TYPES OF BODY BUILD AND THEIR RELATION TO SPECIAL APTITUDES AND CAPACITIES.

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(With 2 Charts.)

In recognition of the need for understanding, and for making proper allowances for differences in body growth and physical development during school life, it has been the custom at the Manchester Grammar School to take annual measurements of standing and sitting height, girth of chest, of upper and lower arm, and also range of vital capacity of all the boys amounting to about 1000 in number, and to compare their physical growth with their school attainments. The measurements are graded for each boy as regards height, weight, chest girth and vital capacity, in order to discover the rate and range of growth in each category, and see how far the growth in one category is commensurate with the growth in another. The grading in each category is expressed in time-increments of six months' growth above or below the normal boy of his age, so that, *e.g.* a boy who is a year ahead or a year behind the average boy of his age in height is graded $+2$ or -2 in height, and so forth. Similar and separate gradings are used for weight, chest girth and vital capacity. At the time of annual measurement, enquiry is also made into the physical activities in which each boy participates, *e.g.* the games he plays, his performance in the swimming bath, in the gymnasium, etc.

Although growth in height, weight and chest girth and range of vital capacity constitute important factors in general development, no one who is familiar with the daily life of school children will claim that the rate and range of progress in one direction is necessarily identical with the rate and range of progress in others. Radiographical examination of the limb bones of a number of Manchester Grammar School boys showed that, even when growth in height, weight and chest girth was in all three directions as much as $3\frac{1}{2}$ years ahead of that of the average boy at the school, the degree of ossification and union of the ends of the limb bones showed little, if any, such advance, but closely approximated to the condition natural to the real or calendar age of the boy. The same was found to be true of a number of boys who were $3\frac{1}{2}$ years behind in their growth age (Paterson, March 1929). A memorandum by the late Prof. J. G. Adami (1923) draws attention to the profound influence of the blood changes which take place during adolescence upon development. Both the degree of ossification and the changes which take place in the blood afford a better indication of maturity than actual growth in size.

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The relation which precocity of growth in height and weight during adolescence bears to maturity of physical aptitudes is, however, still very obscure. It is not entirely a matter of muscular development, certainly not of actual size. Physical aptitude requires proper development of the circulatory, respiratory and nervous systems, which do not necessarily occur *pari passu* with the growth of the physical frame, nor does the growth of any single one of such organic systems necessarily occur *pari passu* with that of another. It is the wide diversity in the rate and range of development of the different parts and systems of the human body that is the main cause of the wide diversity in attainment which exists among different individuals.

Some extensive and helpful enquiries into the best means of making proper allowance for such divergence in the rate and range of body growth of school children of similar age were made by Dr Carl Schiötz in 1922–6, among 2664 boys and girls between the ages of 10 and 20, in several public high schools in Christiana (Schiötz, C. and Skau, J., 1926; Schiötz, C., 1928, 1929). The exercises chosen by him for observation were high jump, broad jump, 60 metres sprinting, throwing the cricket ball, throwing the football, and "muscling up" a horizontal bar. Beginning with the records of the high jump, Schiötz constructed tables and graphs to express the average height jumped, together with standard deviation, etc., for each year of age. He found the most regular curves of increment were those for the years between 13 and 16. Schiötz (1928, pp. 7–9, *loc. cit.*) is careful not to introduce arbitrary features into his measurements, but bases them upon statistical constants. He calls the mean performance at age = 50 and, calculating σ, the standard deviation of performance at age, he designates by 0 the performance which is = mean $- 3\sigma$, and by 100, therefore, the performance which is = mean $+ 3\sigma$. He was thus able to assign to each boy marks in terms of his performances.

He then took all the boys of each year of age, and divided them into four groups, whose limits were the means and the standard deviations. He placed the boys, whose height was less than that of the average boy of his year by more than the standard deviation in the group of *small* boys. They constituted approximately 16 per cent. of the total. Those boys whose height was below the average by less than the standard deviation were placed in the *minus-average* group and constituted 34 per cent. of the total. In the third group were placed the boys whose heights were above the average, but only so by less than the standard deviation. They also constituted about 34 per cent. of the total number and were called the *plus-average* group. Finally, the boys whose heights were above the average by more than the standard deviation were put in the fourth or *tall group*. They constituted about 16 per cent. of the total.

Schiötz then took the athletic assessments of the boys in each of these size groups for each age (1928, pp. 10–11). He showed that the taller boys gained a larger percentage of marks than the plus-average boys; the plus-average boys a larger percentage than the minus-average boys, and the minus-average boys a larger proportion than the short boys. He found that this applied to each of the five athletic events: 60 metres run, high jump, broad jump, throwing the cricket ball and throwing the football.

Schiötz finally collected the results of the five kinds of performance, already collected for the different age groups, and found as a composite result that the four height groups within an age group produced mean performances 44·4, 48·3, 52·2, 55·0, on the above scale. Treating weight in the same way as height he obtained the figures 42·8, 48·3, 52·2, 55·0. Thus a continued benefit appeared to come from increased precocity in either height or weight, but Schiötz showed that the very exceptionally tall or heavy are actually at a disadvantage. The numbers are, however, very scanty. The benefit attributable to precocity in height appears to be nearly equal to the benefit attributable to precocity in weight, although the figures are not analysed to yield their proper statistical implications. Height and weight must be close statistical correlatives, but Schiötz avoids the statistical analysis, and on grounds that are not made clear presents as a practical result of his considerations the formula:

$$\text{Competitive or physiological age} = (2 \text{ calendar age} + \text{height age} + \text{weight age}) \div 4.$$

Thus, suppose a boy aged 14 has the average weight of a boy of 15 and the average height of a boy of 16, Schiötz would assess him as having a physiological age of $(14 \times 2 + 15 + 16)/4 = 14{\cdot}75$ years, and would assess his performance in any particular test in terms of the standard for a boy of 14·75 years.

