CHEST GIRTH OF MEN RELATED TO STATURE, AGE, BODY-WEIGHT, AND SOCIAL STATUS

CHEST GIRTH OF SCOTSMEN MEASURED IN 1941

BY

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INTRODUCTION

The relative growth of parts of the body has attracted considerable attention. It reflects the activity of fundamental biological processes (Thompson, 1917; Huxley, 1932); it underlies the various rules of proportion defined in the field of art (Dürer, 1528); it is the basis of all the schemes put forward at one time or another for classifying men and women into constitutional types (Kretschmer, 1925; Sheldon, Stevens, and Tucker, 1940); to-day endocrinologists and nutritionists regard unusual relationships in growth as important physical signs in several clinical conditions. It is not surprising, therefore, that a variety of anthropometric measurements has accumulated over the years. On the other hand, many of the results are presented in the form of indices, and because these are now recognized to be in many ways unsatisfactory forms of presentation (Tanner, 1949), only the results of some recent surveys are readily available for study.

The analyses of Morant (1945) and O'Brien, Girshik, and Hunt (1941) show that measurements of body length are highly correlated. On the other hand, although measurements of body girth and weight are also correlated, the relationships are complex and have not been fully defined. The purpose of this paper is to discuss the relationship of chest girth (a typical measurement of body girth) to body-weight, stature, age, and socio-economic factors. The data used in this study are those for Scotsmen recorded in 1941 during the medical examinations made before national service, because these records are readily available, and are already the basis of earlier studies of stature and body-weight (Clements and Pickett, 1952, 1954).

TECHNIQUE OF MEASURING

The medical boards were instructed to measure chest girth by the following technique:

The man must stand erect during the measurement of the chest, with his feet together and his arms raised above his head. The tape is then so adjusted that its upper border touches the lower angles of the scapulae behind and its lower border the nipples in front. The arms are then lowered slowly to the sides, the tape being retained in position, and the girth is noted after both extreme expiration and extreme inspiration.

The mean of the measurement of chest girth recorded at extreme inspiration and expiration has been taken as the measurement of chest girth throughout this analysis.

No information exists on the extent of the "observer error" of measurements between medical boards, but measurements of chest girth are known to be subject to variations in technique (Davenport, Steggerda, and Drager, 1934). The mean chest girths of men measured by each board are statistically heterogeneous when examined within the same region and social class, and this may indicate a variation in technique from board to board. On the other hand, reasonably consistent mean chest girths are obtained when the data from the medical boards are pooled and sorted into a large number of groups according to stature and weight (Table VI).

Measurements made to fractions of an inch were converted to the first place of decimals ($\frac{1}{4}$ in. being taken down to 0.2 in. and $\frac{3}{4}$ in. up to 0.8 in. to eliminate bias). A frequency distribution shows that whole numbers are most favoured, followed by measurements of $\frac{1}{2}$ in., $\frac{1}{4}$ in., and $\frac{3}{4}$ in. in that order. Measurements were rarely recorded to eighths of an inch.

RESULTS OF THE ANALYSIS

The mean chest girth for the whole sample of 3,692 records is 34.78 ± 0.03 in. Table I gives the mean chest girth for each region by age groups. The mean chest girth increases with age in every region, but within the same age group the variation is small between geographical regions, although the means of the samples from the Northern Region are consistently the largest. The mean stature and weight of these men were also found in the previous studies to be greater than those of any other regional sample. Table I takes no account of possible differences between the various socio-economic groups of men in the sample, and so the records have been separated into the social classes of the Registrar-General according to the men's stated occupation. Further, the samples from a few small geographical areas, termed "separate" areas, where the mean stature differed significantly from that of the region, have been excluded. The samples for each social class may thus be regarded as homogeneous for socio-economic status and for measurements of stature. Table II gives the mean chest girths of the samples of men according to region and social class. The mean chest girth of the men in Class 1.2 is significantly greater ($P < 0.01$) than the means of either Class 3 or Class 4, but the difference between Class 1.2 and Class 5 is not significant. The

distribution of the measurements of chest girth and the relationship of this measurement to the other variables have been determined for each of the samples in turn.

