BRITISH MEDICAL JOURNAL

LONDON SATURDAY AUGUST 12 1944

THE NUTRITIONAL STATUS OF CAMBRIDGE SCHOOL-CHILDREN

BY

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A survey of over 1,100 Cambridge children was conducted in Jan. and Feb., 1942, and the majority were re-examined a year later. The purpose of the investigation was fourfold: first, to determine nutritional trends during the war by repeated examinations of the children; secondly, to see whether vitamin supplements would affect the children in any detectable way; thirdly, to examine the possible interrelation of the various physical and mental attributes of the children; and, fourthly, within the limited scope possible in an investigation which was primarily nutritional, to determine the relation between social conditions and the physical state of the children.

The children were between 4 and 11 years of age, attending elementary schools. There were altogether about 7,500 children attending these schools in Cambridge, of whom some 6,000 were between 4 and 11 years old; the children included in this investigation were thus about 15% of the total or nearly 20% of the age group 4-11. Of those between 4 and 10 years, approximately half were from a school in a fairly poor district (junior school A) and the others from a school in a comparatively well-to-do district (junior school B); the 11-year-old children were from a senior elementary school in the same better-class district as junior school B.

Although the senior school and the junior school B were so close to each other, the children attending them were not exactly comparable. The senior school received children from a rather wider area than the junior school; some of its pupils had attended the latter, but many had attended schools from slightly poorer though neighbouring districts. Moreover, the children at the senior school were a selected group in the sense that they were children from the junior schools who had not gone on to a central, secondary, or public school. This selection of children for higher education depended partly on the results of a scholarship examination held when the children were aged 10 or 11, and partly on the financial circumstances of the family. Some children, usually of poor families, did not avail themselves of the scholarships although they had reached the requisite standard at the examination; on the other hand, several of the children were sent to one of the higher schools by parents who could afford to do so, even though their children had not been awarded a scholarship.

Although, therefore, we may legitimately compare the children from the two junior schools, those from the senior school fall into a rather special category; and the findings which are recorded here must be viewed in the light of the selection to which they have been subjected.

The Investigations Undertaken

The procedure consisted of measurement of the height and weight; clinical examination, especially for signs of nutritional deficiency; examination of the gums and teeth; determination of haemoglobin; measurement of physical strength by the grip dynamometer. Additional data were obtained with the older children. Measurements of visual acuity, examination of the fundus oculi, slit-lamp examination of the eyes, and measurement of intelligence and educational attainment were carried out in children of 8 years and over, and dark-adaptation was determined in children of 11 years. The dark-adaptation

findings are described elsewhere (Robertson and Yudkin, 1944). The results of the clinical and dental examinations, which were undertaken by the School Medical Officer and the School Dental Officer, and the results of the mental tests will be published later.

Since the first examination half of the children at each school have daily been receiving pellets containing 5,000 i.u. vitamin A, 1 mg. vitamin B₁, 25 mg. vitamin C, and 500 i.u. vitamin D, so that, allowing for holidays and possible absences from school, the pellets supplied roughly half the daily requirements of these substances. The other half of the children have been given control pellets of similar size and taste but different in colour.* Neither the teachers nor the parents were aware that half of the pellets were devoid of vitamins. Records of absences from school, of illness, and of general behaviour are being kept by the teachers.

At the second examination some further studies were made on about 200 of the oldest children. These tests were carried out in order to see if it could be confirmed that vitamin supplements, as has been reported, result in improved physiological performance; they have been recorded elsewhere (Jenkins and Yudkin, 1943).

Unless otherwise stated, all the results described in this paper refer to the first examination, carried out early in 1942.

FIG. 1.—Height of Cambridge school-children: comparison of "good" and "poor" school.

(a) *Height and Weight.*—The children were weighed completely stripped except for shorts or knickers. Their average heights and weights were higher than those reported for most other areas of the country; they are similar, for example, to the figures for 1938 for London school-children, which are said to be above average for the country generally† (Benjamin, 1943).

* The pellets were generously manufactured to my specifications and given by Messrs. British Drug Houses Ltd.

