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CHANGES IN THE MEAN STATURE AND WEIGHT OF BRITISH CHILDREN OVER THE PAST SEVENTY YEARS

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The popular belief that modern men are taller than their forebears is largely based on such evidence as the small size of the armour worn in the Middle Ages. This belief has been questioned in recent years. For example, there is no clear evidence to show that the mean height of men in this island has altered over the past hundred years. On the other hand, it has been definitely established that in Great Britain adult stature is reached earlier now than it was 70 years ago. In years gone by men belonging to the wealthier classes attained their maximum height at an earlier age than did men of the poorer classes. Recent data for Scotland have shown that the difference in growth rate between the social classes has now been eliminated (Clements and Pickett, 1952). Thus, Scotsmen in the lower-income groups attain their maximum height at the same age as those in the upper-income group. It is likely that similar changes in the stature of men will have occurred throughout the rest of Great Britain. All this would seem to imply that our forefathers, living in harder conditions, continued growing for some years after they had assumed such adult responsibilities as soldiering. It would also seem that the quicker rate at which children mature to-day, and the elimination of differences in the rate of growth between social classes, reflect a general improvement in the living conditions and health of the whole population.

The present paper deals with records of the mean stature and weight of British children over the past 70 years. Data earlier than this are both meagre and selected, and refer mainly to children applying for permission to work in factories. Changes in factory legislation over the years would obviously affect the sampling of such children ; for example, many children who would have been regarded as useful labourers in earlier times were no longer passed as fit for work in the 1870s.

Data

Anthropometric data have been examined for each of the following five periods:

(1) The late nineteenth century : the data for this period are represented by the records of the British Association Anthropometric Survey of 1883.

(2) The early twentieth century: the data for this period are represented by the following records: (*a*) a survey of children living in Glasgow in 1905 (Elderton, 1914); (*b*) measurements of children from English urban areas (Tuxford and Glegg, 1911) ; (*c*) measurements of London children (Heron, 1910) ; and (*d*) measurements of Birmingham children (Auden, 1909).

(3) The period after the first world war : the data for this period are represented by measurements of Glasgow children in 1921 (Tully, 1924).

(4) The period before the second world war : the data for this period are represented by measurements of children living in the North-east Health Division of London in 1938 (Menzies, 1940).

(5) The period after the second world war : the data for this period are represented by measurements of children living in the North-east Health Division of London in 1947 (Daley, 1950), and of children living in Birmingham in 1947–8 (Clements and Pickett, to be published).

Most of the children measured in these surveys were town dwellers.

With regard to the use of data relating to London children, it is of interest to note that Daley (1950) found no statistically significant differences between London divisional and London county averages. We may therefore take it that the figures used for children living in North-east London are representative of children living in the whole of London.

The data which have been compared in this paper are reported in Tables I to IV. All the data have been standardized.

Standardization of Measurements

Before any conclusions are drawn some of the factors which may account for the differences between the measurements of successive surveys must be considered. The differences may be due wholly, or in part, to errors of random sampling, to systematic errors in technique, to factors operative in different geographical localities, or to socio-economic factors. The size of the error due to random sampling may be minimized by restricting comparisons to mean measurements of large samples of children. The second possible source of error is more difficult to minimize. The major trouble is due to systematic differences in the way the data were reported rather than to differences in the way the measurements were taken. Thus, whereas anthropometric techniques are unlikely to differ for measurements of stature and weight, a difference of six months' growth in the mean measurements may be introduced by the method of recording children's ages. In some cases age is taken to the nearest birthday and in others to the previous birthday. Sometimes, as in the recent surveys of London children, age is calculated from the year of birth. Systematic errors will also be introduced by different methods of rounding the measurements at the time of the examination. For instance, in some surveys stature is recorded to ⅛ in., and in others to ½ in., while weight is sometimes recorded to the nearest 0.1 kg. and sometimes to the nearest pound. The amount of clothing worn when measurements are made is not constant. Occasionally measurements of nude subjects are reported, but more often the subjects wear indoor clothing, with or without footwear.

Social and Economic Background of the Children.—The mean stature and weight of children attending elementary schools vary according to the socio-economic background of the family (Healy, 1952).§ Comparisons have therefore been made wherever possible between children with similar backgrounds. This was done by using the social classification of the Registrar-General (1931). In this scheme "social class" is determined by the occupation followed by the father or head of the household, as coded in the Classification of Occupations of the Registrar-General. Class I comprises professional occupations; class II, intermediate; class III, skilled; class IV, semi-skilled; and class V, unskilled occupations.

Geographical Factors.—Tables I to IV show that contemporary data from different urban areas are all very similar. Thus there is little difference between the mean statures and weights of children of the same age measured in London (Heron, 1910), Glasgow (Elderton, 1914), Birmingham (Auden, 1909), and "urban areas of England" (Tuxford and Glegg, 1911). The mean measurements recorded in 1947 of Birmingham and London children are also very similar. These findings suggest that geographical factors are hardly likely to account for any differences which may exist between measurements of successive surveys.