DISTRIBUTION OF MEASUREMENTS OF CHEST GIRTH.—The character of the distribution of measurements of chest girth was determined by the method described by Snedecor (1946). A significant skewness exists in three out of four samples, and two of the four samples show a significant kurtosis. The data were transformed into logarithms to base 10, and re-tested. The statistic indicating skewness was no longer significant in three out of four of the samples, although little improvement in the degree of kurtosis resulted from the transformation. The mean chest girth in inches derived from an analysis of the data using the logarithmic scale is 34.71 in. The arithmetical mean of the untransformed data is 34.77 in. and the median value 34.51 in. Clearly, the transformation has very little effect on the value of the mean of the distribution.

A comparison of the observed figures after transformation with the calculated frequencies assuming a normal distribution shows that the distribution is not normal ($\chi^2 = 77.6$ d.f. 16). There were no obvious discrepancies in either tails of the distribution, and most of the deviations from

TABLE I
MEAN CHEST GIRTH (in.) FOR REGIONS BY AGE GROUPS (UNSTANDARDIZED)

Region	Age Group (yrs)				All Ages
	17-19	20-29	30-39	40-42	
Southern	34.19 ± 0.16	34.81 ± 0.15	35.23 ± 0.22	(1)	34.76 ± 0.11
West Central .. .	34.22 ± 0.10	34.55 ± 0.10	34.86 ± 0.11	34.41 ± 0.56	34.54 ± 0.06
East Central .. .	34.18 ± 0.11	34.84 ± 0.11	35.02 ± 0.11	—	34.71 ± 0.06
Northern	34.24 ± 0.10	35.02 ± 0.10	35.43 ± 0.09	36.02 ± 0.43	35.04 ± 0.06
Total	34.21 ± 0.06	34.80 ± 0.06	35.18 ± 0.06	35.50 ± 0.36	34.78 ± 0.03

TABLE II
MEAN CHEST GIRTH (in.) FOR REGIONS BY SOCIAL CLASS

Region	Class 1 and 2	Class 3	Class 4	Class 5
Southern	34.78 ± 0.43 (28)	—	34.70 ± 0.21 (85)	—
West Central .. .	34.84 ± 0.20 (105)	34.52 ± 0.08 (542)	34.41 ± 0.15 (188)	34.64 ± 0.14 (174)
East Central .. .	34.97 ± 0.25 (77)	34.52 ± 0.08 (455)	34.74 ± 0.17 (136)	35.00 ± 0.13 (227)
Northern	35.53 ± 0.22 (129)	34.84 ± 0.09 (464)	35.01 ± 0.17 (163)	35.09 ± 0.11 (319)
Total	35.13 ± 0.12 (339)	34.65 ± 0.04 (1,461)	34.70 ± 0.09 (572)	34.95 ± 0.07 (720)

expected frequencies occur in four groups in the centre of the distribution. The frequencies of these groups are alternately greater and less than expected. Transformations of the form $\log(\text{chest measurement} \pm \text{constant})$, where the constant was given arbitrary values varying between 5 and 50, were tried and gave no better results than simply taking the logarithm (to base 10) of the measurement. All the remaining analyses in this paper have been made with the data on chest girth measured on the transformed scale, and referred to as "log chest girth".

The relationship between the mean values may be expressed as follows:

Mean Chest Girth (in.) = $0.54 + 0.99$ Mean Chest Girth (log in.).

The standard deviation of the whole distribution of chest girth in inches is 2.02 in., or 0.025 log in. when the data are measured on the transformed scale.