This formula was tried among the competitors at the Norwegian sports in 1923 and 1924, and at the Copenhagen sports in 1924, and was considered by Schiötz to give satisfactory results.

Since, however, Schiötz (1928, p. 38) himself has pointed out that the relation of, for instance, weight to performance is different in athletic tests and gymnastic tests ("muscling up"), and the present results point to some differentiation, it is improbable that a uniform system of weighting would be generally satisfactory.

The relation between body build and physical activity has long been a matter of enquiry at the Manchester Grammar School. The investigations were primarily directed towards obtaining reliable data by means of which the medical officer, as well as the physical instructor, could judge the "physical fitness" or proper physical development of the average boy. The observations included studies in the degree of development of the respiratory organs by measurements of the chest girth and the vital capacity—measurements which were graded for comparison with development in body growth in other directions.

The information derived from such measurements helped the medical officer and the physical instructor when giving advice to particular boys who seemed to be below their proper standard. Experience with boys had early shown that all-round "physical fitness" was a very elusive term, since excellence in one form of physical activity was often associated with poor achievement in another. Studies were therefore made into the body build associated with different forms of physical prowess, runners, swimmers, gymnasts, etc., those who excelled in one direction being compared with those who excelled in another. It was discovered that all showed physical development in advance of their age in chest girth and in weight, though not always in height, and that there were different types of physical build as well as types of physical aptitude (Mumford, 1927).

However satisfactory may be the provision of opportunity for games in large public day schools, yet there are always many "square pegs in round holes," *i.e.* many boys who, often after considerable pressure, present themselves at various games and sports but make such a poor show that they soon abandon the effort. Much disappointment at failure would be avoided if it were possible to discover objective signs and causes of failure, and, still more, if signs of unrecognised aptitudes could be revealed and the boy encouraged to take up something within the range of his natural powers.

Clinical observation and frequent talks with boys and with the physical instructor soon suggested that such objective factors of aptitude might exist in the proportionate development of length and musculature of limbs, or in the proportionate development of different parts of the respiratory mechanism. If such objective signs could not only be detected but also measured, then the school medical officer and the physical instructor or games masters could avoid pressing a boy in those forms of physical activity for which he was physically ill-fitted, and would be able to encourage him in those forms of physical activity for which he was better equipped. Following the lines of his natural equipment the boy would be more likely to find his complete development.

In the pursuit of this enquiry concerning suitability of body build for special physical activity, certain measurements were taken in addition to those already in use. These were: arm-reach or span, girths of waist, of shoulder, of upper and of lower arm. These measurements were not those which have been generally recommended for systematic anthropometric work, but were measurements chosen for this special enquiry, partly because they varied with special groups of action rather than with movements of particular muscles, and partly because they were easily and quickly taken so that a large number of boys could be passed under review in a short space of time. Half the span was taken as representative of the ordinary full reach of the outstretched arm, while a "functional" or virtual leg-length was obtained by subtracting the sitting height from the standing height. Limb-lengths were thus easily obtained, which could be expressed conveniently as percentages of trunk-lengths. Such percentage proportions, though not independent of age up to about 13, were found to become practically so after that age. Chest girth and waist girth were also expressed as percentages of stem-length in order to provide evidence of variation during adolescence of the respiratory and assimilatory qualities from an ascertained mean. Finally, the girths of the shoulder, upper- and fore-arm were also expressed as percentages of trunk-length, in order to provide evidence of variation in the muscular development of the upper limb. There were thus seven *functional* indices of body proportions: two of proportional length of limb, one of proportional girth of the respiratory cavities, one of the proportional girth of the area occupied by the important organs of nutrition, three of the proportional girth of the muscles of the upper limb.

Although such measurements were taken, and the proportions calculated for *all* the thousand boys attending the school, the measurements for boys under 14 were not used, not only because their limb proportions had not yet become stabilised, but also because their special form of physical activity had not become pronounced. The boys over 17 were also left out of account. The latter represented only a branch of the main stream of boyhood. They consisted principally of those preparing for subsequent higher intellectual work at the universities and technological institutes, and it was thought at first that they might not be strictly comparable with the boys of the whole school. When, in the second part of this enquiry, actual winners as well as participants came to be considered, these older boys, who formed the large proportion of the sports winners and colour holders in the school, were, however, included, further enquiry having shown that their proportions did not, as a matter of fact, depart materially from those of the rest of the school. The first part of the enquiry was, therefore, confined to 524 boys over 14 and under 17 years of age. The second part included a further 84 boys over 17.

In order to grade the variation of these body proportions or functional indices in a way somewhat comparable to the grading of the variation of absolute measurements, which we have already described as being in general use at the school, the array of indices under each heading, that is, body proportion, was divided into three numerically equal parts or tertiles. Each boy was marked A, B or C in the body proportion. According to the proportional length of his arm-span compared with his trunk-length, he was considered as relatively long-armed, medium-armed or short-armed; and marked A^1, B^1 or C^1. According to his proportional length of leg, he was marked A^2, B^2 or C^2. The proportional development of chest, shoulder, waist, upper- and lower-arm girth marked him as A^3, B^3, C^3; A^4, B^4, C^4; A^5, B^5, C^5; A^6, B^6, C^6; and A^7, B^7, C^7.[1]

[1] The plan here adopted, which amounts to characterising a distribution of values (body proportions) by the two tertile values, that is, the values which divide the whole into three numerically equal parts, the A's, the B's and the C's, and of characterising a particular or selected group as possessing such and such per cent. excess or defect from the expected equal numbers of A, of B and of C, has much to recommend it in simplifying the presentment. If it is desired, however, to pass from *numbers* to *values*, the mean for the whole group may be taken to be half the sum of the two tertile values and the standard deviation as 1·16 times the tertile difference.