† The average weights of the Cambridge children were actually very slightly lower than those recorded for the London children; if, however, one allows for the fact that the London children were weighed in their ordinary indoor clothing, the weights are slightly higher.

Nevertheless the children from the poorer junior school A were about 3/4 in. shorter and 2½ lb. lighter than those from junior school B (Figs. 1 and 2). The average heights and weights for the children of the senior school (age 11+) were as follows. Height: boys (90) 53.8 in.; girls (98) 56.0 in. Weight: boys (83) 73.8 lb.; girls (98) 76.3 lb.

FIG. 2.—Weight of Cambridge school-children: comparison of "good" and "poor" school.

FIG. 3.—The Tuxford indices of the school-children.

Many workers have attempted to express the nutritional status of a child by an index which is usually derived from a combination of two or more anthropometric measurements. The most frequently used of these are derived from formulae involving the height and weight of the child. By testing a number of such formulae Huws Jones (1938) decided that the

most reliable is the Tuxford index. In its original form (Tuxford, 1917) the index is:

$$\text{Boys: } \frac{W}{H} \times \frac{(381 - \text{age in months})}{54}$$

$$\text{Girls: } \frac{W}{H} \times \frac{(354 - \text{age in months})}{48}$$

More recently, Tuxford (1942) has revised the formula so that it now becomes:

$$\text{Boys: } \frac{W}{H} \times \frac{(335 - \text{age in months})}{48}$$

$$\text{Girls: } \frac{W}{H} \times \frac{(308 - \text{age in months})}{42}$$

This latest formula is based on the figures for London school-children of 1938, which, as mentioned above, are very similar to those of our Cambridge children.

In general, such weight-for-height formulae indicate whether a child is heavy enough for his height—i.e., is well enough "covered." Now, it is well known that slight but long-continued malnutrition affects growth in height as well as in weight, and it might be thought that the retardation of both might possibly be such as to lead to no change in a weight-for-height index. This hypothesis is supported by the findings with the Cambridge school-children. Although, compared with the children from the better-class school, those from the poorer school are of inferior nutritional status, as shown by their heights, weights, and other attributes (see below), the Tuxford indices of the children of both these schools are exactly similar (Fig. 3; this includes the distribution of the indices for the senior school).

(b) *Haemoglobin*.—The haemoglobin was estimated on blood obtained from pricking the left thumb. The estimations in 1942 were carried out by using a Dare haemoglobinometer, which, through the kindness of Dr. Lucy Wills, I was able to calibrate against a standard Haldane apparatus. In 1943 the more satisfactory alkaline haematin method of King was used. Very little change in haemoglobin levels was found during the year (see below). The results shown in Fig. 4 are

FIG. 4.—The haemoglobin readings.

those obtained in 1943, using the better technique. The average haemoglobin value of the school-children was 91% (Haldane). This is much higher than that found by Wills *et al.* (1942) for London school-children and by Davidson and co-workers (1942, 1943) for Edinburgh school-children. Both groups of investigators reported an average haemoglobin level of 80-82% in children examined in 1942. As with heights and weights, children from the poorer junior school A showed lower readings (by about 2%) than those from junior school B (Fig. 4). For children of the senior school the average haemoglobin level was 92.2%. There was no difference in haemoglobin between the boys and the girls.

(c) *Dynamometer*.—The strength of grip of the right hand was measured with a hand dynamometer. The boys, as would

be expected, had a stronger grip than the girls. Once again the children from the better-class school were superior to those from the poorer school, and this was seen both in the boys and in the girls (Table I; Fig. 5).

TABLE I.—*Dynamometer Readings of Cambridge School-children*

Age	Average Grip in Kilogrammes					
	Junior School A		Junior School B		Senior School	
	No.	Dyn. kilo.	No.	Dyn. kilo.	No.	Dyn. kilo.
Boys						
4+	6	8.7	18	10.0		
5+	32	11.1	23	11.7		
6+	32	13.0	43	13.9		
7+	43	15.5	38	17.8		
8+	34	18.6	52	19.5		
9+	38	19.7	49	21.2		
10+	14	19.8	54	24.9		
11+					88	24.6
Girls						
4+	5	8.6	15	8.5		
5+	30	9.8	29	10.4		
6+	36	11.1	36	13.4		
7+	35	14.2	44	15.3		
8+	38	16.9	39	17.5		
9+	40	17.8	54	19.4		
10+			42	21.7		
11+					95	22.0

FIG. 5.—Dynamometer recordings of the strength of grip.