RELATIONSHIP OF CHEST GIRTH TO WEIGHT.—Measurements of body-weight have been transformed into the logarithm (to base 10) of the weight in lb. and the transformed measurements are referred to as "log-weight" (Clements and Pickett, 1954). The bivariate distribution of log chest girth and log weight is given in Table III. The measurements of log-weight are, for convenience, grouped in intervals of 0.050 log lb., and those of log chest girth in intervals of 0.020 log in., but the computations have been made on the ungrouped data. Clearly, the variables are highly correlated and the calculated coefficient of correlation is 0.77.

If the relationship between two variables is linear, it may be expressed as a regression equation of the form $y = a + bx$, where x and y are variables, a is a

constant, and b is the regression coefficient. The latter statistic indicates the degree of association between the two variables. Curvilinear relationships may be expressed by multiple regression equations which include higher terms of x as additional variables.

Partial regression coefficients relating log chest girth, log-weight, and the square of log-weight, have been computed from the data for the social classes separately, and analysis shows that the coefficients for the separate classes do not differ significantly.¹ On the other hand, the mean log chest girth of the sample of men from each social class differs significantly when weight differences between the samples have been taken into account. These findings indicate that the regressions are parallel and that the coefficients can be pooled, but the constants in the equations will differ according to the social class of the sample.

Further analysis shows that the second degree term (the square of log-weight) is significant and this indicates that the relationship between log chest girth and log-weight is not linear.

The best estimates of the regression coefficients have been derived from the pooled data of the social classes and are:

$$b_1 (\text{relating to log-Weight}) = 0.18 \pm 0.01$$

$$b_2 (\text{relating to (log-Weight)}^2) = 0.043 \pm 0.003$$

The constant takes the following values:

Class 1.2	+ 0.93;
Class 3	+ 0.96;
Class 4	+ 0.95;
Class 5	+ 0.94;
Pooled classes	+ 0.95.

¹ The 1 per cent. level of probability has been taken to indicate statistical significance throughout this paper.

TABLE III
DISTRIBUTION OF CHEST GIRTH (log in.) AND BODY-WEIGHT (log lb.)

Log Chest Girth	Log-Weight									
	1.900- 1.949	1.950- 1.999	2.000- 2.049	2.050- 2.099	2.100- 2.149	2.150- 2.199	2.200- 2.249	2.250- 2.299	2.300- 2.349	2.350- 2.399
1.640-1.659 ..	—	—	—	—	—	—	—	—	1	1
1.620-1.639 ..	—	—	—	—	—	—	—	3	2	1
1.600-1.619 ..	—	—	—	—	1	4	5	10	2	—
1.580-1.599 ..	—	—	—	—	2	32	69	24	1	—
1.560-1.579 ..	—	—	1	10	72	223	131	15	—	—
1.540-1.559 ..	—	—	3	52	405	393	74	2	—	—
1.520-1.539 ..	—	—	33	224	517	166	8	—	—	—
1.500-1.519 ..	—	4	77	214	157	15	—	—	—	—
1.480-1.499 ..	—	6	47	49	12	—	—	—	—	—
1.460-1.479 ..	1	4	11	4	—	2	—	—	—	—
1.440-1.459 ..	1	—	—	—	—	—	—	—	—	—
1.420-1.439 ..	—	—	—	1	—	—	—	—	—	—
99th centile ..	1.4995	1.5171	1.5350	1.5531	1.5714	1.5899	1.6087	1.6277	1.6468	1.6662
Observed mean ..	1.4564	1.4892	1.5066	1.5208	1.5366	1.5528	1.5700	1.5900	1.6217	1.6393
Mean from regressions ..	1.4646	1.4822	1.5001	1.5182	1.5365	1.5550	1.5738	1.5928	1.6119	1.6313
1st centile ..	1.4297	1.4473	1.4652	1.4833	1.5016	1.5201	1.5389	1.5579	1.5770	1.5964

These statistics provide the following relationship:¹

Chest Girth (log in.) = Constant (depending upon social class) + 0.18 log-Weight (log lb.) + 0.043 (log-Weight)².

