THE ESTIMATION OF PHYSIQUE AND NUTRITION IN CHILDREN

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(With 1 Chart in the Text)

The process of physical growth in children is manifested by changes in their size, mass and shape. Changes in size are ascertained by measurement, usually, of the standing height of the child, but occasionally of the sitting height, and sometimes, also, of the chest circumference and the width between the hips. Changes in mass are detected by weighing, whilst changes in shape, which are due to unequal rates of growth in height and in mass, are estimated by methods referred to later.

Standard measurements

It is impossible accurately to assess the growth of any child in the absence of standards for comparison, showing the growth of the normal child. Opinions may, of course, be formed and may possibly be correct, but, as they are based chiefly on memory aided by guesswork, it is quite a common event for two or more opinions to differ regarding the same child.

The introduction of medical inspection of the children attending the elementary schools of this country in 1907 afforded a unique opportunity for the study of the growth of children; the material—nearly five million children —was the largest ever brought under one control, and, at that time, one could reasonably anticipate that contributions of permanent value would be made to anthropometrical science, which would also be of considerable benefit to the children themselves. Now, thirty years later, a whole generation of the English race has passed through the schools, and the first step in such a research, namely the establishment of national standards of height and weight of the children, still remains to be taken. From the beginning, medical inspectors were instructed to record the height and weight of every child examined, though, in the absence of such standards, the object of this is not clear. Many school medical officers constructed their own tables of averages but, apart from having a merely local value, the numbers were too small, in all but the largest and most populous areas, to allow of the formation of reliable standards.

With a view to obtaining, at any rate, approximate figures for use in the schools, school medical officers were asked by two of their number, in 1910, to furnish the aggregate sums of height and weight for each age and sex, with the numbers examined in their areas during that and the preceding year. Averages (arithmetical means) were subsequently calculated from the figures sent in from 61 of the 288 local education authorities in the country. They were derived from the measurements, in ordinary indoor clothing and without foot-gear, of 583,640 children of whom 294,966 were boys and 288,674 were girls; 277,614 were from 17 county and 306,026 from 44 urban areas; and 345,010 were from the north and 238,630 from the south of England, the line of demarcation being the southern borders of the counties of Salop, Stafford, Leicester, Rutland and Lincoln. The averages thus refer to less than one-eighth of the total school population, though this proportion was so distributed throughout the country as to constitute a fair sample of that population as a whole.

They were, however, obtained at a time when the machinery of the School Medical Service was hardly in full working order, and were based on data collected under all sorts of conditions, scientific and otherwise; it was, in fact, necessary to exclude a number of obviously inaccurate returns. Moreover, it is probable that the measurements of children aged 7–10 were below the true averages, most of these children having been specially examined on account of some defect. It is also probable that a majority of the children aged 5 were measured in the earlier half of their year of age, and of those aged 12 in the latter half, owing to the mode of their selection for examination. It cannot, therefore, be claimed that these averages are true mean measurements, though the curves formed by them were fairly regular, those for the urban areas, as might be expected, being most uniformly so. Nevertheless, these figures served their purpose as a temporary expedient for the first few years following their issue.

The averages for the whole country are reproduced in Table I. Those for the various subgroups are not included; they showed that, on the whole, the advantage in physique lay with children in the county areas and in the south of England. Except in one instance, the county averages were always better than the urban, exceeding them by 2 cm. in height in four cases out of twenty-four, and by ½ kg. in weight in seven cases. The differences between north and south were less marked. Though the heights of southern children were less in

Table I. *Average height and weight of English elementary schoolchildren,* 1909–10

Age last birth-day	Boys					Girls				
		Height		Weight			Height		Weight	
	No.	cm.	in.	kg.	lb.	No.	cm.	in.	kg.	lb.
3	9,388	92·4	36·4	14·86	32·76	8,478	91·6	36·1	14·44	31·83
4	24,047	98·2	38·7	16·29	35·91	21,362	98·1	38·6	15·82	34·88
5	65,438	103·0	40·6	17·54	38·67	63,825	102·6	40·4	17·07	37·63
6	20,554	108·0	42·5	19·33	42·62	21,238	107·6	42·4	18·58	40·96
7	37,515	114·7	45·2	21·20	46·74	36,477	113·9	44·8	20·50	45·19
8	9,684	119·3	47·0	22·86	50·40	12,014	117·6	46·3	22·19	48·92
9	7,873	124·7	49·1	25·12	55·38	8,138	123·7	48·7	24·75	54·56
10	21,579	129·4	51·0	27·42	60·45	21,017	129·8	51·1	26·71	58·89
11	5,084	134·2	52·8	29·93	65·98	5,139	133·5	52·6	29·59	65·23
12	37,230	139·8	55·0	33·05	72·86	36,577	138·7	54·6	33·51	73·88
13	52,232	142·5	56·1	35·15	77·49	50,717	144·5	56·9	36·31	80·05
14	4,342	147·1	57·9	38·15	84·11	3,702	149·0	58·7	39·81	87·77