Small but consistent changes in human stature and weight will appear as changes in the mean measurements when they are recorded at intervals. On the other hand, the foregoing considerations indicate that, unless anthropometric techniques are closely standardized, small differences between the same measurements may be entirely fortuitous.

To facilitate comparison, the following conventions have been employed in standardizing the data used in the present paper:

Age has been taken to the last birthday. The adjustments necessary to standardize the mean height and weight for age have been made by simple interpolation from the recorded data.

Stature is given in inches, as measured without shoes.

Weight is given in pounds, as measured in indoor clothing but without shoes. Some data contained estimates of the weight of footwear, and where necessary these have been used in making adjustments.

The social and economic backgrounds of the children have been classified under three headings. Data for children from social classes I and II (professional and intermediate) have been combined under a composite "upper-income group"; data for children from class III (skilled) have been placed under the heading "middle-income group," whilst the data for children from social classes IV and V (semi-skilled and unskilled) have been combined under the composite heading "lower-income group." The authors of many of the surveys used in this study state either the

Table I.—*Standardized Mean Statures of Boys Aged* 5–13 *Years From* 1880 *to* 1947

Age	Clements and Pickett (to be pubd)	Daley (1950)	Menzies (1940)	Tully (1924)	Tuxford and Glegg (Urban) (1911)	Auden (1909)	Heron (1910)	Elderton* (1914)	British Association (1883)
	1947	1947	1938	1921–2	1909–10	1908	About 1905	1905	About 1880
					Heterogeneous				
5	43·5	43·3	42·9	40·9	43·4	41·1†	—	40·9	39·7†
6	46·0	45·5	45·1	42·8	42·3	43·3	—	42·8	41·9
7	48·0	47·6	47·3	44·7	45·0	44·7	—	44·7	44·6
8	50·1	49·6	49·3	46·2	46·9	—	47·1	46·8	46·5
9	52·0	51·5	51·3	47·6	48·7	—	49·1	48·5	48·9
10	53·9	53·3	53·1	49·9	50·8	—	51·0	50·3	50·7
11	55·6	55·2	54·9	51·6	52·6	53·1	52·6	51·9	52·7
12	57·6	57·2	56·6	52·7	54·7	55·0	54·4	53·8	53·7
13	59·5	59·3	58·4	54·7	56·1	57·1	56·2	55·4	55·8
					Upper-income Group				
5	(45·0)			42·0		—	—	42·1	—
6	(46·7)			44·1		—	—	43·9	—
7	(50·9)			46·0		—	—	45·8	—
8	(49·8)			47·9		—	47·7	47·9	47·6‡
9	(51·3)			48·9		—	50·1	49·9	50·0
10	(54·9)			51·8		—	52·3	51·7	52·0
11	(56·4)			52·8		55·0	53·7	53·4	53·7
12	(57·1)			54·5		56·6	55·5	55·0	55·3
13	(60·4)			56·9		58·6	57·8	56·8	57·4
					Middle-income Group				
5	43·5			40·8		41·1	—	41·2	39·7
6	45·9			42·8		43·3	—	43·0	41·9
7	48·0			44·5		44·7	—	45·1	44·6
8	50·3			46·7		—	47·4	47·1	46·5
9	52·1			48·2		—	49·6	49·0	48·9
10	54·1			49·8		—	51·6	50·7	50·7
11	55·6			51·8		53·1	53·0	52·5	52·7
12	57·8			52·7		55·0	54·7	54·2	53·7
13	59·4			53·9		57·1	56·5	56·1	55·8
					Lower-income Group				
5	43·0			40·3		39·1	—	40·8	38·6
6	45·9			42·4		41·6	—	42·6	41·1
7	47·8			44·3		42·6	—	44·5	43·5
8	49·4			45·4		—	46·5	46·4	44·6
9	51·6			47·1		—	48·4	48·3	47·0
10	52·7			49·5		49·5	50·2	50·0	48·1
11	55·2			50·9		50·0	51·8	51·5	49·1
12	57·4			52·1		53·5	53·6	53·5	51·8
13	59·6			53·9		54·9	55·2	54·7	53·2

Parentheses indicate samples of fewer than 20.

* The measurements of Elderton (1914) have been taken as representative of those of the second period when computing the differences given in Table V. The measurements used in the sample from the lower-income group are the means of Elderton's Samples A and B.

† Data derived from the samples of children in the middle-income group are used for the heterogeneous group if no better data exist.

‡ In the first period, the measurements of children in the upper, middle, and lower income groups are the measurements recorded for social class 2, the town artisan, and the pooled industrial schools respectively in the British Association Survey, 1883.

§It should be pointed out that measurements of children in independent schools are not considered.

