Table XI A. *Incidence of whooping cough, during school life*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	193	159	130	137	619
No. of cases recorded	92	64	59	65	280
Incidence %	47·7	40·3	45·4	47·4	45·2

$\chi^2=2{\cdot}34$; $P=$greater than 0·5.

Table XI B. *Whooping cough, total incidence*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	182	162	119	157	620
Incidence %	64·3	63·0	62·6	68·6	64·7

$\chi^2=2{\cdot}18$; $P=$greater than 0·5.

Table XII. *Incidence of mumps, before school life*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	38	19	18	19	94
Incidence %	13·4	7·4	9·5	8·3	9·8

$\chi^2=6{\cdot}44$; $P=$greater than 0·05.

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Table XII A. *Incidence of mumps, during school life*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	245	238	172	210	865
No. of cases recorded	97	76	71	74	318
Incidence %	39·6	31·9	41·3	35·2	36·8

$\chi^2=4{\cdot}15$; P = greater than 0·2.

Table XII B. *Mumps, total incidence*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	135	95	89	93	412
Incidence %	47·7	37·0	46·8	40·6	43·0

$\chi^2=7{\cdot}22$; P = greater than 0·05.

Table XIII. *Incidence of chickenpox, before school age*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	29	31	20	32	112
Incidence %	10·2	12·1	10·5	14·0	11·7

$\chi^2=1{\cdot}60$; P = greater than 0·5.

Table XIII A. *Incidence of chickenpox, during school life*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	254	226	170	197	847
No. of cases recorded	77	76	65	66	284
Incidence %	30·3	33·6	38·2	33·5	33·5

$\chi^2=2{\cdot}78$; P = greater than 0·3.

Table XIII B. *Chickenpox, total incidence*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	106	107	85	98	396
Incidence %	37·5	41·7	44·7	43·0	41·3

$\chi^2=2{\cdot}89$; P = greater than 0·3.

Table XIV. *Incidence of diphtheria*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	12	7	6	2	27
Incidence %	4·2	2·7	3·2	0·9	2·8

$\chi^2=5{\cdot}4$; P = greater than 0·1.

Table XV. *Incidence of some of the infectious diseases during school life grouped*

Disease I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
	No. of cases noted				
Measles	165	126	97	118	506
Mumps	97	76	71	74	318
Whooping cough	92	64	59	65	280
Chickenpox	77	76	65	66	284
Total	431	342	292	323	1388
No. of possible cases of four infectious diseases	879	761	589	674	2903
Incidence, *i.e.* observed cases as % of possible	49·0	44·9	49·6	47·9	—

Table XV A. *Incidence of some of the infectious diseases during school life grouped*

Disease I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
	No. of cases noted				
Measles	96	119	73	99	387
Mumps	38	19	18	19	94
Whooping cough	90	98	60	92	340
Chickenpox	29	31	20	32	112
Total	253	267	171	242	933
No. of possible cases of four infectious cases	1132	1028	760	916	3836
Incidence, *i.e.* observed cases as % of possible	22·3	26·0	22·5	26·4	—

Table XVI. *Total incidence of some of the infectious diseases grouped*

Disease I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
	No. of cases noted				
Measles	261	245	170	217	893
Mumps	135	95	89	93	412
Diphtheria	12	7	6	2	27
Scarlet fever	27	26	18	31	102
Whooping cough	182	162	119	157	620
Chickenpox	106	107	85	98	396
Total incidence	723	642	487	598	2450
No. of children in each group	283	257	190	229	959
No. of possible cases of six infectious diseases	1698	1542	1140	1374	5754
Incidence, *i.e.* observed cases as % of possible	42·6	41·6	42·7	43·5	—
Average no. of diseases per child	2·55	2·50	2·56	2·61	—

Table XVII. *Incidence of infectious diseases. Comparison with Terman* (24)

	Holland	Terman
Total no. of children	959	584
Measles %	93·1	87·0
Pertussis %	64·7	67·6
Varicella %	41·3	61·1
Mumps %	43·0	35·4
Scarlet fever %	10·6	8·2
Diphtheria %	2·8	6·5
Pneumonia %	4·4	4·6