three cases, and their weights in eight cases, at earlier ages, they exceeded the northern figures by 2 cm. in two, and by $\frac{1}{2}$ kg. in three, of the later years. The inference to be drawn is presumably that, owing to the fusion of the various elements of the population, local racial differences in this country are now almost obliterated and are certainly of much less effect than those due to environment, as shown by the differences between the county and urban averages.

Imperfect as, no doubt, these averages were, it has been necessary, in the absence of any better figures, to rely upon them as the source of all the deductions that follow. The averages of the British Association, published in 1883, are derived from such small numbers and are of such ancient date that they do not form very suitable material for comparison, though they are useful for confirming certain of the inferences drawn.

Rates of growth

On examining the curves formed on plotting out these heights and weights for successive years, certain irregularities appear, as, for instance, in the heights at age 7 and the weights at age 12. Instead of seeking for physiological or environmental reasons for all these irregularities, they have, with one important exception, been assigned to the most probable cause, namely defects in the data used, on the not unreasonable assumption that natural processes tend, on the whole, to evolve in an orderly and regular manner. This assumption, in respect of observations taken of large groups and at all seasons of the year, is not invalidated by the fact that, in individual children, height is gained more rapidly in the first, and weight in the second, half of the calendar year.

Growth in height took place by yearly increments varying from 2·7 cm. in boys aged 13 to 6·7 cm. in boys aged 7, but averaging, through the eleven years 3–14, 5·0 cm. for boys and 5·2 cm. for girls. It is a remarkable fact that, though variations to the extent mentioned above do occur in the table, and are largely attributable to defective data, there was very little difference between the annual additions to height at the beginning and at the end of school life. At ages 5 and 14, these additions were for boys 4·8 cm. and 4·6 cm., and for girls 4·5 cm. in each case. Similar results are seen in the British Association figures, where the yearly increase for girls at both age 4 and age 14 is 2·03 in. It is, therefore, inferred that normal growth in height takes place by the regular addition of about 5 cm., or 2 in., during each year of school life.

Weight was gained in an entirely different manner. The weight of boys increased by an average of 9 % per annum, and of girls by an average of 9·7 %, throughout these years. The beginning and the end of school life may again be compared. At ages 4 and 14, the annual increase for boys was 9·7 and 8·5 %, and for girls 9·6 % in each case; in the British Association tables, the increases for girls at these ages are 11·6 and 11·5 %. The increases were not regular, but varied between 6·3 % for boys aged 13, most of whom were examined in the

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early months of this year of age, and 13·2% for girls aged 12. The latter increase was not accompanied by a proportional gain in height, and must therefore be attributed mainly to the increased development that occurs at the onset of puberty; a larger percentage increase in weight must be regarded as a normal occurrence in girls of this age.

Comparing the sexes, the average heights of boys and girls were, to all intents and purposes, identical. They never differed by more than 2 cm., and at most of the earlier ages the boys were taller by $\frac{1}{2}$–1 cm.; the greatest differences occurred after the age of 12 when the girls had the higher averages. Substituting kilograms for centimetres, the above description applies almost as accurately to the children's weights, though, since a kilogram is of more importance in this connexion than a centimetre, the weights cannot be considered identical for both sexes; the girls started their school life lighter than the boys by nearly half a kilogram, and ended it heavier by more than $1\frac{1}{2}$ kg. At about the age of $11\frac{1}{2}$–12, both boys and girls were of practically the same height and weight, that is, they were at the same stage of physical development. These facts suggest a rather curious parallel between physical development and the probability of living one year. According to most life tables, the chances of surviving for a year are worse for girls than for boys at all ages between, on an average, 7 and 13 years, after which their chances of survival are the better; and the probability of living one year is greatest at ages 11 and 12, when it is practically the same for both sexes. At these ages, children have largely outgrown the risks of death from the commoner infections of childhood, and both brain and muscle have, by now, developed to such an extent as to provide ample insurance against most kinds of accident.