If, in some selected group, the A's are a per cent. in excess of the expected number of A's and the C's are γ per cent. in excess of the expected number of C's, then the mean has been increased by 0·53 $(a-\gamma)$ per cent. of the tertile difference and the standard deviation has been increased by 1·24 $(a+\gamma)$ per cent. of the tertile difference.

These derived values of statistical constants assume the distribution to be normal and suffer of course from considerable casual errors.

Table I.

Types of body build in relation to special forms of physical activity found among participants in sports and games out of the 524 *boys who were between* 14–17.

Proportions*	21 High jumpers			20 Broad jumpers			206 Footballers		
	A	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*
rm A^1 = Over 101 % C^1 = Below 98 %	8 +14·3 %	6 −14·3 %	7 —	7 +5·8 %	5 −25 %	8 +20·0 %	59 −14·1 %	71 +3·4 %	76 +10·7 %
eg A^2 = Over 98 % C^2 = Below 93 %	6 −14·3 %	7 —	8 +14·3 %	6 −10 %	4 −40 %	10 +50 %	62 −9·7 %	63 −8·3 %	81 +18 %
hest A^3 = Over 95 % C^3 = Below 90 %	8 +14·3 %	9 +28·6 %	4 −42·9 %	3 −55 %	10 +50 %	7 +5 %	69 −2·4 %	79 +15·0 %	60 −12·6 %
Vaist A^4 = Over 84 % C^4 = Below 79 %	5 −28·6 %	9 +28·6 %	7 —	4 −40 %	6 −10 %	10 +50 %	66 −3·9 %	70 +1·9 %	70 +1·9 %
houlder A^5 = Over 73 % C^5 = Below 69 %	6 −14·3 %	9 +28·6 %	6 −14·3 %	10 + 50 %	5 −25 %	5 −25 %	69 +0·5 %	77 +12·1 %	60 −12·6 %
Jpper-arm girth A^6 = Over 30 % C^6 = Below 28 %	10 +42·9 %	8 + 14·3 %	3 −57·1 %	12 +80 %	4 −40 %	4 −40 %	75 +9·2 %	66 −3·9 %	65 −5·3 %
Fore-arm girth A^7 = Over 28 % C^7 = Below 27 %	12 +71·4 %	6 −14·3 %	3 −57·1 %	11 +65 %	3 −55 %	6 −10 %	61 −11·1 %	77 +12·1 %	68 −1·0 %
Standard error		±30·9 %			±31·6 %			±9·9 %	

Proportions*	139 Cricketers			88 Gymnasts			61 Lacrosse players		
	A	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*
Arm A^1 = Over 101 % C^1 = Below 98 %	52 +12·2 %	39 −15·8 %	48 +3·6 %	22 −25·0 %	29 −1·1 %	37 +26·1 %	20 −1·6 %	18 −11·5 %	23 +13·1 %
Leg A^2 = Over 98 % C^2 = Below 93 %	46 −0·7 %	38 −18 %	55 +18·5 %	17 −42·0 %	28 −4·5 %	43 +46·6 %	19 −6·6 %	19 −6·6 %	23 +13·1 %
Chest A^3 = Over 95 % C^3 = Below 90 %	54 +16·5 %	47 +1·4 %	38 −18·0 %	25 −14·8 %	32 +9·1 %	31 +5·7 %	23 +13·1 %	20 −1·6 %	18 −11·8 %
Waist A^4 = Over 84 % C^4 = Below 79 %	53 +14·4 %	37 −20·2 %	49 +5·7 %	24 −18·2 %	35 +19·3 %	29 −1·1 %	25 +22·9 %	19 −6·6 %	17 −16·4 %
Shoulder A^5 = Over 73 % C^5 = Below 69 %	51 +10·1 %	44 −5·0 %	44 −5·0 %	26 −11·4 %	31 +5·7 %	31 +5·7 %	26 +27·9 %	19 −6·6 %	16 −21·3 %
Upper-arm girth A^6 = Over 30 % C^6 = Below 28 %	51 +10·1 %	54 +16·5 %	34 −26·6 %	29 −1·1 %	31 +5·7 %	28 −4·5 %	29 +42·6 %	18 −11·5 %	14 −31·1 %
Fore-arm girth A^7 = Over 28 % C^7 = Below 27 %	46 −0·7 %	55 +18·7 %	38 −18·0 %	31 +5·7 %	34 +15·9 %	23 −21·6 %	35 +72·1 %	14 −31·1 %	12 −41·0 %
Standard error		±12·0 %			±15·1 %			±18·1 %	

* Whole numbers of percentage body proportions only given.

Table II.

Types of body build in relation to special forms of physical activity found among participants out of the 524 *boys between* 14 *and* 17 *and in the winners out of* 605 *boys all over* 14.