Table II.—*Standardized Mean Statures of Girls Aged* 5–13 *Years From* 1880 *to* 1947

Age	Clements and Pickett (to be pubd)	Daley (1950)	Menzies (1940)	Tully (1924)	Tuxford and Glegg (Urban) (1911)	Auden (1909)	Heron (1910)	Elderton* (1914)	British Association (1883)
	1947	1947	1938	1921–2	1909–10	1908	About 1905	1905	About 1880
					Heterogeneous				
5	43·2	43·0	42·5	40·4	40·2	41·1†	—	40·8	39·8†
6	45·6	45·0	44·5	42·0	42·2	43·3	—	42·4	41·8
7	47·5	47·2	46·6	43·9	44·6	44·7	—	44·1	43·6
8	49·4	49·3	48·8	46·0	46·3	—	47·1	46·2	45·6
9	51·4	51·4	50·9	47·9	48·3	—	48·8	48·0	47·4
10	53·7	53·3	53·0	49·6	50·9	—	50·7	49·9	49·0
11	55·9	55·4	55·2	51·2	52·1	53·4	52·8	51·9	51·5
12	58·0	57·7	57·3	53·6	54·8	55·8	55·2	53·9	54·0
13	60·2	59·6	59·3	55·9	56·7	57·4	57·3	56·1	56·2
					Upper-income Group				
5	(43·6)			41·5			—	41·8	(40·0)‡
6	(45·7)			43·2			—	43·7	(42·5)
7	(47·8)			46·0			—	45·6	44·4
8	(49·0)			47·0			47·8	47·5	(47·2)
9	(53·9)			49·5			50·0	49·5	49·9
10	(54·8)			51·0			51·7	51·3	51·4
11	—			52·3			53·6	53·1	53·3
12	(60·0)			55·3			55·8	55·3	55·7
13	(59·3)			57·8			58·1	57·6	58·5
					Middle-income Group				
5	43·2			40·5		41·1	—	41·0	39·8
6	45·7			42·0		43·3	—	42·8	41·8
7	47·4			44·1		44·7	—	44·6	43·6
8	49·6			46·3		—	47·2	46·6	45·6
9	51·3			48·5		—	49·0	48·5	47·4
10	53·7			50·0		—	51·1	50·3	49·0
11	55·8			51·6		53·4	53·2	52·2	51·5
12	57·8			53·9		55·8	55·4	54·3	54·0
13	60·2			54·7		57·4	57·4	56·2	56·2
					Lower-income Group				
5	43·0			39·9		39·1	—	40·6	39·2
6	44·9			41·1		41·6	—	41·1	41·2
7	47·8			43·3		42·6	—	44·2	42·4
8	49·1			45·5		—	47·2	46·1	44·7
9	51·5			47·1		—	48·6	47·9	46·4
10	53·4			48·9		48·7	50·1	49·8	47·7
11	56·3			50·5		50·7	52·2	51·7	51·5
12	57·9			53·0		54·2	54·6	53·8	51·2
13	60·2			55·2		55·9	56·6	55·6	53·0

Parentheses indicate samples of fewer than 20. For footnotes, see Table I.

character of the district represented by the sample or the usual occupation followed by the children's parents. This knowledge has enabled much of the data to be grouped into the three broad groups given above. Material which could not be classified has been termed "heterogeneous" and is reported in a separate section of the tables.

TABLE III.—*Standardized Mean Weights of Boys Aged* 5–13 *Years From* 1880 *to* 1947

Age	Clements and Pickett (to be pubd)	Daley (1950)	Menzies (1940)	Tully (1924)	Tuxford and Glegg (Urban) (1911)	Auden (1909)	Heron (1910)	Elderton* (1914)	British Association (1883)
	1947	1947	1938	1921–2	1909–10	1908	About 1905	1905	About 1880
					Heterogeneous				
5	44·0	42·4	42·4	39·9	38·1	—	—	40·0	38·4†
6	48·7	47·2	47·2	44·0	42·5	—	—	43·5	42·1
7	53·6	52·2	52·1	47·5	46·3	—	—	47·5	48·2
8	59·1	59·6	57·2	50·9	50·3	—	48·9	51·5	51·8
9	63·7	62·7	62·7	55·4	54·5	—	53·8	56·5	55·8
10	70·3	68·4	68·5	60·6	60·0	—	58·3	61·0	61·5
11	75·0	75·0	72·7	65·0	65·0	65·8†	63·0	66·0	66·5
12	82·7	82·3	81·6	68·5	71·6	70·0	69·1	71·0	70·5
13	91·7	91·2	89·0	74·8	77·2	78·5	75·9	77·0	76·5
					Upper-income Group				
5	(46·2)			40·7			—	41·6	—
6	(50·2)			44·3			—	44·9	—
7	(57·6)			48·1			—	48·9	—
8	(56·3)			52·3			50·6	53·7	53·0‡
9	(57·6)			55·6			56·1	58·8	59·8
10	(72·2)			64·1			60·6	63·7	62·7
11	(77·9)			67·8			65·6	68·6	65·5
12	(80·0)			73·1			71·8	73·8	70·7
13	(104·5)			80·5			81·6	80·0	77·6
					Middle-income Group				
5	44·0			41·3		—	—	40·2	38·4
6	48·2			44·4		—	—	44·2	42·1
7	53·0			47·0		—	—	48·0	48·2
8	59·0			52·0		—	48·9	52·2	51·8
9	63·6			56·6		—	54·4	57·0	55·8
10	70·7			58·5		—	59·7	61·7	61·5
11	75·5			63·9		65·8	64·1	65·2	66·5
12	82·7			65·6		70·0	69·0	72·3	70·5
13	90·9			68·1		78·5	79·1	78·9	76·5
					Lower-income Group				
5	44·2			38·5		—	—	39·8	34·2
6	48·4			43·7		—	—	43·2	37·9
7	53·9			47·6		—	—	46·9	43·2
8	58·3			49·7		—	48·9	50·9	44·6
9	62·7			54·8		—	53·1	55·4	49·9
10	67·5			61·0		58·1	57·0	59·9	54·3
11	72·4			64·3		57·0	62·1	64·6	60·7
12	82·7			67·8		65·1	67·2	69·7	64·9
13	90·4			74·6		73·0	72·2	74·4	69·8