(d) *Slit-lamp Examination of the Eyes.*—The results of the examination of the eyes with the slit-lamp microscope have been described in a previous publication (Kodicek and Yudkin, 1942).

Changes between 1942 and 1943

In order to see whether the fourth year of the war had any appreciable effect on the condition of the Cambridge children, their physical measurements at the second examination were compared with those of the same age groups examined a year previously; for example, the average weight for 7-year-old children examined in 1943 has been compared with that of 7-year-old children seen in 1942. No significant difference was found in the dynamometer readings (Table II), but the average heights and weights of children in 1943 were greater than those of children of the same age a year ago (Tables III and IV). The average height of boys and girls of junior

TABLE II.—*Dynamometer Readings of Cambridge School-children. Comparison of Children of 1942 and 1943*

Age	Average Grip in Kilogrammes			
	Boys		Girls	
	1942	1943	1942	1943
Junior School A				
6	13.0	13.1	11.1	13.7
7	15.5	15.6	14.2	14.6
8	18.6	18.0	16.9	16.2
Junior School B				
5	11.7	13.2	10.4	10.6
6	13.9	14.7	13.4	13.4
7	17.8	17.9	15.3	15.1
8	19.5	20.1	17.5	17.7
9	21.2	21.1	19.4	20.8
10	24.9	24.3	21.7	

TABLE III.—*Height of Cambridge School-children. Comparison of Children of 1942 and 1943*

Age	Average Height in Inches			
	Boys		Girls	
	1942	1943	1942	1943
Junior School A				
5	42.6	43.6	42.2	44.7
6	44.7	45.0	44.4	45.4
7	47.0	47.0	47.4	46.7
8	49.3	50.5	49.1	50.0
9	51.4	51.3	51.1	51.3
10	51.6	52.6	51.9	54.1
Junior School B				
5	43.5	43.9	43.7	44.0
6	45.8	46.2	44.7	45.5
7	48.0	48.2	46.6	47.6
8	50.6	50.5	50.0	50.2
9	52.1	52.5	51.8	52.5
10	54.3	54.4	54.1	54.2

TABLE IV.—*Weight of Cambridge School-children. Comparison of Children of 1942 and 1943*

Age	Average Weight in Pounds			
	Boys		Girls	
	1942	1943	1942	1943
Junior School A				
5	40.9	41.7	39.8	44.3
6	44.9	44.5	44.4	44.3
7	48.8	50.0	49.3	49.4
8	55.4	54.9	53.5	55.6
9	60.5	63.7	57.0	58.6
10	61.8	65.5	62.9	67.5
Junior School B				
5	42.0	43.7	41.6	43.2
6	46.2	47.6	44.2	47.7
7	51.3	51.4	49.7	50.3
8	57.6	58.4	57.0	56.0
9	62.7	63.1	62.5	63.3
10	68.4	67.0	68.0	71.4

school A in 1943 was about 0.6 in. more than in 1942; in the better-class junior school B it was about 0.3 in. The difference in weight was about 1½ lb. in junior school A; in junior school B there was no appreciable change in weight in the boys, but an increase of just over 1 lb. in the girls. The haemoglobin levels were about 1% higher; since, however, the estimations in 1942 and 1943 were carried out with different techniques it would be unwise to attach any great significance to the comparison of the values at the two examinations.

It is evident that, far from any adverse effect being apparent during the fourth year of the war, there was in fact an improvement in physique. There has been in general a gradual increase of height and weight of children since the beginning of the century, and that this increase is still observed suggests that the present nutrition of at least this group of children is being satisfactorily maintained. The fact that the increases in height and weight were greater in the poorer-class school is also a matter for satisfaction, indicating as it does that the differences between the nutritional status of the children of the two schools are being minimized.