Broadly speaking, one may say that the heights of children of school age form, for successive years of age, a series in arithmetical progression with a common difference of about 5 cm., whilst their weights form geometrical progressions, the common ratios of which are 1·09 for boys and 1·097 for girls. The effect of these two very diverse rates of growth is that the physique or bodily structure alters with age, the build or shape of the child becoming more filled out as its physical development proceeds. The proportion of weight to height is a little more than half as much again at age 15 as it is at age 5.

Physique and nutrition

Before considering the relation between the stage of physical development of a child and its state of nutrition, it is necessary to understand clearly the meaning of the latter word. In the *Oxford English Dictionary*, nutrition is defined as "the action or process of supplying or of receiving nourishment". In the older *Chambers's Etymological Dictionary*, it is described as "the act of nourishing; the process of promoting the growth of bodies". These definitions, taken together, imply that nutrition is the process to which is due the development and maintenance of the physical structure of the body. Un-

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fortunately, the definition has, lately, been enlarged to such an extent that the facies, posture and condition of the mucous membranes are now regarded as criteria to be taken into consideration in assessing the state of nutrition; indeed, a combination of alertness, bright eyes and a good colour has been accepted as a proof of good nutrition, apart from any other consideration. These signs, some of which, at any rate, may be present in the poorly nourished and absent in the well nourished, have only the remotest connexion with nutrition as defined above. The meaning of the word has, in fact, been so distorted that it now has practically the same significance as health.

Physique is defined as the physical structure, organization or development of an individual. It is concerned only with organic form, or the arrangement of parts, and not at all with size.

Adhering to the original definition, nutrition is seen to be a physiological process which, during childhood, is chiefly engaged in building up and developing the tissues of the body, and this connotes the provision of an adequate supply of food, fresh air, exercise and sleep, all of which are essential to growth. Physique, on the other hand, is an anatomical condition, and the relation between physique and nutrition lies in the fact that, ultimately, every anatomical structure owes its form, as well as its existence, to past nutritional processes. The normal structure of every species may, thus, be regarded as the expression of the effects of nutrition on past generations of the species, and variations from the normal as indicating the effect of abnormal processes of nutrition on the family or the individual; the physique of a child, from this point of view, epitomizes the results of nutrition, first on the race, then on its own forebears for at least a few generations back, and lastly, and more definitely, on itself. Nutrition, being a process, is measurable only by its effects, and these are displayed most clearly in variations from the normal physique. The latter, however, indicate not necessarily the present state, but the sum of the previous states, of the child's nutritional processes, and they can only be accepted as a measure when it is known that, in a child of normal parentage, these states have always been constant. But changes in the relation of a child's physique to the normal physique for its age, over a given period, afford a reliable indication of its nutritional processes during that period.

Normal standards of physique and nutrition are not optimum or ideal standards beyond which no improvement can take place; they are probable mean standards, derived from the average standards of the child population, and, as such, have a relative value only, being liable to vary with time, place and race. In this country, normal standards may be presumed to be the product of a food supply which is sufficient in quantity, though doubtless capable of improvement in quality, and they are, therefore, subnormal from a physiological point of view. Insufficient food results in under-nourishment, the wrong kind of food in malnutrition; of these two varieties of subnormal nutrition, the latter is by far the more frequently met with, though its effect on physical development may be slighter and may require a longer time to become evident.

Measurement of nutrition

Numerous attempts have been made to discover indices which will express, by themselves, the nutritional state of a child at any given moment. One of the best known of these is Livi's formula $\frac{100\sqrt[3]{(\text{wt. (kg.)})}}{\text{ht. (cm.)}}$ which is, apparently, based on the assumption that weight, being a three-dimensional quality, must be reduced to a condition in which it is comparable with unidimensional height. The index obtained by the use of this formula varies from about 2·7 at age 3 to 2·3 at age 14; it is, thus, certainly not a measure of physical development, since the older the child the lower is its index, whereas physique develops with age. However, the formula was applied to the English averages, and the resulting indices are set out in Table II. In order to render indices for different

Table II. *Nutritional indices of English schoolchildren*, 1909–10

Age last birthday	Boys: Crude index	Boys: Standardized index	Girls: Crude index	Girls: Standardized index
3	2·661	2·129	2·658	2·127
4	2·581	2·151	2·559	2·133
5	2·522	2·162	2·510	2·151
6	2·485	2·174	2·461	2·154
7	2·413	2·145	2·403	2·136
8	2·379	2·141	2·389	2·151
9	2·349	2·135	2·356	2·142
10	2·330	2·136	2·303	2·111
11	2·314	2·136	2·317	2·139
12	2·295	2·132	2·324	2·158
13	2·299	2·145	2·292	2·139
14	2·288	2·145	2·292	2·148