Parentheses indicate samples of fewer than 20. For footnotes, see Table I.

Method of Measuring Differences

The method of estimating differences between measurements is the same for all social classes and for all periods from 1880 to 1947. A change in a measurement is determined by comparing the average measurement for each age-class at the beginning of a period with the corresponding

TABLE IV.—*Standardized Mean Weights of Girls Aged* 5–13 *Years From* 1880 *to* 1947

Age	Clements and Pickett (to be pubd)	Daley (1950)	Menzies (1940)	Tully (1924)	Tuxford and Glegg (Urban) (1911)	Auden (1909)	Heron (1910)	Elderton* (1914)	British Association (1883)
	1947	1947	1938	1921–2	1909–10	1908	About 1905	1905	About 1880
					Heterogeneous				
5	41·2	41·3	41·2	38·4	37·3	—	—	39·0	38·3†
6	44·8	45·5	45·8	42·1	40·6	—	—	42·0	41·1
7	49·6	50·5	50·7	45·0	45·0	—	—	46·0	44·2
8	54·0	56·1	56·2	49·4	48·9	—	48·2	49·5	49·8
9	59·3	61·5	61·9	53·9	54·2	—	52·7	54·0	53·2
10	67·0	67·9	68·1	57·4	58·6	—	57·8	58·5	58·5
11	76·5	76·3	75·7	61·2	64·4	65·6†	64·2	64·5	64·8
12	83·3	86·1	84·9	68·9	72·3	74·1	72·1	71·0	72·9
13	93·7	95·5	94·6	79·1	79·1	81·2	78·9	79·0	82·9
					Upper-income Group				
5	(44·5)			39·2			—	39·9	(36·8)
6	(48·3)			42·8			—	43·7	(39·4)
7	(52·7)			46·4			—	47·5	43·4
8	(55·8)			50·1			48·3	51·8	(50·5)
9	(67·0)			55·0			55·1	56·6	53·0
10	(75·4)			59·8			59·9	61·6	60·9
11	—			64·1			66·3	67·4	66·5
12	(105·6)			74·0			74·3	74·6	75·3
13	(84·2)			—			82·4	83·9	86·2
					Middle-income Group				
5	43·9			40·1		—	—	39·6	38·3
6	47·4			43·3		—	—	43·0	41·1
7	51·8			45·8		—	—	46·4	44·2
8	56·7			50·7		—	48·3	50·4	49·8
9	61·1			55·9		—	52·7	54·8	53·2
10	69·0			57·6		—	58·2	59·4	58·5
11	78·9			60·3		65·6	64·8	65·1	64·8
12	83·8			66·4		74·1	72·7	72·2	72·9
13	95·9			71·3		81·2	80·9	79·5	82·9
					Lower-income Group				
5	43·4			37·0		—	—	38·6	35·0
6	45·2			41·3		—	—	41·8	38·7
7	52·7			44·3		—	—	44·3	42·1
8	55·8			48·5		—	48·9	49·1	45·8
9	63·3			52·4		—	52·9	53·2	50·8
10	67·0			56·4		52·6	57·3	57·7	54·0
11	78·0			60·7		57·9	62·0	63·1	59·0
12	85·8			68·6		69·3	70·8	69·7	66·3
13	96·6			78·9		76·3	77·4	76·2	70·8

Parentheses indicate samples of fewer than 20. For footnotes, see Table I.