Proportions	Long distance runners	A	B	C	Sprinters	A	B	C
Arm	Participants	43	35	35	Participants*	11	9	6
A^1 = Over 101 %	(113)	+14·2 %	−7·1 %	−7·1 %	(26)	+26·9 %	+3·8 %	−30·8 %
C^1 = Below 98 %	Winners	14	13	18	Winners†	19	21	10
	(45)	−6·5 %	−13·5 %	+20 %	(50)	+14 %	+26 %	−40 %
Leg	Participants	37	34	42	Participants	9	7	10
A^2 = Over 98 %	(113)	−1·8 %	−9·7 %	+11·5 %	(26)	+3·8 %	−19·2 %	+15·4 %
C^2 = Below 93 %	Winners	14	16	15	Winners	22	16	12
	(45)	−6·5 %	+6·5 %	—	(50)	+32·0 %	−4·0 %	−28 %
Chest	Participants	43	38	32	Participants	9	9	8
A^3 = Over 95 %	(113)	+14·2 %	+0·9 %	−15·0 %	(26)	+3·8 %	+3·8 %	−7·7 %
C^3 = Below 90 %	Winners	22	16	7	Winners†	23	17	10
	(45)	+46 %	+6·4 %	−53·4 %	(50)	+38 %	+2·0 %	−40 %
Waist	Participants	39	43	31	Participants	10	8	8
A^4 = Over 84 %	(113)	+3·5 %	+14·2 %	−17·7 %	(26)	+15·4 %	−7·7 %	−7·7 %
C^4 = Below 79 %	Winners	21	12	12	Winners†	19	17	14
	(45)	+40·0 %	−20·0 %	−20·0 %	(50)	+14·0 %	+2·0 %	−16·0 %
Shoulder	Participants	43	41	29	Participants	12	7	7
A^5 = Over 73 %	(113)	+14·2 %	+8·9 %	−23·0 %	(26)	+13·5 %	−19·2 %	−19·2 %
C^5 = Below 69 %	Winners	18	18	9	Winners†	24	17	9
	(45)	+20·0 %	+20·0 %	−40 %	(50)	+44·0 %	+2 %	−46 %
Upper-arm girth	Participants	44	42	27	Participants	10	11	5
A^6 = Over 30 %	(113)	+16·8 %	+11·5 %	−28·3 %	(26)	+15·4 %	+26·9 %	−42·3 %
C^6 = Below 28 %	Winners	20	18	7	Winners†	27	19	7
	(45)	+33·3 %	+20·0 %	−53·3 %	(50)	+44·0 %	+14·0 %	−58 %
Fore-arm girth	Participants	49	33	31	Participants	13	5	8
A^7 = Over 28 %	(113)	+30·1 %	−12·4 %	−17·7 %	(26)	+50 %	−42·3 %	−7·7 %
C^7 = Below 27 %	Winners	20	16	9	Winners†	21	21	8
	(45)	+33·3 %	+6·6 %	−40·0 %	(50)	+26·0 %	+26·0 %	−52·0 %
Standard error		Participants	±13·3 %			Participants	±27·7 %	
		Winners	±21·08 %			Winners	±20·0 %	

Proportions	Sprinters	A	B	C	Swimmers	A	B	C
Arm	—	—	—	—	Participants	45	64	58
A^1 = Over 101 %					(167)	−19·2 %	+15·4 %	+4·2 %
C^1 = Below 98 %	Winners‡	15	17	11	Winners	14	17	17
	(43)	+4·6 %	+18·6 %	−23·2 %	(48)	−12·5 %	+6·25 %	+6·25 %
Leg	—	—	—	—	Participants	46	54	67
A^2 = Over 98 %					(167)	−17·4 %	−3·0 %	+20·4 %
C^2 = Below 93 %	Winners‡	14	15	14	Winners	12	18	18
	(43)	−2·3 %	+4·6 %	−2·3 %	(48)	−25·0 %	+12·5 %	+12·5 %
Chest	—	—	—	—	Participants	62	52	53
A^3 = Over 95 %					(167)	+11·5 %	−6·6 %	−4·8 %
C^3 = Below 90 %	Winners‡	20	12	11	Winners	23	17	8
	(43)	+39·5 %	−16·2 %	−23·3 %	(48)	+43·8 %	+6·2 %	−50 %
Waist	—	—	—	—	Participants	64	53	50
A^4 = Over 84 %					(167)	+15·0 %	−4·8 %	−10·2 %
C^4 = Below 79 %	Winners‡	14	13	16	Winners	19	16	13
	(43)	−2·3 %	−9·3 %	+11·6 %	(48)	+18·7 %	—	−18·7 %
Shoulder	—	—	—	—	Participants	54	65	48
A^5 = Over 73 %					(167)	−3 %	+16·8 %	−13·8 %
C^5 = Below 69 %	Winners‡	18	16	9	Winners	17	16	15
	(43)	+25·5 %	+11·7 %	−37·2 %	(48)	+6·2 %	—	−6·2 %
Upper-arm girth	—	—	—	—	Participants	63	52	52
A^6 = Over 30 %					(167)	+13·2 %	−6·6 %	−6·6 %
C^6 = Below 28 %	Winners‡	23	12	8	Winners	24	17	7
	(43)	+60·3 %	−16·2 %	−44·0 %	(48)	+50·0 %	+6·2 %	−56·2 %
Fore-arm girth	—	—	—	—	Participants	60	53	54
A^7 = Over 28 %					(167)	+7·8 %	−4·8 %	−3·0 %
C^7 = Below 27 %	Winners‡	17	15	11	Winners	21	20	7
	(43)	+18·6 %	+4·5 %	−23·1 %	(48)	+31·2 %	+25·0 %	−56·0 %
Standard error		Winners 100 yds	±21·5 %			Participants	±11·0 %	
						Winners	±20·4 %	

* 220 yds and 100 yds. † 440 and 220 yds. ‡ 100 yds.