ages comparable with each other, and for ease in grasping the significance of any particular index, a formula was sought which would yield a more or less constant index for normal children of all ages. After experiment, a standardizing factor, $\frac{\text{age}+1}{\text{age}+2}$, was found to give the most uniform results, the age in this factor being that at the beginning of the period for which the index has been calculated, e.g. for the age period 3–4 the factor is $\frac{4}{5}$. The factor expresses, very nearly, the physiological ages of the child (dating from the commencement of growth *in utero*) at the beginning and end of each age period, and may, therefore, possibly be applicable over a more extensive range of years than those of school life. The difference between the highest and the lowest crude index, namely, 0·373, was by this means reduced to 0·063, or not quite 3% of the smallest corrected index, the average index for all ages and both sexes being 2·142.

Practically, this index proved unsatisfactory. Apart from the inconvenience of using logarithms, the indices obtained can only be described as misleading. Indices for the urban areas and the north of England were superior to those for the county areas and the south, notwithstanding that the averages of both height and weight for the two latter groups were generally the better. The formula allows too much adverse influence to height; stature is at a discount and a short thickset type of child is at a premium; in fact, the child whose shape approximates most closely to that of an oblate spheroid obtains the highest index.

Another formula which is sometimes used is the weight for height index, or ratio of the child's weight to the normal weight corresponding to its height. This appears, at first sight, to be an ideal measure of nutrition at any given moment; it allots to skeletons of various heights their appropriate allowance of flesh, and measures nutrition by the extent of the deviations from such allowance. But it takes no account of age with its accompanying changes in physique, and most people would probably regard two boys aged 7 and 11, each of whom had the normal height and weight of a boy aged 9, as being, respectively, over- and under-nourished for their age.

MEASUREMENT OF PHYSIQUE

The degree of physical development of a child is more easily ascertainable than its nutritional state, notwithstanding that the normal standard of physique is not fixed, but varies from age to age. It is, therefore, necessary, in the first place, to choose a formula that will express adequately, and in the simplest possible terms, the varying stages of normal development at different ages, as well as deviations from these normal standards at each age.

The most conspicuous features in the build of a child are its height, chest girth and mass. Measurements of the chest circumference afford more opportunities for error than do those of height and weight and, whilst they add to the complexity of a formula, it has been found that they do not add, proportionately, to its value. The choice of material for a formula is thus reduced to the two factors of height and weight, expressed as the ratio weight/height. This ratio not only has the merit of extreme simplicity, but it does, in fact, represent, fairly graphically, what it is intended to represent. Ratios expanding gradually between the ages of 4 and 14, from 1·6 to 2·6 metrically or from 0·9 to 1·5 by English measures, give a very fair numerical indication of the changes in the proportions of children during these years. The degree of physical development of any child can now be measured by comparing its ratio with the normal ratio for its own age, though it is not possible to compare the physique of two children of different ages until the formula has been standardized, to give uniform figures in respect of the normal ratios for all ages. Advantage was, therefore, taken of a property possessed by these ratios, when arranged in series for successive years, to obtain a factor capable of reducing every normal ratio to a common value.

In any two series,

$$(1+r),\ (1+r)^2,\ (1+r)^3,\ \ldots, \quad \text{and} \quad \frac{1+a}{1-a}, \frac{1+2a}{1-2a}, \frac{1+3a}{1-3a}, \ldots,$$

the first terms are equal to one another only when $r=\dfrac{2a}{1-a}$, and the smaller the values of r and a, the more closely do later terms of the two series, also, correspond with each other, though the disparity between them increases with each successive term. For instance, if $r=\frac{1}{10}$, $a=\frac{1}{21}$ and the first five terms of the two series are

$$\begin{cases} 1\cdot1,\ 1\cdot2100,\ 1\cdot3310,\ 1\cdot4641,\ 1\cdot6105. \\ 1\cdot1,\ 1\cdot2105,\ 1\cdot3333,\ 1\cdot4706,\ 1\cdot6250. \end{cases}$$