The observed mean log chest girths and the estimated values derived from the quadratic regression are given for log-weight groups in Table III, and from these it appears that for a unit increase in body-weight (measured in log lb.) the mean log chest girth increases more in the light-weight and heavy-weight groups of men than in the medium-weight groups.

The variances of the distributions of log chest girth within the weight groups are homogeneous according to the test devised by Bartlett (1937). The fact that this distribution is homoscedastic is an additional factor in favour of using the logarithmic rather than the arithmetic scale in analyses of measurements of chest girth.

The 1st and 99th centile limits of chest girth within each weight group have been calculated and are also included in Table III. The results have been transformed into inches, and the regression, 1st and 99th centile lines for chest girth on weight are given in Fig. 1. The values of the 1st centile changed from 26.90 in. for the group of men with a weight of from 80 to 88 lb., to 38.48 in. for the group of men with a weight of 224 to 250 lb., and the values of the 99th centile limit for the same groups are 31.59 in. and 46.37 in. respectively.

¹ The results derived from the linear relationship are very similar in practice: $b = 0.35 \pm 0.01$.
Constant (a) = for Class 1.2 0.75
 Class 3 0.82
 Class 4 0.79
 Class 5 0.78
 Pooled classes 0.80
Chest Girth (log in.) = Constant (depending upon social class) + 0.35 log-Weight (log lb.).

FIG. 1.—Regression, 1st, and 99th centile lines for chest girth on weight. Values calculated in log in. and log lb. have been transformed into linear inches, and pounds avoirdupois respectively.

RELATIONSHIP OF CHEST GIRTH TO STATURE.—A bivariate frequency distribution of log chest girth and stature is given in Table IV. Stature has been grouped into intervals with a range of 2 in. in Table IV, but computations have been carried out on the ungrouped data. The correlation coefficient relating the two variables is 0.37. The Table includes the observed mean chest girth for each stature group, together with the estimated mean values derived from linear regression. The observed and estimated values agree well, although there is some suggestion that the rate of increase in log chest girth is less than expected in tall men. Analysis does not confirm this impression, and the relationship is shown to be linear.

TABLE IV
DISTRIBUTION OF CHEST GIRTH (log in.) AND STATURE (in.)

Log Chest Girth	Stature									
	57-58.9	59-60.9	61-62.9	63-64.9	65-66.9	67-68.9	69-70.9	71-72.9	73-74.9	75-76.9
1.640-1.659 ..	—	—	—	—	—	—	—	1	1	—
1.620-1.639 ..	—	—	—	—	—	—	5	1	—	—
1.600-1.619 ..	—	—	—	—	—	—	2	2	1	—
1.580-1.599 ..	—	—	1	4	6	7	32	13	4	1
1.560-1.579 ..	1	—	5	9	21	47	103	44	8	—
1.540-1.559 ..	—	2	33	126	243	288	172	49	16	—
1.520-1.539 ..	3	11	52	164	308	262	112	31	5	—
1.500-1.519 ..	1	8	47	117	150	102	35	6	1	—
1.480-1.499 ..	—	7	23	30	38	11	4	1	—	—
1.460-1.479 ..	1	1	6	6	6	2	—	—	—	—
1.440-1.459 ..	1	—	—	—	—	—	—	—	—	—
1.420-1.439 ..	—	—	—	—	—	1	—	—	—	—
99th centile ..	1.5650	1.5718	1.5785	1.5853	1.5920	1.5987	1.6055	1.6122	1.6189	1.6257
Observed mean ..	1.5130	1.5138	1.5221	1.5324	1.5373	1.5441	1.5507	1.5567	1.5590	1.5855
Mean from regressions ..	1.5108	1.5176	1.5243	1.5311	1.5378	1.5445	1.5513	1.5580	1.5647	1.5715
1st centile ..	1.4567	1.4635	1.4702	1.4770	1.4837	1.4904	1.4972	1.5039	1.5106	1.5174

The regression coefficients relating log chest girth to stature have been calculated from the data for the social classes separately. Analysis shows that the regression coefficients do not differ significantly, but the mean chest girths for each social class do so. The regression lines are therefore parallel but the constants of the equations will differ from class to class.