TABLE V.—*Changes in Mean Stature and Weight by Age and Income Group from 1880 to 1947*

Income Group	Period	Approximate Dates	Boys						Girls					
			Height in Inches			Weight in lb.			Height in Inches			Weight in lb.		
			5/7	8/10	11/13	5/7	8/10	11/13	5/7	8/10	11/13	5/7	8/10	11/13
Heterogeneous	Late 19th century	1880 to 1905	0·5	0·0	0·0	0·5	0·0	0·0	0·5	0·5	0·0	1·0	0·0	−2·0
	First world war ..	1905 ,, 1920	0·0	−0·5	−0·5	0·0	−0·5	−2·0	0·0	0·0	0·0	−0·5	−0·5	−1·5
	Inter-war years ..	1920 ,, 1940	2·0	3·0	3·5	3·5	7·0	12·0	2·0	3·0	3·5	4·0	8·5	15·0
	Second world war	1940 ,, 1947	0·0	0·0	0·5	0·0	0·5	1·5	0·5	0·5	0·0	0·0	0·0	1·0
	Total ..		2·5	2·5	3·5	4·0	7·0	11·5	3·0	4·0	3·5	4·5	8·0	12·5
Upper-income group	Late 19th century	1880 ,, 1905	—	0·0	0·0	—	0·0	2·5	1·5	0·0	−0·5	3·5	2·0	−0·5
	First world war ..	1905 ,, 1920	0·0	0·0	0·0	−0·5	−1·0	0·0	0·0	0·0	0·0	−1·0	−1·5	−0·5
	Inter-war years .. Second world war	1920 ,, 1940 1940 ,, 1947	3·5	2·5	3·0	7·0	4·5	13·5	2·0	3·5	3·0	5·5	11·0	—
	Total ..		3·5*	2·5	3·0	6·5*	3·5	16·0	3·5	3·5	2·5	8·0	11·5	—
Middle-income group	Late 19th century	1880 ,, 1905	1·0	0·0	0·5	1·0	0·5	1·0	1·0	1·0	0·0	1·5	1·0	−1·0
	First world war ..	1905 ,, 1920	0·0	−0·5	−1·5	0·0	−1·0	−6·5	−0·5	0·0	−0·5	0·0	0·0	−6·0
	Inter-war years .. Second world war	1920 ,, 1940 1940 ,, 1947	3·0	4·0	5·0	4·0	8·5	17·0	3·0	3·0	4·5	4·5	7·5	20·0
	Total ..		4·0	3·5	4·0	5·0	8·0	11·5	3·5	4·0	4·0	6·0	8·5	13·0
Lower-income group	Late 19th century	1880 ,, 1905	1·5	1·5	1·5	4·5	5·5	4·0	1·5	1·5	1·5	3·0	3·0	4·0
	First world war ..	1905 ,, 1920	0·0	−1·0	−1·0	0·0	0·0	−0·5	−1·0	−0·5	−0·5	−1·0	−1·0	0·0
	Inter-war years .. Second world war	1920 ,, 1940 1940 ,, 1947	3·0	4·0	5·0	5·5	7·5	13·0	3·5	4·0	5·0	6·0	9·5	17·5
	Total ..		4·5	4·5	5·5	10·0	13·0	16·5	4·0	5·0	6·0	8·0	11·5	21·5

* No data for 1880–1905.

measurement at its end. To illustrate the procedure adopted, data will be considered for boys from the heterogeneous class. Examination of Table I will show that the differences between the mean measurements of 5-, 6-, and 7-year-old boys are similar. Consequently it was considered justifiable to regard these three age-classes as a single sample. The stature of this sample is represented by the average of the three measurements. In a similar way average figures have been calculated for the mean heights of the 8-, 9-, and 10-year-old boys and for the 11-, 12-, and 13-year-old boys. Thus it can be calculated from the figures given in Table I that the average stature for the 5 to 7 age-class of boys was 42.07 in. in 1880 and 42.8 in. in 1905. Hence the change in height of the boys of the 5 to 7 age-class between 1880 and 1905 was 0.73 in. The mean weight of boys is given in Table III, and the mean statures and weights of girls are given in Tables II and IV respectively. Changes in the weights of the boys and of the weights and heights of the girls have been determined by the method outlined above. The differences found between the measurements are given in Table V and shown in Charts 1 and 2.

Differences in the measurements of less than 0.5 in. or 0.5 lb. are regarded as unimportant and recorded as 0. Differences of one-half but less than one are recorded as 0.5 in. or lb., and so on. Thus the difference between the average heights of the samples of 5- to 7-year-old boys at 1880 and 1905 was 0.73 in. This figure is recorded as 0.5 in.

The use of the word "children" in the text implies both boys and girls; otherwise the sex is specified. When measurements in Table V are similar for boys and girls of the same age-class, the average of the two measurements is given in the text and referred to as "measurements of children."

Results

Data given in Tables I to IV indicate that children are growing more quickly now than they were some years ago. Comparison of the figures given by Heron (1910) and Daley (1950) serves to illustrate this trend. In both surveys measurements were recorded of children living in London. Possible variations due to sampling in different geographical localities are thus minimized. It will be apparent that average children living in 1947 are 2 in. taller and 8 lb. heavier than children of the corresponding age and income group living in 1910. Furthermore, the more recent data show that children of the heterogeneous group are taller and heavier than children in the upper-income group living in 1910.

The broad outline of the changes in each period will be evident on consideration of the data for the heterogeneous income groups given in Table V. The sample of 5-, 6-, and 7-year-old children measured in 1947 was 2.5 in. taller and 4 lb. heavier on the average than the sample measured in 1883. Children aged 8, 9, and 10 years were about 3 in. taller and 7 lb. heavier, and those aged 11, 12, and 13 years were 3.5 in. taller and 9 lb. heavier.