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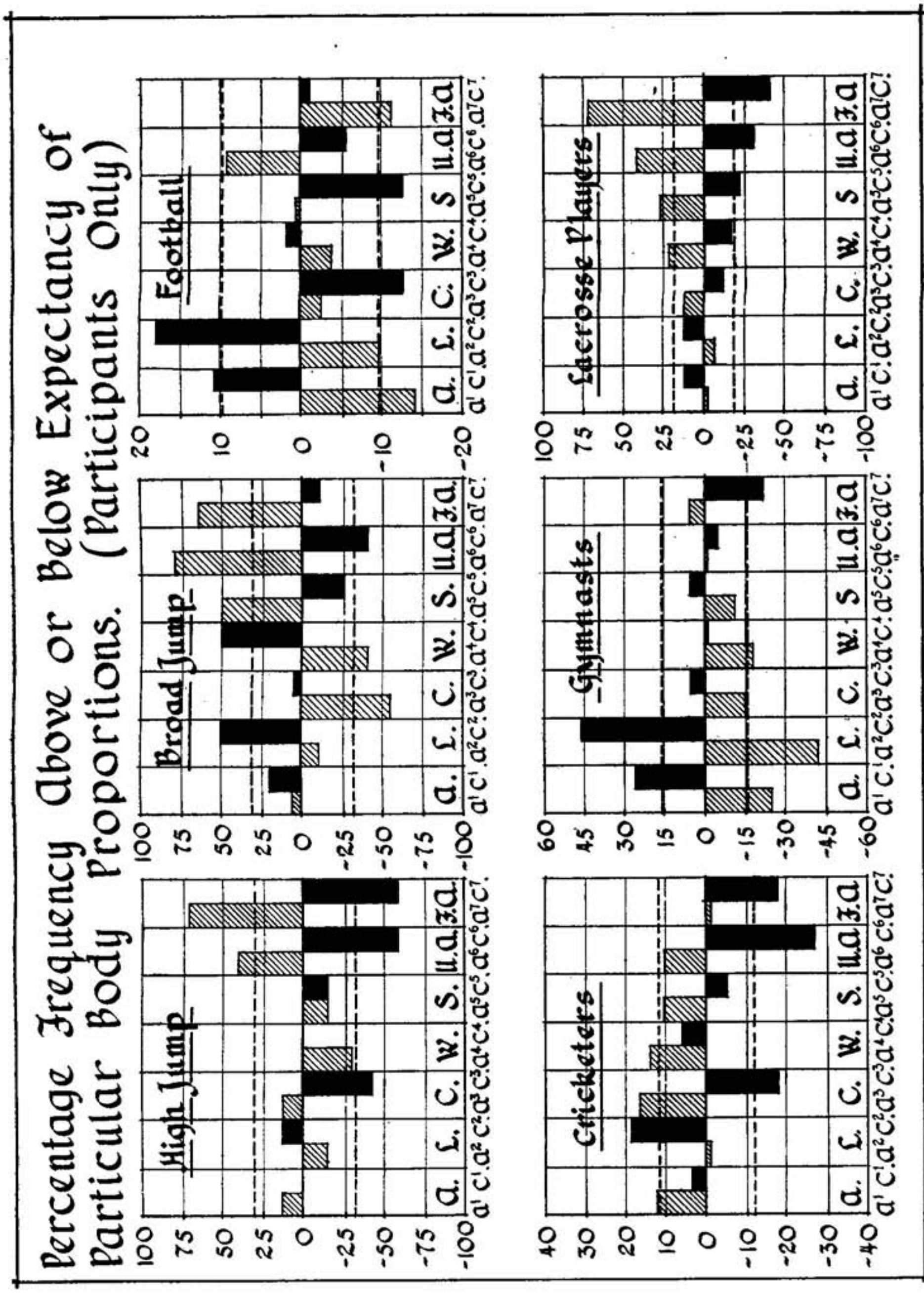
Percentage Frequency Above or Below Expectancy of Particular Body Proportions. (Participants Only)
High Jump
Broad Jump
Football
Cricketers
Gymnasts
Lacrosse Players
a. L. C. W. S. U.a. Z.a.

Chart A.