Now, at about 8 years of age, near the middle period of school life, the proportional yearly increase in weight, r, is about 0·095 or $\frac{1}{10\frac{1}{2}}$, and the proportional yearly increase in height is, at this age, roughly the corresponding value of a, or $\frac{1}{22}$. It is thus possible to calculate approximate weight/height ratios for successive years by means of the following equations:

$$\frac{W(1+r)}{H(1+a)}=\frac{W}{H(1-a)},\quad \frac{W(1+r)^2}{H(1+2a)}=\frac{W}{H(1-2a)},\quad \frac{W(1+r)^3}{H(1+3a)}=\frac{W}{H(1-3a)},\ \text{etc.},$$

where W and H are the normal weight and height at $7\frac{1}{2}$ years of age. These equations show that consecutive terms of a geometrical series of weights, divided by the corresponding terms of an arithmetical progression of heights, form a series of weight/height ratios which are, very nearly, in harmonical progression. Actually, none of these series is strictly adhered to by the average figures, though the ratios do give good harmonic curves, at any rate so far as the boys are concerned. Weight/height ratios, calculated in this way for successive years above and below the mid-school age, may be accepted as, approximately, the normal ratios, and they form a series of which the terms representing ages 4, 9 and 14 are, respectively, $\frac{1}{6\cdot3}$, $\frac{1}{5\cdot1}$ and $\frac{1}{3\cdot9}$. These terms can also be written as $\frac{50}{363-48}$, $\frac{50}{363-108}$ and $\frac{50}{363-168}$, that is, as fractions containing only one variable quantity corresponding to the age of the child in months. It is obvious that a normal weight/height ratio thus formed, when divided by its appropriate fraction, is equal to unity, and, should the ratio be that of an abnormal child, this fact will be demonstrated in the divergence of the quotient from unity.

A formula, $\frac{\text{weight (kg.)}}{\text{height (cm.)}}\times\frac{363-\text{age in months}}{50}$, is now obtained, the age factor in which reduces the weight/height ratios of children of all ages and both sexes to a common standard. The construction of such an age factor is rendered possible, only, by the peculiar relations of the proportional yearly increases in weight and height at the middle school age. For the same reason, also, these factors are only valid for, perhaps, half a dozen years above and below that age; their applicability is, therefore, restricted to children of school age.

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More accurate standardizing factors were subsequently calculated for each sex. These were:

For boys: $\frac{\text{weight (kg.)}}{\text{height (cm.)}} \times \frac{381 - \text{months}}{54}$, or $\frac{\text{weight (lb.)}}{\text{height (in.)}} \times \frac{379 - \text{months}}{300}$.

For girls: $\frac{\text{weight (kg.)}}{\text{height (cm.)}} \times \frac{354 - \text{months}}{48}$, or $\frac{\text{weight (lb.)}}{\text{height (in.)}} \times \frac{355 - \text{months}}{270}$.

Normal weight/height ratios, that is ratios which, after the application of the age factors, become equal to unity, are contrasted in Table III with the average ratios of English children for each age and sex. The indices obtained, after correction of these average ratios by means of the age factors, are also shown in the table; they were calculated with the metric factors, but the English factors gave practically the same figures, differences never exceeding 0·001, except in three cases in which they were 0·002. The average of these indices was 1·0007, being 1·00025 for boys and 1·0011 for girls. In six cases the average index deviated from the normal by 1% or more, and most of the differences could be attributed to defects in the data used. In the case of girls in their thirteenth year, however, the deviation of nearly 3% must be ascribed largely to their intensified development at puberty, though it is also partly due to the large proportion of these girls who were selected for examination in the latter half of this age; it is, apparently, the only school age at which a reliable index cannot be obtained without some small adjustment, such as the deduction of 0·01 or 0·02 from the calculated index.

Table III. *Developmental indices of English schoolchildren*, 1909–10

	Boys				Girls			
	Crude index				Crude index			
	Metric measures		English measures	Standardized average index	Metric measures		English measures	Standardized average index
Age	Normal	Average	Average		Normal	Average	Average	
3½	0·1593	0·1608	0·900	1·009	0·1538	0·1576	0·883	1·025
4½	0·1651	0·1659	0·929	1·005	0·1600	0·1613	0·903	1·008
5½	0·1714	0·1703	0·954	0·993	0·1666	0·1664	0·932	0·998
6½	0·1782	0·1790	1·002	1·004	0·1739	0·1727	0·967	0·993
7½	0·1856	0·1848	1·035	0·996	0·1818	0·1800	1·008	0·990
8½	0·1935	0·1916	1·073	0·990	0·1905	0·1887	1·057	0·991
9½	0·2022	0·2014	1·128	0·996	0·2000	0·2001	1·120	1·000
10½	0·2118	0·2119	1·186	1·001	0·2105	0·2058	1·152	0·977
11½	0·2222	0·2230	1·249	1·004	0·2222	0·2216	1·241	0·997
12½	0·2338	0·2364	1·324	1·011	0·2353	0·2416	1·353	1·027
13½	0·2466	0·2467	1·381	1·000	0·2500	0·2513	1·407	1·005
14½	0·2609	0·2594	1·452	0·994	0·2666	0·2672	1·496	1·002

A test of the general accuracy of the standardization is the fact that the metric factors at age $11\frac{1}{2}$, and the English factors at age $11\frac{7}{12}$, give exactly the same normal index for boys as for girls, that is, at ages at which both sexes have been shown to have reached the same stage of physical development. Many other age factors give nearly as good results, and one advantage of this method of standardization is the ease with which the formulae can be adjusted

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to meet changes in the normal physique, due to altered standards of height or weight.