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probability be greatest before school life, when "the elementary mental mechanisms essential to formal reasoning" are being formed, rather than at a later age when development is merely an extension of these mechanisms. Only "Measles before school age" (Table X) shows any significant association, and that seems to be rather the reverse of any that might be anticipated, the incidence being greatest on the 80–89 and over 100 per cent. groups and least on the under 80 and 90–99 per cent. groups. In the case of diphtheria the percentages suggest a fall of incidence as intelligence rises, 4·2 per cent. suffering in the lowest I.Q. group and only 0·9 per cent. in the highest group. Unfortunately the numbers available are too small for any reliable conclusions to be drawn from them; the χ^2 test demonstrating that the results obtained might easily have arisen by chance.

The tables in which several infectious diseases were grouped (Tables XV, XV A and XVI) are also instructive. The incidence of these diseases upon the I.Q. groups varies less than 6 per cent. and this variation is not evenly distributed. Table XVI may be quoted as an example (total incidence of some of the infectious diseases grouped), the incidence on the lowest group being 42·6 per cent. and on the highest group 43·5 per cent. the maximum variation in this case being only 1 per cent.

As eleven separate schools were involved in this investigation and in consequence many variable factors introduced, unequal exposure to risk might be considered to have influenced the result. If this were so, it hardly seems credible that the results would show such uniformity in the distribution of the diseases in the I.Q. groups both collectively and in the subdivisions. In this respect Table XVII might be considered. It compares the incidence of some of the common infectious diseases in this series of children with those published by Terman (25) for a group of highly intelligent American children. In the original tables Terman's figures were subdivided so as to show the incidence on males and females separately. As no material difference was noted, in this report the figures are combined for the sake of simplicity. No details were given by Terman as to the age composition of his group of children so that some reservation must be made that, in this respect, the groups may not be comparable. However, the upper limit of age was given as 14, as in this present series, but the lower limit is two years younger age 7 instead of 9 years. The medical histories were obtained in a similar manner. Comparing the tables, only in the case of varicella is there any marked difference. The variation in pneumonia is only 0·2 per cent.; scarlet fever and whooping cough vary by less than 5 per cent.; mumps and measles by less than 8 per cent. The gifted children show a slightly higher incidence in pertussis, varicella, diphtheria and pneumonia but a lower incidence in measles, mumps and scarlet fever. The children can have had little in common; and have been exposed to a variety of different circumstances and yet, on the whole, the comparability of the two series is remarkable.

The mortality rates from infectious disease in England and Wales were studied and compared with those in the Holland area. In common with the rest of the country a steady decline was recorded; only one outburst of epidemic proportions was noted and that was in respect of measles in 1922.

Table XVIII. *Incidence of rheumatism*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	5	14	8	6	33
Incidence %	1·8	5·4	4·2	2·6	3·4

$\chi^2 = 6{\cdot}33$; P = greater than 0·05.

Table XIX. *Incidence of scarlet fever*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	27	26	18	31	102
Incidence %	9·5	10·1	9·5	13·5	10·6

$\chi^2 = 2{\cdot}74$; P = greater than 0·3.

Table XX. *Incidence of chorea*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	2	1	1	1	5
Incidence %	0·7	0·4	0·5	0·4	0·5

Table XXI. *Incidence of scarlet fever, chorea, rheumatism (combined)*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	34	41	27	38	140
Incidence %	12·0	16·0	14·2	16·6	14·6

$\chi^2 = 2{\cdot}67$; P = greater than 0·03.

Table XXII. *Incidence of fits*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	13	4	4	3	24
Incidence %	4·6	1·6	2·1	1·3	2·5

$\chi^2 = 7{\cdot}39$; P = greater than 0·05.

Table XXIII. *Incidence of visual defects*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	31	24	12	27	94
Incidence %	11·0	9·3	6·3	11·8	9·8

$\chi^2 = 4{\cdot}07$; P = greater than 0·2.