The best estimate of the regression coefficient has been derived from the data for the pooled social classes and is 0.0034 ± 0.0002 log inches/inch. The constant takes the following values:

Class 1.2	+ 1.32;
Class 3	+ 1.33;
Class 4	+ 1.28;
Class 5	+ 1.30;
Pooled classes	+ 1.32.

These statistics provide the relationship:

Chest Girth (log in.) = Constant (depending upon Social Class) + 0.0034 Stature (in.).

The variances of the distributions of log chest girth within stature groups having a range of 2 in. are not homogeneous. An inspection of the variances suggests that this finding is attributable to unduly large values in the tallest and in the two shortest groups. These three groups also have the fewest number of observations, and in these circumstances the heterogeneity has been disregarded and the variance for the whole sample taken as the best estimate. The 1st and the 99th centile limits of the distribution of log chest girth in each stature group have been derived from the regression relationship and are given in Table IV. These results have been transformed into inches, and the regression, 1st and 99th centile lines for chest girth on stature are given in Fig. 2.

FIG. 2.—Regression, 1st, and 99th centile lines for chest girth on stature.

RELATIONSHIP OF LOG CHEST GIRTH TO AGE.—A bivariate frequency distribution between log chest girth and age is given in Table V. The age groups used in Table V have a span of 2 years, but the statistics have been computed from the data grouped by intervals of one year. A small correlation exists and the calculated coefficient is 0.19. The mean values show a definite trend. Clearly, the mean chest

TABLE V
DISTRIBUTION OF CHEST GIRTH (log in.) AND AGE (yrs)

Log Chest Girth	Age													
	17	18-19	20-21	22-23	24-25	26-27	28-29	30-31	32-33	34-35	36-37	38-39	40-41	42-
1.640-1.659 ..	—	—	—	—	—	—	—	—	—	1	1	—	—	—
1.620-1.639 ..	—	—	1	—	—	1	—	—	—	—	4	—	—	—
1.600-1.619 ..	—	—	5	—	—	—	—	—	—	—	8	—	—	—
1.580-1.599 ..	—	13	9	3	3	10	16	2	4	17	35	5	—	1
1.560-1.579 ..	—	91	56	5	17	27	33	54	24	44	90	6	5	—
1.540-1.559 ..	—	239	178	4	26	49	63	63	57	69	154	18	9	—
1.520-1.539 ..	1	291	189	11	19	52	43	66	44	49	161	16	6	—
1.500-1.519 ..	1	184	111	3	3	14	18	15	19	21	67	6	5	—
1.480-1.499 ..	1	40	30	—	—	5	—	5	2	8	16	5	2	—
1.460-1.479 ..	—	11	6	—	—	2	—	—	—	—	2	—	—	—
1.440-1.459 ..	—	—	—	—	—	—	—	—	—	—	1	—	—	—
1.420-1.439 ..	—	1	—	—	—	—	—	—	—	—	—	—	—	—
99th centile ..	1.5815	1.5872	1.5922	1.5965	1.5999	1.6025	1.6043	1.6054	1.6057	1.6052	1.6039	1.6017	1.5989	1.5952
Observed mean ..	1.5126	1.5339	1.5358	1.5446	1.5493	1.5438	1.5488	1.5473	1.5438	1.5468	1.5447	1.5398	1.5380	1.6031
Mean from regressions ..	1.5289	1.5340	1.5382	1.5417	1.5443	1.5462	1.5473	1.5476	1.5471	1.5459	1.5438	1.5409	1.5373	1.5329
1st centile ..	1.4764	1.4807	1.4842	1.4869	1.4888	1.4899	1.4903	1.4898	1.4886	1.4866	1.4837	1.4801	1.4757	1.4706

girth increases up to about the age of 30 years, after which the mean measurements slowly decline.