Every unit of 0·001 by which an index diverges from 1·000 indicates a deviation from the normal of one thousandth part either of the normal weight for the child's age or of the child's own weight, and represents, between the ages of 4 and 14, values varying from 0·016 to 0·04 kg. or from 0·1 to 0·15 cm.

The utility of indices

The work already described was undertaken with a view to obtaining, firstly, standard measurements of the children for reference and comparison and, secondly, standards of physical development and, if possible, of nutrition also, so that estimates might be made which had a definite basis in physical fact; for it does not require a very long experience of School Medical Inspection to become convinced of the fallibility of human judgment in the assessment of the nutritional state of the children examined. Medical Officers so frequently differ, sometimes widely, in their opinion of individual children that it is impossible to judge of the true value of the mass of statistics, based almost entirely on personal opinion, which are published year by year on this subject, or to draw any useful deductions therefrom.

This conviction has lately received striking confirmation in a paper read before the Royal Statistical Society on 16 November 1937, by Mr R. Huws Jones of Liverpool University, on the comparative merits of physical indices and clinical assessments of nutrition. As the result of a scientifically planned investigation in the schools of Liverpool, Manchester and neighbouring districts, he found that different doctors varied widely in their assessments of the same children, that the same doctors varied widely in their reassessments of the same children after a week's interval, and that the results obtained by the use of a formula, selected from 26 different formulae as being the most reliable for the purpose, were found, in the collective opinion of two or more doctors, to be somewhat more accurate than the assessments of the average medical officer. The formula selected was one of those described above; it was employed as a direct measure of nutrition and, as such, achieved results far beyond those originally anticipated from its use.

The formulae were designed to give, for every child of whatever age, an index showing the ratio of its stage of physical development to the normal stage for the child's age, expressed as unity. If the index be taken at intervals, nutritional changes, even when small, can be detected and measured by the difference between the indices at the beginning and end of a period; such differences may be regarded as indices of the process of nutrition. When the formulae were published, it was suggested that the developmental condition must be regarded as bad when the index is below 0·9, poor between 0·9 and 0·95, fair between 0·95 and 1·05 and good above the latter figure. Since then, however, the average physique of elementary schoolchildren has improved, and this classification now understates the limits of each category by a proportion possibly as high as 0·01. It has to be remembered that the formulae are based on the average measurements of nearly 30 years ago.

For comparing groups of children, closer limits of categories are required. The average index of all the children attending six small schools, containing about forty scholars each, was found to vary between 0·992 at a school where the children were of the agricultural labouring class, and lived largely on potatoes and tea, and 1·035 at another school attended by the children of smallholders, who were exceptionally well cared for and had ample supplies of milk.

But the main use of the formulae is in the case of individual children. A series of indices in cases of malnutrition or tuberculosis affords more reliable evidence of progress, or the reverse, than do the usual records of repeated weighings, in which it is difficult or impossible to differentiate between an increase in weight due to improved nutrition and one due to normal growth. The following cases illustrate two of the uses of the formulae: the index of a boy, suffering from pulmonary tuberculosis, improved from 0·860 to 0·942 after two years' treatment: a girl, whose parents had been imprisoned for neglect, later attended school in a cleaner condition and better clothed, and gave the impression of being, also, better nourished; but appearances were deceptive, her index having fallen during four years from 0·929 to 0·903.

If the index of every child entering school life be taken, and all those with indices below 0·96, i.e. 4% or more below normal, be dealt with as cases of malnutrition, a very short period should suffice to distinguish those whose physique is due simply to hereditary causes, e.g. the thin wiry type, whose index probably remains unaltered, from those whose defect is due to environment, in whom the index improves under treatment. Any falling away in the normal rate of development, as shown by indices taken at later dates, indicates some failure of the nutritional process. A loss of 1, and certainly of 2% in any child's index should be enquired into.

The index could also be used as a sieve, as in the Liverpool investigation, to sort out all children whose physical development falls below a certain standard; the cases of malnutrition thus selected would, of course, include the above exceptions, and would not include the types referred to below.