Effect of Multiple Vitamin Preparations on School-children

Apart from the slit-lamp examination, all the examinations of the Cambridge school-children have been repeated after one year's feeding with the vitamin preparation. In addition, the records of the school-teachers were analysed, the opinions of the parents regarding the progress of their children were obtained, and additional examinations were made with a view to determining physiological function and the response to the vitamin C saturation test.

Physique.—No difference was detected in the gain in weight or height, in haemoglobin, or in strength of grip between the children receiving the vitamin pellets and those receiving control pellets.

Dark-adaptation.—There was no alteration in the dark-adaptation (final rod threshold) after the ingestion of the vitamin supplements (see also Robertson and Yudkin, 1944).

Illness.—The records of absences kept by the teachers have been analysed so as to give so far as is possible an idea of the relative

incidence of the major groups of illness. Since, however, the only difference was seen in those illnesses classed as respiratory (colds, coughs, bronchitis, influenza) I have for simplicity given in Table V the incidence and duration of respiratory illness only on the one hand and of all other illnesses on the other. I have also included absences due to causes other than illness. It will be seen that the "vitamin" children in both the junior schools were less often away because of colds, and on the average for a fewer number of days per illness, than the control children. This difference was not seen

The higher proportion of "vitamin" children in the senior school whose behaviour, according to the teachers, had improved is not statistically significant. On the other hand, the difference in both junior schools is significant.

In both the teachers' and the parents' records the high proportion of children who had apparently been improved by the control pellets is noteworthy, and once again stresses the importance of adequate controls in attempting to assess the value of vitamins in affecting behaviour and general health. It is perhaps worth repeating that

TABLE V.—Absences from School of Cambridge School-children

	Respiratory Illnesses			Other Illnesses			Other Absences		
	Absences per Child	Days Away per Child	Days Away per Absence	Absences per Child	Days Away per Child	Days Away per Absence	Absences per Child	Days Away per Child	Days Away per Absence
Junior School A									
Vitamin group	0.74	2.73	3.69	3.11	12.18	3.91	1.47	2.83	1.92
Control group	0.79	3.54	4.45	3.14	12.88	4.10	1.35	2.58	1.91
Difference in favour of vitamin group	0.05	0.81	0.76	0.03	0.70	0.19	-0.12	-0.25	-0.01
Junior School B									
Vitamin group	1.37	4.87	3.40	1.81	12.65	7.00	1.09	3.05	2.80
Control group	1.67	6.86	4.01	1.91	11.00	5.76	1.07	2.78	2.60
Difference in favour of vitamin group	0.30*	1.99*	0.61†	0.10	-1.65	-1.24	-0.02	-0.27	-0.20
Senior School									
Vitamin group	0.91	3.31	3.61	1.75	4.82	2.75	2.47	5.52	2.23
Control group	0.95	3.40	3.58	1.52	5.78	3.80	2.20	3.91	1.78
Difference in favour of vitamin group	0.04	0.09	-0.03	-0.23	0.96	1.05	-0.27	-1.61	-0.45

* Significant difference. † Nearly significant difference.

in the older children of the senior school. In junior school B the difference in both incidence and duration of colds was statistically significant. The difference in the number of children at this school who had no colds—76 of the 217 "vitamin" children and 55 of the 212 "control" children—was also statistically significant. In junior school A the differences were not statistically significant, but this may be due to the fact that the records of the teachers in this poorer school were not so well kept as in junior school B. For example, the average attendance during the year, according to the official records of the local education authorities, was slightly better at junior school B (90% attendance) than at junior school A (89%); yet the absences recorded by the teachers were appreciably fewer at the latter.

Behaviour.—Both the parents and the teachers were asked for their opinion regarding the children's general well-being and behaviour, the former six months after the beginning of the experiment and the teachers throughout the year. The parents were asked to state whether appetite, sleep, nervousness, and tiredness had improved, deteriorated, or remained unaltered. If we consider only those children in whom improvement was recorded for at least two of the four items mentioned, then there was in each school a slightly

neither the teachers nor the parents were aware that the pellets given to half of the children were devoid of vitamins.