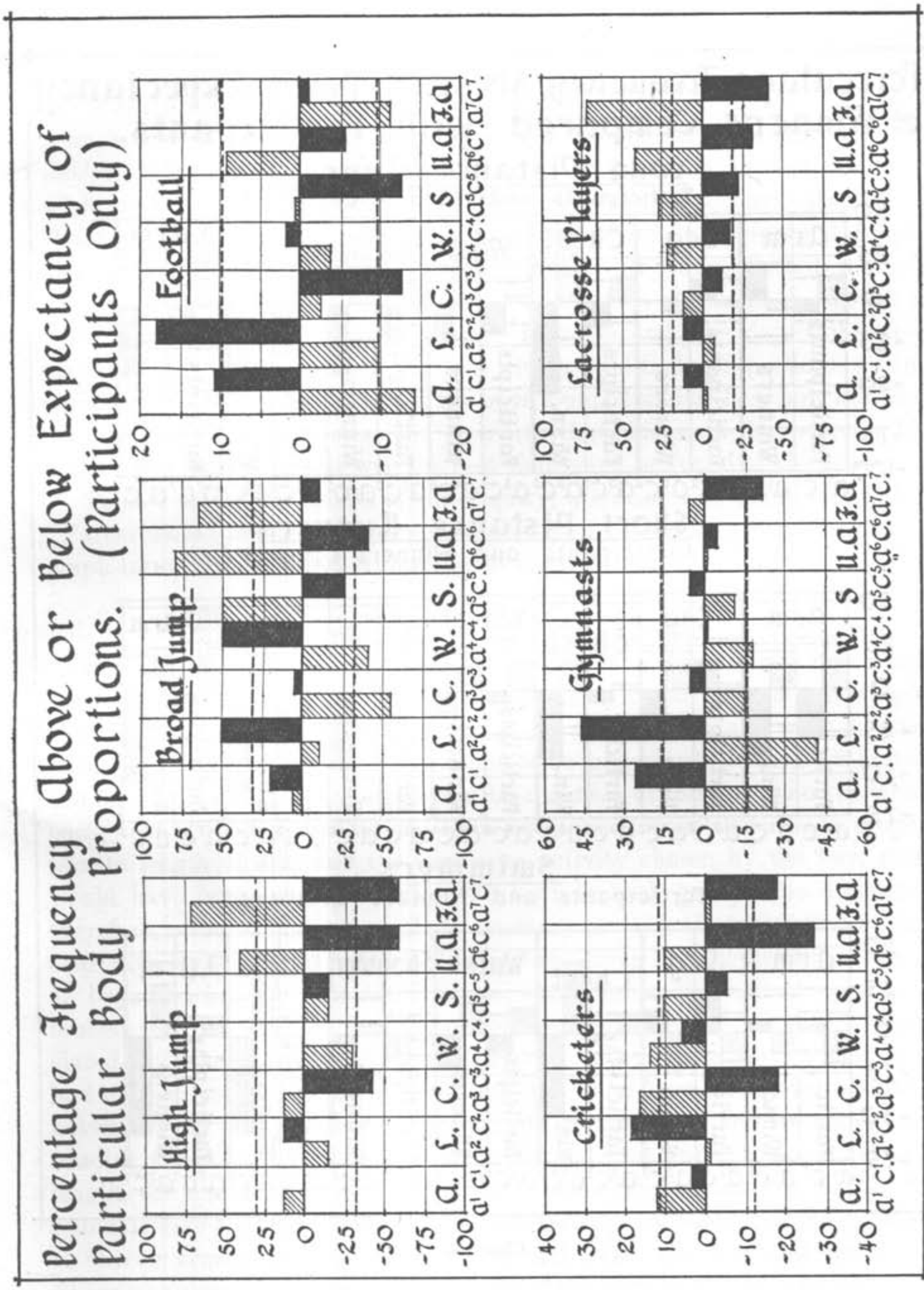
Percentage Frequency Above or Below Expectancy of
Particular Body Proportions. (Participants Only)
High Jump
Broad Jump
Football
Cricketers
Gymnasts
Lacrosse Players

Chart A.

At the time of the annual school measurings it is customary, as already stated, to ask each boy what kind of exercise he takes and what games he plays. He is encouraged to name as many of the activities in which he participates as he likes but, in order to make his statement reliable, his answers are checked at the time by the form monitor and the sports monitor of his form, one or both of whom are more or less familiar with his activities and habits. Many boys share freely in many activities, some boys in few only, while some manifest no interest in games or sports at all. The physical activities thus claimed consisted of long-distance running (especially harriers and steeplechase), sprinting, swimming, high jumping, broad jumping, and football, cricket, gymnasium work, and lacrosse. There were thus nine categories in which different boys might be compared. If choice, and some degree of fitness, are associated in any significant degree with special body proportions, a comparison of the body proportions of the boys grouped under these nine headings might reveal such an association. It is true that this method of enquiry left much to be desired, but it was the best that could be found at the time.

Table I shows the results of the enquiry, attention now being directed to "Participants" only. The figures in the body of the tables are reproduced in graph form (Charts A and B) for ease of appreciation.

PARTICIPANTS IN GAMES AND SPORTS.

Sorting out the 524 cards of boys between 14 and 17, it was found that 113 boys had claimed that they had participated in harrier runs and steeplechases, or had received commendation at the athletic sports for long-distance running. Forty-three of these were found to be long-armed, 35 medium-armed, and 35 short-armed. If the cards had been chosen at random from the whole pack, that is to say, if there had been no connection at all between proportionate length of arm and the particular activity chosen by the boy, there would have been, on the average, 38 boys in each group. The difference, therefore, revealed only a very slight tendency towards the association of long arms with long-distance running. In the same group of long-distance runners, 43 boys had big shoulder development, 41 medium, 29 small—suggesting a tendency to a somewhat broader or medium development of shoulder associated with this particular form of activity. As regards the group of 88 who had claimed activity in the gymnasium, had there been no connection at all between body proportions and the activity chosen, the numbers under each heading would have been on the average 29, whereas under proportional arm-length, the numbers were 22, 29 and 37; under proportional leg length, the numbers were 17, 28, 43, and so forth—suggesting a tendency in the gymnast to shorter arms and legs, medium chest and waist, shoulder and arm girth. Those who claimed to be active swimmers (167) appeared to tend in the direction of medium arms, shorter legs, broader chests, bigger waists, medium shoulders, with bigger arm girth, both of the upper- and fore-arm. Participants in football (206) also appeared to stand out as tending to possess

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shorter arms and legs, broader chests and shoulders, with larger upper-arm girth. The number of those who mentioned their participation in broad jumping was particularly small, which was probably due to the fact that most competitors did not remember to claim participation in such a minor event when relating their other physical activities. The few, however, who did refer to their participation in jumping had attained special credit in the sports in the face of keen competition—they were, therefore, a highly selected group and were short-legged, medium-chested, small-waisted, broad-shouldered, with thick upper- and lower-arm girth.