Similar trends are found when data for the three income groups are examined in detail. In addition, however, several subtle variations in the findings become apparent when the groups are compared one with another. Thus, over the seventy-year period the increases in average stature and weight of children in the lower-income group were greater than those in the corresponding samples of children in the upper-income group. Average children in the lower group aged 5 to 7 years increased in stature and weight by 4 in. and 9 lb., those aged 8 to 10 years by 4.5 in. and 12 lb., and those aged 11 to 13 years by 5.5 in. and 19 lb.

Period of the Late Nineteenth Century.—It will be seen from the samples of the heterogeneous income groups that at the beginning of the twentieth century average girls of the age-classes 5 to 7 and 8 to 11 were both 0.5 in. taller than their earlier counterparts. The 5- to 7-year-olds were also 1 lb. heavier. The sample of boys aged 5, 6, and 7 years measured in 1905 were 0.5 in. taller and 0.5 lb. heavier on the average than the corresponding sample measured in 1883. Children in every age-class of the lower-income group were, on the average, about 1.5 in. taller and 4 lb. heavier at the end of this period than they were at the

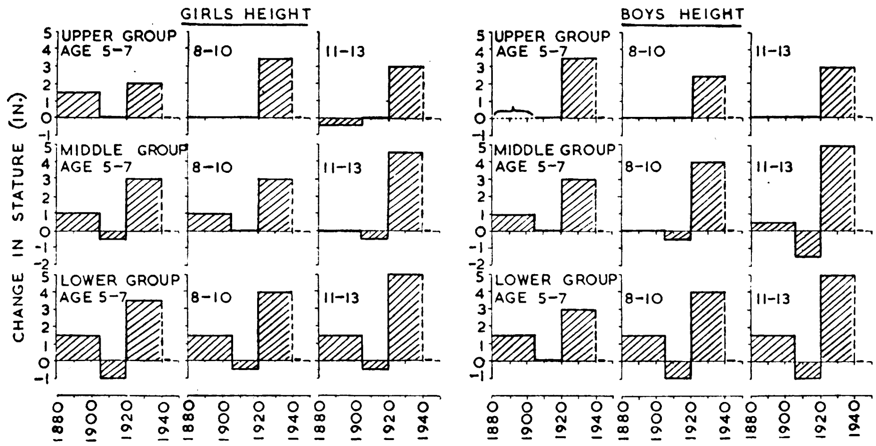

Chart 1.—Changes in mean stature, by age and income group, from 1880 to 1947. Changes found in the years from 1920 to 1947 (period of the inter-war years and the second world war) have been attributed to the years from 1920 to 1940. This is indicated by a coarse broken line terminating the period in 1940. For explanation see text. A finely broken bracketed base line indicates no data.

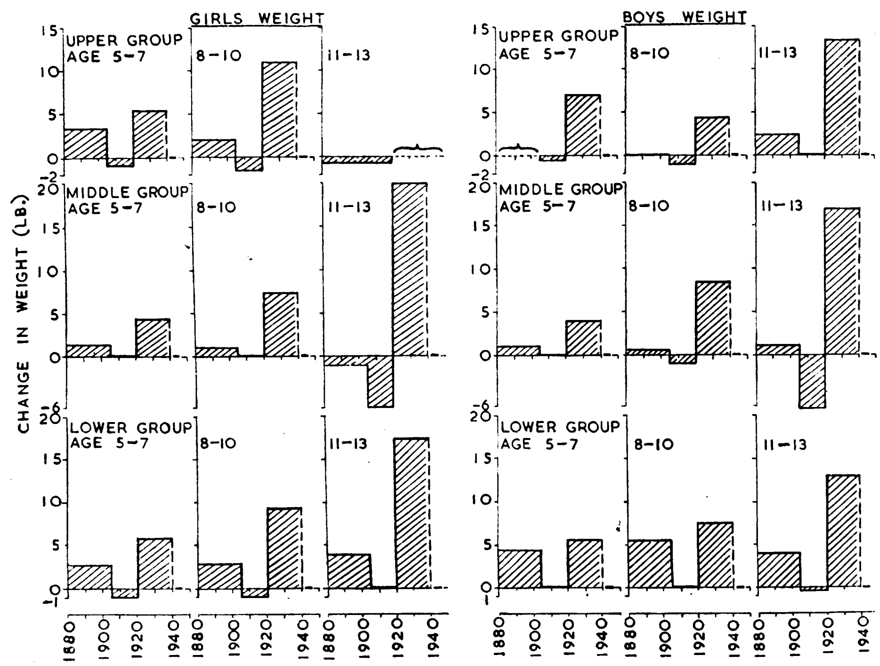

Chart 2.—Changes in mean weight, by age and income group, from 1880 to 1947.

beginning. Increases in the mean stature and weight of children in the upper- and middle-income groups were generally smaller and less consistent, and were usually confined to the youngest samples of children. In the upper-income group, for example, only the sample of girls aged 5 to 7 years showed an increase in height, amounting to 1.5 in. Girls aged 11 to 13 years in the upper-income group were 0.5 in. shorter and weighed 0.5 lb. less at the end of the period than at the beginning.