Physiological Function.—Following a report by Harper *et al.* (1943) that a short period of feeding with vitamin supplements improved the physiological function of a group of cadets, some of the older children were tested to see whether a similar effect could be observed. The four tests—vital capacity, breath-holding, endurance (R.A.F. 40 mm. mercury test), and the resting heart rate—which the Manchester workers claim were affected were carried out on 178 children in March, 1943; that is, after one year of feeding with vitamin supplements. No difference was observed between the "vitamin" children and the controls (see Jenkins and Yudkin, 1943).

Vitamin C Saturation.—Senior-school boys were tested by the method of Harris and Abbasy (1937). In this method, which is modified from Harris and Ray (1933), daily doses of vitamin C equivalent to 70 mg. per stone body-weight are given at about 10.30 a.m. and the urine is for analysis collected between 2 and 4.30 p.m. The dosing and the urine collection are repeated each day for five days. An excretion of 50 mg. or more in the specimen of urine is taken to indicate saturation.

Altogether, 109 senior-school boys were investigated, of whom 22 were 11 and the remainder 12 years old. Since some of the boys were absent during the week of the test, complete records were obtained on only 95 subjects. Of these, 45 had been taking the vitamin pellets and 50 the control pellets. The average number of days to reach saturation was 1.84 in the vitamin group and 2.59 in the control group. The proportion of boys reaching saturation on each of the five days is shown in Fig. 6.

Dietary vitamin C tends to be lowest in spring and early summer, when green vegetables are difficult to obtain (Harris and Olliver, 1943). The fact that the control group was saturated in as short a time as 2½ days (average) indicates that the intake of vitamin C of these children was higher than that of other groups of children studied in the spring during the war (see, for example, Harris, 1942). This is no doubt associated with the fact that green vegetables were unusually plentiful during the winter 1942-3.

Discussion

Differences in height and weight have often been reported in children from different classes; thus, children from public schools are heavier and taller at a given age than children from elementary schools. But that differences in height and weight, and incidentally also in dynamometer readings, should exist between children of different elementary schools in the same town seems worthy of note, especially in a town like Cambridge. Cambridge is comparatively prosperous, and one would certainly not regard it as a town in which to observe widespread poverty or malnutrition. Severe or even moderate rickets, for example, is rare in Cambridge. And, as we have said, the average height and weight of the children as a whole compare favourably with those of most towns in Britain. That

TABLE VI.—Parents' Impressions of Improvement

School	Vitamin Group			Control Group		
	No. Improved	No. Not Improved	% Improved	No. Improved	No. Not Improved	% Improved
Junior school A ..	82	107	44.2	71	102	41.0
Junior school B ..	107	152	41.2	86	167	34.0
Senior school ..	42	49	46.1	41	53	43.6

greater proportion of improvement in children receiving the vitamins (Table VI). The difference between the vitamin group and the control group is greatest in the children from junior school B. However, even this difference is not significant statistically.

The teachers were asked to record each month their impression of any changes in behaviour such as sociability, concentration, and memory. These records were, however, not kept very consistently, and it was difficult to assess them in any detail. All that has been done, therefore, is to note whether there has been any record of definite and maintained improvement in behaviour during the year (Table VII).

TABLE VII.—Teachers' Impressions of Improvement

School	Vitamin Group			Control Group		
	No. Improved	No. Not Improved	% Improved	No. Improved	No. Not Improved	% Improved
Junior school A ..	68	118	35.6	44	128	25.6
Junior school B ..	74	129	36.3	54	152	26.2
Senior school ..	32	56	36.4	39	49	44.4

the differences are due to economic factors is supported by a study of the relation between nutritional status and family size (Yudkin, 1944a) and by the results of an investigation of children from industrial areas (Yudkin, 1944b).