Before we can compare one group with another in their several body proportions it is necessary, however, to turn the *actual* numbers falling in *A*, *B* and *C* into percentage excesses or defects from the expected numbers. These percentage differences—given in the table below the actual numbers—are comparable figures throughout the table. The association of long arms, broad chests and broad shoulders with long-distance running showed in each case a percentage above expectancy in the *A* group of 14·2. The tendency in the gymnast to shorter arms and legs was shown by a percentage above expectancy in the *C* group of 26·1 and 46·6 respectively. In the same group the tendency to medium chest, waist, shoulder and arm girths was shown by percentages in the *B* group of 9·1, 19·3, 5·7 and 15·9, *i.e.* a noticeable percentage only as regards waist and arm girths; and so forth.

A comparison of the percentage differences in all nine groups showed that broad jumpers (20 per cent.) and gymnasts (26 per cent.)—and to a less extent footballers (10·7 per cent.) and lacrosse players (13·1 per cent.)—tended somewhat to belong to the group of proportionally short-armed. This would not mean that they were actually short-limbed, but that any considerable length of arm tended to be associated with a more considerably long back. Proportionately short legs, curiously enough, predominated in all nine groups, markedly so in the group of broad jumpers (50 per cent.) and gymnasts (46·6 per cent.). Proportionately broad chests were not outstanding in the general body of participants, the highest percentages being shown in cricketers (16·5), long-distance runners (14·2) and lacrosse players (13·1). Well-developed waists showed the highest percentages in lacrosse (22·9), sprinting (15·4), swimming (15·0) and cricket (14·4). Relatively big upper-arm girths showed the highest percentage in broad jumping (80), in high jumping (42·9) and in lacrosse (42·6). The physiological type revealed by this analysis among the 206 football players showed very little differentiation in any direction. Gymnasts appeared to be of small build altogether, with relatively short upper and lower limbs.

In estimating at its true value, however, the extent of the tendency among participants towards a certain body build which these percentage differences suggested, it was necessary to make allowances for the element of *chance*. It is only *in the long run* that the so-called "expected" numbers would constitute one-third of the whole group, even if aptitudes were wholly indifferent to body proportions. The numbers in each group—in any drawn detachment, *e.g.* the group of gymnasts—will differ from 29, 29, 29, by errors of chance in sampling, and the percentage differences in the actual numbers must be considered in relation to the percentage differences that would inevitably occur as the result of *chance*. The errors of chance are given at the foot of each column in the table and shown as dotted lines in the chart. They have a root mean square value, or standard error, of

$$\frac{100 \times \sqrt{n \times \frac{1}{3} \times \frac{2}{3}}}{n \times \frac{1}{3}} = \frac{100}{\sqrt{\frac{1}{2}n}},$$

where n is the number in the group[1].

An error of chance exceeds its standard error once in three times, and *exceeds twice its standard error once in twenty-two times, approximately. In the group of gymnasts, the actual number of C's, or relatively short-armed* boys, was 26 per cent. in excess of expectancy. Since the standard error is 15 per cent., the *error of chance* will exceed 30 per cent. once in twenty-two times. We should, therefore, expect a deficiency of 26 per cent. more frequently than once in twenty-two. In the same group the actual number of C^2's, or proportionately short-legged, was 46·6 per cent. in excess of expectancy—a percentage high enough to outweigh the error of chance and point towards a definite tendency in the gymnast to relatively short legs. Similarly, in the group of broad jumpers and lacrosse players, percentage differences of 80 and 42·6 above expectancy as regards proportionately big upper-arm girths would be sufficient to weigh against the percentage errors of chance of 31·6 and 18·1 respectively.

The number of times in the whole table of 231 percentage differences that these differences exceed their standard errors is 94. As the result of chance only, we should expect the differences to exceed their standard errors about once in three times, or, more exactly, 71 times. Hence, on the whole, the differences shown are not much beyond that which might be expected to occur as the result of chance only in a single experiment. Only in a few special groups, *e.g.* in long-distance runners (113 boys), broad jumpers (a small picked group of 20 boys) and cricketers (139 boys), was a condition beyond chance indicated.

This did not mean that the results found were due only to chance, but that the numbers were too small to stand surety for the differences brought out. Otherwise, that the method of selection is not sufficiently stringent. The small-

[1] I have to express my gratefulness and indebtedness to the late Mr H. E. Soper, who for the last ten years has taken personal interest in the various attempts made at the Manchester Grammar School to present in statistical form the relationship believed to exist between body form on function and physical and mental excellence. He has not only been my guide in the statistical theory and the calculation of the errors of sampling in the present paper, but has also *given much helpful criticism concerning the actual methods of enquiry adopted.* See Soper, H. E. (*The Field*, Jan. 11th, 1923), "Grading Athletic Performances: A biometric contribution." Statistical science has experienced a heavy loss in his death which took place on the 10th Sept. 1930.

ness of the association revealed is due partly to the chance nature of many boys' early choice of activities. A boy's early choice of games is often dependent upon such extraneous causes as his friendship with other boys and the games which those boys have already chosen, the distance of his home from the school playing fields, and so forth. Moreover, to some extent between 14 and 17—and to a greater extent after 17—preparation for examinations interferes with participation in the physical activities of the school by limiting the time at the boys' disposal. This hinders the selective process. At the ages chosen, nearly half the boys under consideration, that is, 218, were preparing for the School Certificate Examination. Enquiries had already elicited the fact that such preparation made extensive demands upon leisure time, so that, out of 117 boys who satisfied the examiners sufficiently well to be passed at the higher, *i.e.* the Matriculation standard, only 56 per cent. claimed to have participated in school games; out of 65 who passed at the Lower or Certificate standard, 66 per cent. claimed to have participated. Out of those who failed, 86 per cent. claimed to have participated.