DISEASES ASSOCIATED WITH STREPTOCOCCAL INFECTIONS

The probability of a common etiological factor or factors suggested the grouping of chorea, scarlet fever and rheumatism for the purpose of this investigation. Certainly chorea and rheumatism may be combined (Price (21)).

It is realised that scarlet fever is caused by a different member of the *Streptococcus* group from that supposed to be the cause of chorea. However, both scarlet fever and chorea are definitely associated with rheumatic conditions, and each is related to the *Streptococcus* family (Topley and Wilson (26)). Thus if any association with intelligence were found it might possibly be common to the group.

Tables XVIII–XXI show the results.

The hint of an association in the upper intelligence groups for rheumatism 5·4, 4·2 and 2·6 per cent. is negatived by the 1·8 per cent. finding for the lowest I.Q. group.

The figures for chorea were too small for the calculation of χ^2. For this group of tables no association of statistical significance was found either in the subdivisions or in the total. Dawson (7) also found no association of intelligence with rheumatism and chorea.

FITS

Table XXII shows a slightly higher incidence of fits amongst children of the lowest intelligence group (4·6 per cent. against 1–2 per cent. in the higher intelligence groups) but the numbers are not sufficiently large to eliminate the possibility of the result being due to chance.

VISUAL DEFECTS

Table XXIII shows a declining incidence of visual defects with intelligence until the most intelligent group is reached, amongst whom the incidence is high. The differences are, however, not more than might easily have arisen by chance in the small populations observed.

Table XXIV. *Incidence of bronchitis. History*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	33	30	19	24	106
Incidence %	11·7	11·7	10·0	10·5	11·1

$\chi^2 = 0{\cdot}49$; P = greater than 0·9.

Table XXV. *Incidence of bronchitis. At inspection*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	19	24	15	21	79
Incidence %	6·7	9·3	7·9	9·2	8·2

$\chi^2 = 1{\cdot}60$; P = greater than 0·5.

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Table XXVI. *Incidence of pleurisy*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	5	3	3	6	17
Incidence %	1·8	1·2	1·6	2·6	1·8

Table XXVII. *Incidence of pneumonia*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	20	12	4	6	42
Incidence %	7·1	4·7	2·1	2·6	4·4

Pleurisy and pneumonia combined: $\chi^2 = 5{\cdot}94$; P = greater than 0·1.

Table XXVIII. *Incidence of pleurisy, bronchitis and pneumonia. Combined*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	77	69	41	57	244
Incidence %	27·2	26·8	21·6	24·9	25·4

$\chi^2 = 2{\cdot}25$; P = greater than 0·5.

Table XXIX. *Incidence of gross tonsilar disease*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	40	34	13	17	104
Incidence %	14·1	13·2	6·8	7·4	10·8

$\chi^2 = 10{\cdot}68$; P = between 0·02 and 0·01.

Table XXX. *Tonsils removed during school life*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	31	21	29	41	122
Incidence %	11·0	8·2	15·3	17·9	12·7

$\chi^2 = 12{\cdot}22$; P = greater than 0·01.

Table XXXI. *Total incidence of tonsilar disease*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	71	56	43	59	229
Incidence %	25·1	21·8	22·6	25·8	23·9

$\chi^2 = 1{\cdot}45$; P = greater than 0·5.

Diseases of the respiratory tract

The grouping of bronchitis, pleurisy and pneumonia has been adopted on the grounds that it is extremely difficult to obtain histories from parents sufficiently accurate to warrant the distinctions implied.

Tables XXIV–XXVIII show the results. The figures for bronchitis history and pneumonia suggest a slight decline in incidence with increasing intelligence.

This slight relationship, however, is not supported by bronchitis at inspection or by the small figures for pleurisy, and, taking the conditions separately or as a whole, reveals no significant association.