The formulae, being founded on the weight/height ratio, have the defects of that ratio. Physique, as defined both by the dictionary and the ratio, has no relation to size, but only to proportion, i.e. roughly to shape. Three boys aged 9, one of whom has the normal measurements of his age, the second has the weight of age 7 and the height of age 4, and the third has the weight of age 11 and the height of age 14, are all regarded as of normal development for their age, because their weight/height ratios are equal; they all have the build of a boy aged 9, though, of the two who are obviously extreme examples, one might be considered under-developed and over-nourished and the other over-developed and under-nourished. Similarly, children whose growth has been stunted in early life by disease, deformity or accident, may later have an unduly high index, owing to their relatively short stature. Height has an adverse effect on the indices, though to nothing like the same extent as with Livi's formula. Again, the index can only indicate the structure of the body in the most general terms; it cannot, for instance, differentiate between muscular and fatty development. Obese children will, naturally, have a high index, but it does not require a particularly well-organized medical service to recognize these, and the other abnormal cases referred to above, without the aid of an index. There is, in any case, a limit beyond which a high index is undesirable. The optimum index is probably in the neighbourhood of 1·200 or 1·250, and

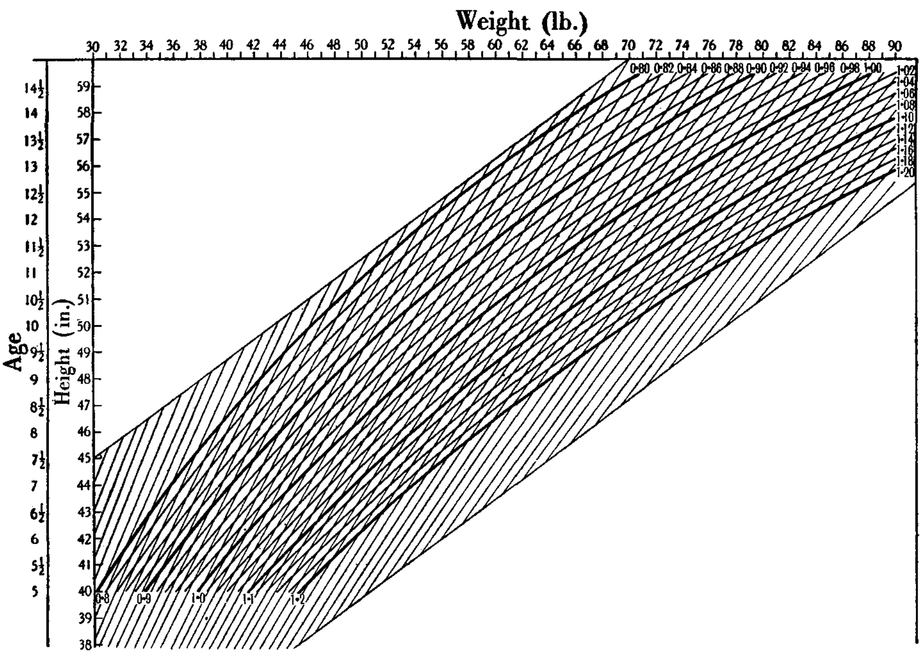

Chart for estimating the physique and nutrition of boys.

children with indices of 1·300 and above, including most abnormally fat children, should be examined to determine whether their development is physiological or pathological.

An objection frequently raised to the use of formulae is the amount of calculation required, for which either time or inclination is lacking. Though the calculations demanded by these formulae are not very arduous, they can be obviated altogether by the use of charts, one of which is shown here on a reduced scale.

On this chart, a scale of index curves is superimposed on another scale of diagonal lines representing weight/height ratios which, in turn, rests on simple scales of weights and heights, the latter functioning also as a scale of ages. The technique is quite simple. The junction of the vertical and horizontal lines,

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representing the child's weight and height, shows the position of its weight/height ratio in the scale of diagonal lines; on taking the same position in this scale on the horizontal line representing the child's age, this weight/height ratio becomes standardized for age in the scale of index curves, and the index of development can then be read on that scale. On a chart of convenient dimensions, the true index may be ascertained to within the nearest $\frac{1}{2}\%$ of the normal index, and, with larger charts, there is no limit to the degree of accuracy attainable. In the case of children under observation, indices may be taken periodically and recorded on the chart, as on a temperature chart; small nutritional changes can then be detected and measured by the difference between consecutive indices. For example:

Boy's age years	Weight lb.	Height in.	Index of development
9	58	49	1·070
$9\frac{1}{2}$	60	50	1·060

In this case, the gain in weight is insufficient to maintain the good development of the boy at the beginning of the period, and the measure of his nutritional processes during 6 months is $-0{\cdot}01$, as shown by a loss of physique corresponding to 1% of the normal index. This standardized normal index (1·00) is represented by the central index curve, which also indicates the normal heights and weights (that is, approximately the average English heights and weights) for all school ages.