Period of the First World War.—During the period from 1905 to 1921 there were no increases in average height of comparable samples in the heterogeneous income group. Two samples of boys, aged 8 to 10 and 11 to 13 years, were actually 0.5 in. shorter on the average at the end of the period than they were at the beginning. The average stature of children in every age-class of the upper-income group was unchanged during this period. On the other hand, the average statures of 9 out of 12 samples of children in the middle- and lower-income groups were from 0.5 to 1.5 in. shorter in 1921 than similar samples of children measured in the same city (Glasgow) in 1905. Changes in the average weight of children during this period were less consistent. The average weights of all except one sample in the heterogeneous group were decreased. The exception was the 5- to 7-year-old boys, who showed no change in weight. The greatest change, a reduction of about 6.5 lb., was recorded in 11-, 12-, and 13-year-old children of the middle-income group.

Period of the Inter-war Years, and of the Second World War.—In the inter-war years considerable increases in average stature and weight occurred in every age-class of the heterogeneous income group. Children aged from 5 to 7 years were, on the average, 2 in. taller and 3.5 lb. heavier, those aged 8 to 10 were 3 in. taller and 7 lb. heavier, and those aged 11 to 13 were 3.5 in. taller and 12 lb. heavier at the end of the period than at the beginning. In several instances the increases recorded in this period of about twenty years were greater than the total increase over the seventy-year period, because earlier losses were being made up.

The rapid rate of increase in average stature and weight stopped at the start of the second world war. A comparison of the samples measured in 1938 and 1947 shows small increases of 0.5 in. in mean stature in three out of the six groups. In three of the four groups of children aged 8 to 13 years there were increases in mean weight of up to 1.5 lb.

The period covered by the samples of the separate income groups extends from 1921 to 1947 and includes the second world war. Judging from the evidence of the heterogeneous samples from 1938 to 1947, however, it is likely that the major changes in all income groups occurred before 1938. Children of all age-classes were taller and heavier in 1938 than were corresponding samples in 1921. In the lower-income group the average stature and weight of children aged 5 to 7 years were 3 in. and 5.5 lb. more, those of children aged 8 to 10 years were 4 in. and 8.5 lb. more, and those of children aged 11 to 13 years were 5 in. and 15 lb. more at the end of the period than at its beginning. The average stature of 9 out of 12 samples of children in the middle- and lower-income groups increased by at least 0.5 in. more than that of children in the upper-income group. However, children of the lower-income group show no consistently greater increase in weight.

Discussion

In 1876 Roberts made the observation that "a factory child of the present day at the age of 9 years weighs as much as one of 10 did in 1833 . . . each age has gained one year in 40 years." The tendency noticed by Roberts for children to grow more quickly over a period of time has been continued to the present day. There can be no doubt that there have been great increases in the mean stature and weight of children since 1880. The extent of these increases, which have been described above, indicates an advancement in development of about eighteen months' growth. Thus the average 6-year-old child now has about the same height and weight as an average 7.5-year-old child of 1880: an average child of 12 years of age is about 3.5 in. taller than one of the same age 70 years ago. The change is even greater in the children in the lower-income group, and, on the average, is equivalent to two years' growth.

Contrary to a view expressed by Menzies (1940), a detailed examination of the data indicates that the rate of increase of growth has not been constant over the years. The increase, which was slow at first, ceased during the period of the first world war: indeed, actual losses of both weight and height occurred in many groups. During the following inter-war years, children of all income groups and age-classes increased rapidly in weight and height. This rate of increase was greatly retarded during the period which included the second world war.

In the period of the late nineteenth century the height of all samples of children in the lower-income group increased by 1.5 in. On the other hand, children of the upper- and middle-income groups showed no uniform increase in size. Thus increases of 1 in. or more were restricted to children aged 5, 6, and 7 years of those groups (no data for boys in the upper-income group), and to girls aged 8 to 10 years in the middle group. Two explanations of these increases are considered. One is that some environmental factors have a selective effect upon the younger children in the upper- and middle-income groups, and on children between 5 and 13 years of age in the lower-income group. The second explanation is that these groups of children respond in a sensitive way to slight changes in environment. During the first world war living conditions became more difficult when, for example, there were restrictions on the amount and quality of various foods that could be purchased. In that period the stature of each sample of children in the upper-income group remained unaltered, whilst the mean stature was decreased in four out of the six age-classes of children in the middle-income group, and in five out of the six similar classes in the lower-income group. These facts suggest that the second explanation is the more likely one.