TONSILS AND/OR ADENOIDS

Table XXIX shows the intelligence groups into which children with gross tonsilar disease fell; children in whom the defect was present only slightly were recorded but were not included in the figures of Table XXIX. The association here is that of increased incidence of disease with low intelligence, some 13–14 per cent. of children in the lower intelligence groups having this defect against about 7 per cent. in the higher intelligence groups. Table XXX shows the grouping of those who had had removal of tonsils and/or adenoids during school life. The association between operation and superior intelligence is significant but is the reverse of the previous table, for 15–18 per cent. of children in the higher intelligence group had been operated upon against 8–11 per cent. in the group of lower intelligence. The total incidence of gross tonsilar disease will be the sum of these two tables with the addition of any children who had had the operation for tonsils and/or adenoids before school life. This is represented by Table XXXI. No association is shown.

Gawne (14) studied the relation between adenoids and backwardness by means of Binet tests. He estimated the intelligence of one hundred sufferers and compared them with one hundred control children; his result was similar to that of Table XXIX.

Table XXXII. *Incidence of other defects. History*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	10	13	9	10	42
Incidence %	3·5	5·1	4·7	4·4	4·4

$\chi^2 = 0{\cdot}81$; P = greater than 0·8.

Table XXXIII. *Incidence of other defects. At inspections*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Tota
No. of children observed	283	257	190	229	959
No. of cases recorded	28	18	14	21	81
Incidence %	9·9	7·0	7·4	9·2	8·4

$\chi^2 = 1{\cdot}94$; P = greater than 0·5.

Table XXXIV. *Incidence of other diseases. Before school life*

I.Q. ...	Under 80%	80–89%	90–99%	100% and over	Total
No. of children observed	283	257	190	229	959
No. of cases recorded	7	9	7	6	29
Incidence %	2·5	3·5	3·7	2·6	3·0

$\chi^2 = 0{\cdot}93$; P = greater than 0·8.

Other defects and diseases

A general group of other defects and diseases has been taken as the numbers were too small for separate treatment.

Freeman (12) showed an association between the number of defects and the weight/height ratio, the latter being used as an estimate of nutrition. Terman (25) demonstrated fewer minor defects in his series of gifted children.

Three tables were prepared in this series. Table XXXII records defects in the past history of the child, those recorded including nocturnal enuresis (persistent), cervical adenitis, developmental defects, and rickets. No association was demonstrated. Table XXXIII records other defects at inspection; these include deafness, heart disease, tuberculosis, speech defect, splenic enlargement, spinal curvature, thyroid defects, and ichthyosis. Again no association was found.

Table XXXIV records other diseases before school life; these include jaundice, erysipelas, infantile paralysis, smallpox, colitis and appendicitis. No association was found. By grouping all three, no association could be demonstrated.

Discussion

There have been several suggestions in medical literature of the possible effect of sickness on the powers of reasoning. Sir George Newman (18) quotes Herophilus, "Without health wisdom is darkened". Habakkuk (15): "Each child starts life with a certain capacity for development mental and physical. The efficient adult is the one whose physique is developed to its full capacity and whose mind has been fully trained. The school period is the time when this development and training takes place. The facts presented indicate both may be influenced by nutrition."

Lawrence (16) found a small correlation to exist between health and intelligence, as also did Karl Pearson (20). Dawson (7), on the other hand, found no association between the non-brain diseases and intelligence. He concludes "that children who were suffering from rheumatism, pneumonia, nephritis and other ailments described as non-brain did not differ in intelligence from the healthy members of the population to which they belonged. Hence, disease on the whole does not appear to have any appreciable effect on intelligence."

The tables presented for infectious disease and other defects, apart from nutrition, seem to bear out Dawson's conclusions. No clear or uniform association has been revealed. In the case of tonsils and adenoids, Tables XXIX and XXX show an opposite selection of children; those who have not had the operation have an excess of low-grade children and those operated upon an excess of high grade. Is this not merely a reflection of the intelligence of the parents? Table XXXI, "Total incidence of tonsilar disease", shows no association. If tonsilar disease had a permanent effect on the development of the child's intelligence, an excess incidence of disease in the lower grade groups should have been apparent.