The chart demonstrates two facts of some interest. Firstly, if the position of the junction of the lines representing weight and height be noted, not on the scale of weight/height ratios, but on that of index curves, the weight for height index of the child is obtained, showing the proportion borne by its weight to the normal weight corresponding to its height. It will be realized how divergent, and in some cases how diametrically opposed, may be the two indices taken for the same child, according as its height and age or its height alone is accepted as the factor determining its normal weight. Secondly, given reliable average heights and weights, the curves formed by their ratios would probably be of such regularity that similar charts could be constructed without the aid of any formula. In that case, it would, apparently, be within the power of any community, that took the trouble to ascertain the normal measurements of its children, to control, almost minutely and by the simplest possible means (with the few exceptions already referred to), their processes of nutrition, as defined by the best authorities.

This does not imply that their exact nutritional state, at any given time, is capable of assessment. Nutrition is not a static condition, and the intensity of the process is probably never constant in any child. When attempts are made to assess the "state of nutrition" of a group of children, what really takes place is an assessment of the effects produced during a period of time which cannot be stated definitely. These effects are seen, in the vast majority of children, in their physique. They may, or may not, be seen in their general health, which furnishes most of the criteria for clinical assessment; other factors affecting health, such as the functional condition of all the organic structures of the body or the presence of infections, may entirely neutralize the effects of the nutritional process. Advocates of the latter method sometimes adduce, as proof of its reliability, the constancy of the figures they obtain over a period of years. Equally constant figures could, no doubt, be derived from their developmental indices, but a more definite indication of the effects of the ameliorative measures employed, during a given period, would be the average nutritional index per child for that period. Such average indices could be ascertained from the difference between the sums of the positive and negative indices, taken for periods of one year, and the progress of the children could then be ascertained by comparing the indices for successive years.

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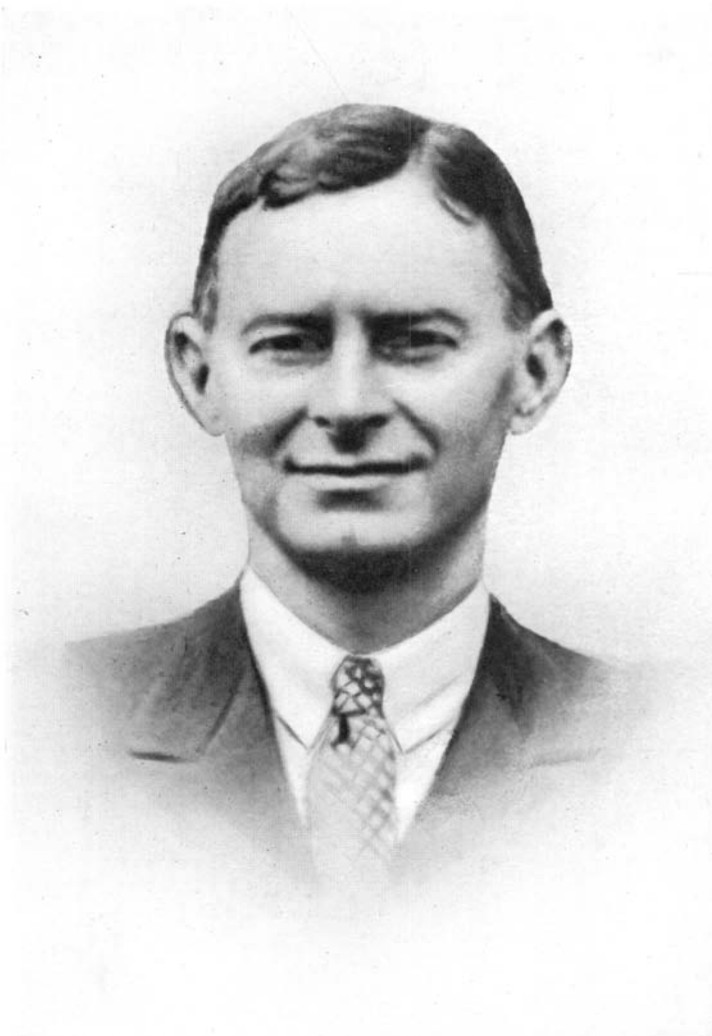

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