Limiting Factors in Nutritional Deficiency.—The absence of effect of vitamin or other nutritional therapy is not necessarily an indication that the diet was completely adequate in these essentials (Yudkin, 1943, 1944c). Let us consider the results of

FIG. 6.—Vitamin C saturation tests.

the Cambridge vitamin investigation from this point of view. Apart from the improvement in vitamin C saturation, which is simply an index of past vitamin C intake, the supplements effected an improvement only in respiratory illness and in general behaviour as assessed by the teachers. The fact that no improvement was produced in height, weight, haemoglobin, etc., even in children from the poorer school, does not mean that these are unaffected by vitamin A, B₁, C, or D. It might mean, of course, that the diets of the children supplied adequate quantities of these components. On the other hand, it might mean that the diets were deficient in other essentials in addition to these vitamins and that one or more of these other essentials was the limiting factor in growth, haemoglobin formation, and so on. An animal showing suboptimal growth on a diet slightly deficient, for example, in protein, calcium, and vitamin A will not be made to grow normally by the administration of only one of them. On the other hand, a similar degree of suboptimal growth caused by deficiency of, say, vitamin A only, will be restored to normal by an increase in this factor alone.

Summary

The nutritional status of about 1,100 Cambridge school-children, determined in Jan. and Feb., 1942, was found to compare favourably with that reported for children in other parts of the country. Nevertheless, in the Cambridge children appreciable differences were seen between those living in a poorer area of the town and those in a better-class area. Compared with the latter, the children from the poorer area were on the average 0.8 in. shorter, 2.6 lb. lighter, had

2% less haemoglobin, and a grip about 1.25 kg. weaker, and showed more changes in conjunctival epithelium.

Most of the children were re-examined in Jan. and Feb., 1943. The average heights and weights were slightly greater than for children of the same age examined a year previously; in other respects no change was seen. It may be said, therefore, that no deterioration in the diets of these children had occurred between the third and fourth years of the war.

Since Feb., 1942, half of the children have been receiving vitamin pellets at school; allowing for absences and school holidays, they were thus being given a supplement containing approximately half the daily requirements of vitamins A, B₁, C, and D. The other half of the children received control pellets containing no vitamins. After a year no effect was seen in the gain in height and weight, haemoglobin, strength of grip, dark-adaptation, resting pulse rate, vital capacity, breath-holding time, or endurance measured by the R.A.F. mercury test. There was, however, an improvement in vitamin C saturation, a decrease in the incidence and duration of colds, and an improvement in school behaviour as assessed by the teachers.

It is pointed out that the absence of effect on growth, haemoglobin, etc., cannot be taken to imply that these are not limited by nutritional factors.

This investigation would have been quite impossible without the co-operation of the teachers of the Cambridge schools, which was given so generously and for which I am very grateful. My thanks are due also to Dr. J. A. Smyth, medical officer of health for Cambridge, Dr. Janet Laidlaw, Mrs. Elsie Walton, my wife, and the many friends who have helped so willingly in the collection and analysis of the results.

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NUTRITION AND SCHOLASTIC ATTAINMENT

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A measure of far-reaching significance which was placed on the Statute Book in 1906 was the Education (Provision of Meals) Act. This Act granted powers enabling Education Authorities to provide meals for children in attendance at public elementary schools who were "unable by reason of lack of food to take full advantage of the education provided for them."

The inquiries of Rowntree (1900) in the city of York and the Report of the Interdepartmental Committee on Physical Deterioration (1904) had revealed that many children received quite insufficient quantities of food and that a condition of semi-starvation was rife. School-children were particularly affected, and it was recognized that the lack of food produced a condition of mind and body which made educational progress extremely improbable. Thus the ultimate object of the Act was the promotion of education among the poorer sections of the community; and it is probably correct to say, from a study of the antecedents, that the means to attain this end which those who framed the Bill had in mind was the prevention of actual hunger rather than the correction of defective nutrition.

Nowadays conditions have so changed that persons living at a correspondingly low economic level are no longer encountered. On the other hand, an enormous amount of defective nutrition, due principally to a long-continuing deficient intake of essential nutrients, exists among children of school and pre-school age. Reliable evidence of this has accrued during the last few years