The largest increases in mean heights and weights are found in children of the lower-income group. The difference between the increases in the mean statures of this group and those of the upper-income group is a matter of about 1 in. in the youngest children, 2 in. in children aged 8 to 10 years, and 3 in. in children aged 11 to 13 years. The increases in the mean weights are less consistent, but amount to about 2 lb. at 5 to 7 years, 5 lb. at 8 to 10 years, and (say) 7 lb. or more at 11 to 13 years. The differences existing between the mean statures and weights of children have been reduced by these changes. To-day, average children of the same age in the middle- and lower-income groups are the same height, whilst the average child in the upper-income group is about 2 in. taller. A similar relation holds true for the weight of girls. The average girls in the upper-income group are 2 lb. heavier than girls of comparable age in the middle- and lower-income groups, between whom there are no weight differences. Furthermore, weight differences between comparably aged boys of the three income groups have now been eliminated.

The findings described above differ greatly from those of seventy years ago. At that time average children in the upper-income group were 2 in. taller and 2 lb. heavier than children in the middle-income group, and the latter children were 2 in. taller and 5 lb. heavier than average children of the same age in the lower-income group.

In 1941 the mean stature of men in the upper-income group was 1.41 ± 0.15 in. more than that of men in the lower-income group (Clements and Pickett, 1952). This fact may indicate the interplay of genetic factors (Dahlberg, 1947), and implies that even when children in all income groups are growing at their optimum rate the mean stature of children of the same age in the different groups will differ from one group to another.

It is certain that similar changes have been taking place in other countries during the period under examination. For instance, in Toronto, Canada, typical 6-year-old elementary-school children were 2 in. taller in 1939 than in 1892, 9-year-old children were 3 in. taller, and 13-year-old girls and 14-year-old boys were about 3.2 in. taller. Half of the observed differences have taken place since 1923 (Meredith and Meredith, 1944).

It is clear that the remarkable changes which have occurred in the mean statures and weights of children over the last seventy years are part of a long-term trend in the growth of children. The changes defined not only imply the need of up-to-date height and weight standards for paediatric practice, and the making of corresponding adjustments in the size and relative dimensions of children's clothing and school equipment, but they make it apparent that anthropometric measurements can yield information of great interest.

Summary

Anthropometric measurements of children aged from 5 to 13 years, made between 1880 and 1947, have been standardized and examined.

The average stature and weight have increased by from 2.5 to 3.5 in. and from 4 to 11 lb. respectively over this period, the increases being greatest in the older children.

The increases found are greater than can be accounted for by systematic and random sampling errors, and indicate that, on the average, there has been an acceleration of 18 months' growth. Thus an average 6-year-old child is now of much the same size as one of 7.5 years in 1880.

The rate of increase in mean stature and weight is not constant over the years. It begins slowly, and is first evident in the lower-income group and in the 5- to 7-year-old children in the upper- and middle-income groups. The rate of increase was greatest in the inter-war years, when it was shown by all groups. The upward trend was interrupted during both the first and the second world wars. The increase in the mean measurements has been greatest in the lower-income group, so that the difference which existed in 1880 between the average measurements of children in this group and the middle-income group no longer exists. The differences in stature and weight between average children in the upper- and lower-income groups were 4 in. and 7 lb. in the late nineteenth century and 2 in. and 2 lb. in 1947.

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A METHOD FOR THE RAPID ESTIMATION OF THE PERCENTAGE OXYGEN SATURATION AND OXYGEN CONTENT OF BLOOD

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The manometric method of Van Slyke and Neill (1924) is the standard procedure for the estimation of blood oxygen content and capacity. This manometric analysis is time-consuming and makes heavy demands on laboratory workers. Further, since the reliability of results diminishes with fatigue, the number of blood samples that can be accurately analysed on any single occasion is limited. In this paper a spectrophotometric method of estimating the percentage oxygen saturation, the oxygen capacity, and the oxygen content of blood is described. It employs relatively simple apparatus, allows the rapid analysis of a large number of blood samples, and has been found most valuable in the study of the cardiac output and the investigation of abnormal shunts in the heart and great vessels.

Photometric methods of estimating the haemoglobin content and oxygen saturation of blood have been in use in laboratories for some 20 years; Hall (1934) and various German workers, notably Kramer (1934), described methods which were not, however, suitable for routine use in clinical investigations.

In 1936 Drabkin and Austin described a new type of spectroscopic cell or cuvette of 0.007 cm. depth which enabled them to study haemolysed undiluted blood under anaerobic conditions. Valuable fundamental information was obtained, but the method was not suited to routine estimations on multiple samples. Most of the subsequent methods are based on the data obtained by these workers, who showed that Beer's law (see below) was valid for haemoglobin solutions. These workers (Drabkin and Austin, 1936; Hickham and Frayser, 1949; Nahas, 1951) employ cuvettes and precision spectrophotometers of the Beckman type, and readings are taken at two wave-lengths to increase accuracy.

The method here described is a modification of that devised by Gatman (1952).

Principle of the Method

The method is based on the measurement of the optical density of haemoglobin solutions. The optical density D of any medium is defined by Lambert's law as follows:

$$D = \log_{10} \frac{Io}{I}$$

where Io is the intensity of the incident light and I the intensity after transmission by the medium considered.