Under these circumstances, it was only to be expected, therefore, that the figures, taken as a whole, might give no very *assured* conclusions of the existence of any constant relationship between physique and special forms of bodily activity. The figures, however, seemed to be sufficiently suggestive to justify a further enquiry concerning those boys who not only participated in particular activities or sports but definitely excelled in them, as in the case of the winners in the annual school athletic sports. In this further enquiry, the boys over 17, 84 in number, were included in order to obtain larger numbers. These boys had been excluded from the first enquiry, not, as we have said, because their limb proportions were different, but because they might be considered as a specially selected group on account of their continuing to study after many others of less scholastic bent had left school. The number of "winners" in the second enquiry is sometimes larger than the number of participants in the first enquiry. This apparent inconsistency occurs, *e.g.* in the case of the short-distance runners, where, although the participants numbered only 26, the winners amounted to 43. Such inconsistency is partly due to the inclusion among the winners group of the 84 older boys who had been previously omitted, but also to the fact that, in the earlier enquiry, dealing with participants only, many boys who claimed football, cricket, etc., because their spare time was generally spent in following one or more of these activities, omitted to mention that they had participated in and even attained excellence in some single event of the athletic sports, *e.g.* broad jumping, sprinting, etc. Further, in the first enquiry, participants in running had been divided into two sections only—long-distance and short-distance runners. To *win* at running, however, demands both higher respiratory storage and higher respiratory exchange, as well as better muscular endowment. In order to bring out the qualities associated with the different forms of running, the winners were, therefore, divided into *three* groups:

(i) Long-distance runners, *i.e.* actual winners in the mile and half-mile races.

(ii) Medium-distance runners (or long sprinting), *i.e.* actual winners in the quarter-mile and 220 yards races.

(iii) Short-distance runners (or short sprinting), *i.e.* actual winners in the 100 yards' race.

Although, in this later enquiry, the element of uncertainty is still evident in face of the errors of sampling in the small numbers available and, in addition, some impropriety of statistical procedure in extending the tertiles found for the 14–17 group to the 17 group must be allowed, yet the probability of there being some connection between certain body proportions and aptitude for special forms of physical activity was definitely increased. In long-distance running, for example (here see "Winners" in the table and chart), whereas the percentage differences above expectancy among the *participants* were only just in excess of the error of chance as regards length of arm, chest, etc., and only the fore-arm girth showed any marked difference (30·1 per cent. compared with the standard error of 13·3 per cent.), in the group of *winners*, the percentage differences above expectancy in the *A* group were considerably in excess of the standard error, both as regards chest, shoulder, upper- and lower-arm girths. In the group of those who claimed *participation* in sprinting, an excess beyond chance was shown in group *A* only as regards proportionate shoulder and fore-arm (38·5 and 50 per cent. compared with a standard error of 27·7 per cent.). Among those who had *won* in the athletic sports for long sprinting, however, a percentage considerably above the standard error (20 per cent.) was shown in the *A* group in proportionate leg-length (32 per cent.), in chest girth (38), in shoulder girth (44) and also in lower-arm girth (44). Among *winners* in short sprinting (standard error 21·57) the percentage difference in the *A* group was considerably above that suggested by chance in chest girth (39·5) and also in upper-arm girth (60·3), and to a less extent in shoulder girth (25·5). Finally, among those who *participated* in swimming, the percentage difference in the *A* group was only slightly in excess as regards leg-length (17·4), waist girth (15) and upper-arm girth (13·2); whereas, among *winners* in the swimming competitions, chests and both upper- and lower-arm girths showed markedly high percentage differences (43·8, 50 and 31, as compared with the standard error of 20·41).

As regards limb proportions there appeared to be a marked tendency for boys of long arms and long legs to fall out during competition in both long- and short-distance running, and also in swimming. There was also a tendency for boys of medium arm-length and medium leg-length to predominate, except in the case of runners of the 220 and 440 yards, where long legs are a distinct advantage. In all forms of physical prowess good proportions of chest were distinctly in evidence; large shoulder girth also predominated, except in swimmers, where a medium proportion of shoulder girth, whose grading is perhaps in some degree due to a long trunk, was more common. The high proportion of upper- and fore-arm girth indicated throughout is, of course, a sign of high range of muscular development.

Objection will naturally be raised to the taking of such special measurements as above put forward on the score that time might be more beneficially employed in other directions. This is exactly the objection which was raised by certain members of the London School Board in 1874 when Dr R. Brudenall Carter, noting the large number of school children attending his out-patient eye clinic, whose eyesight was undergoing steady deterioration during their school life, urged upon the Board that the eyesight of all school children should be examined. I believe there are very few familiar with the daily routine of school life who would not agree that the differences in natural endowment and physical aptitude are as diverse as the differences in eyesight and that the strain of school life is as serious in one direction as in the other. I would urge that the neglect to take into proper account these wide divergencies, and the neglect to make arrangements for the improvement of physique of subnormal, though not actually ailing, adolescent children, has much to do with the present unsatisfactory physique and the overstrain of adolescent school children. All school children are subjected at stated periods to a simple and quick routine examination of their eyesight which serves to bring abnormal cases into prominence. These abnormal cases are chosen for a more detailed enquiry. In the same way, the school medical officer, working in conjunction with the physical instructor and the games master, will form a preliminary judgment of body build and physical fitness, and will note any cases of non-participation or marked ineptitude, in the various forms of physical activity. The boys thus brought into prominence should be examined by means of some such special measurements and physiological tests as have been tried at the Manchester Grammar School.

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