One can only conclude that tonsilar disease, as with other diseases, does not effect intelligence. Gawne's figures (14) do not take into account the possibility of selection as shown above. It is possible that the divergence of opinion as to the association between intelligence and health is due to the use of different terminology; those postulating association with intelligence using such words as "Health" and "Nutrition" and those dissociating intelligence using the word "Disease".

If the results of the tables on nutrition and the weight/height ratio are considered at this stage, it is possible that the conflict of opinion can be harmonised. Satisfactory nutrition as estimated by the Medical Officer, apart from consideration of measurements of weight and height, is noted to be associated with the higher grades of intelligence, and the converse to be true. Previous work, as noted, has demonstrated that children of superior intelligence are on the whole taller than children of lower intelligence grades. The weight/height ratio (Table VI) showed no association. Loss of weight is a common accompaniment of ill health, but, with the return of normal health, restoration usually takes place. Although an association between the clinical estimate of subnormal nutrition and the weight/height ratio has been demonstrated the correlation is not high. A possible explanation is that the weight/height ratio picks out children whose health is temporarily impaired and that this disproportion in physique has no relation to intelligence. Sir George Newman, speaking of healthy and complete nutrition, says "It is part of the sum total of sound physiological being". This is in keeping with the Medical Officer's attempt at assessment. His estimate is based on good physique, absence of disease, and evidence of sound physiological functioning. It has been shown that disease, apart from brain disease, has no apparent effect on intelligence. Friedeman and Elkeles (13) postulate a blood brain barrier which defends the brain against attack.

The Board of Education report on infant and nursery schools (2) contains the following statement: "The brain first and foremost maintains its growth and activity to an inordinate degree." Temporary ill health—if this is demonstrated by the alteration of the weight/height ratio—is not related to Intelligence. Therefore it seems that the only other factor left which the Medical Officer takes into consideration in assessing nutrition, and is known to be related to intelligence, is good physique. Karl Pearson states: "At the same time it is well within the bounds of possibility that those who attribute bad health and bad intelligence the one to the other, and both to bad care and bad environment, may be overlooking that feebleness in health and feebleness in intelligence are too apt to arise from degeneracy in parents, and that the primary public elementary school is precisely where we should expect to find both concentrated." If one adds the result of Table 8 (bad family history) to the

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above conclusions the truth of the above statement seems to be borne out by the results of this inquiry.

It would seem desirable to add one note of caution to the above results, namely, that in the case of the infectious diseases no high death-rate was recorded during the life of the children investigated, except in the case of measles for the year 1922. It is true that, except in the case of diphtheria, nervous complications during the course of the common infectious diseases are rare (22). On the other hand, the virulence of the majority of the commoner infectious diseases, except diphtheria, seems to have declined. Any change of type to the virulent forms might therefore produce an increase of the nervous complications and in that way effect the growth of intelligence.

Conclusions

1. It has been shown that by the criteria of height and weight, the children studied in this investigation appear to be a good sample of rural elementary school children. The intelligence test showed that there was some excess of children in the lower intelligence group.

2. That the incidence of the common infectious diseases seems to be very little different from that noted in a group of gifted children by Terman, though the latter were American children.

3. That after dividing the children into groups according to their intelligence, the incidence of the common infectious diseases and defects upon these groups was found not to be significantly different. This suggests that the susceptibility of the superior children to these diseases and defects is not different from that of the inferior children; that neither the defects nor the diseases can have influenced the intellectual growth of these children. These findings can only refer to the population studied, and to the type of infectious disease that has been prevalent this last fourteen years in the Holland division of Lincolnshire.

4. The absence of any association between intelligence and such conditions as bronchitis, pneumonia, etc., correspond to the results of Shepherd Dawson.

5. That the association between intelligence and nutrition that is noted is possibly an association between intelligence and physique. It therefore seems desirable to eliminate the factor of physique before ascribing intellectual impairment to malnutrition, as both the lower physique and lower intelligence of certain children may be inherited characteristics.

6. It is probable that some of the conflict of opinion that has been noted is due to lack of definition of such terms as "Health" and "Nutrition".

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