The regression coefficients relating log chest girth to age have been calculated from the data for the social classes separately. Analysis confirms that the second degree term is significant and so the data have been fitted by a quadratic regression. Tests show that the regression coefficients are not significantly different in the social classes, but the mean chest girths for each age group differ significantly. It may be concluded that the regression lines are parallel, in which case the estimates of the coefficients may be pooled, but the constants of the equations will differ from class to class. The estimated values of the regression coefficients for the quadratic relationships are:

b₁ (relating to Age) = 0.0061 ± 0.0008
b₂ (relating to (Age)²) = - 0.000099 ± 0.000014.

The constant takes the following values:

- Class 1.2 + 1.46;
- Class 3 + 1.46;
- Class 4 + 1.45;
- Class 5 + 1.44;
- Pooled classes + 1.45.

These statistics provide the relationship:

Chest Girth (log in.) = Constant (depending on social class) + 0.0061 Age (yrs) - 0.000099 (Age)².

The mean chest girth of each age group derived from the quadratic relationship is given in Table V, and the values compare well over the complete range of ages with the observed mean chest girth.

The variance of the log chest girth distribution is not homogeneous. The variance increases from 0.000530 log in. in men aged 18 years up to 0.000805 log in. in men aged 38-39 years.¹ The observed variances have been smoothed by fitting a linear regression. The resulting smoothed values have been used to provide estimates of the 1st and 99th centile limits of chest girth in each age group (Table V). The results have been transformed into inches, and the

regression, 1st and 99th centile lines for chest girth on age are given in Fig. 3. It is difficult to define the trend of the 99th centile with age because, although the variance increases, the mean decreases. However, the data show that the range of measurements of chest girth between the 1st and the 50th centile is less than that between the 50th and the 99th centile at all ages. The variation also increases with age, the range between the 50th and the 99th centile increasing from 4.46 in. for men aged 18 years to 5.22 in. for those aged 38-39 years.

FIG. 3.—Regression, 1st, and 99th centile lines for chest girth on age.

RELATIONSHIP OF LOG CHEST GIRTH TO STATURE AND LOG-WEIGHT:—The data have been separated into groups according to the measurements of stature and body-weight. Each group has a range of stature limited to 2 in. and a range of weight limited to 0.05 log lb. Thus the men in each group have approximately the same stature and weight. The distribution of log chest girth has been examined within each group with six or more observations, and

¹ The last large sample available.

TABLE VI
MEAN CHEST GIRTH (log in.) OF MEN BY STATURE (in.) AND WEIGHT (log. lb.)

Log-Weight	Stature									
	57-58.9	59-60.9	61-62.9	63-64.9	65-66.9	67-68.9	69-70.9	71-72.9	73-74.9	75-76.9
2.250-2.299 ..	—	—	—	—	1.5988	1.5975	1.5906	1.5773	—	—
2.200-2.249 ..	—	—	—	1.5900	1.5727	1.5730	1.5670	1.5670	1.5627	—
2.150-2.199 ..	—	—	1.5460	1.5595	1.5538	1.5527	1.5511	1.5525	1.5370	—
2.100-2.149 ..	—	—	1.5434	1.5400	1.5360	1.5358	1.5351	1.5256	1.5399	—
2.050-2.099 ..	—	1.5164	1.5250	1.5212	1.5190	1.5211	1.5206	—	—	—
2.000-2.049 ..	—	1.5109	1.5047	1.5061	1.5044	1.5090	—	—	—	—
1.950-1.999 ..	—	—	1.4793	—	—	—	—	—	—	—

the mean log chest girths of the groups of men are given in Table VI. Reading the entries vertically, each column shows a steady increase in mean chest girth associated with increase in weight within each stature group. Reading the Table horizontally, each row shows the mean log chest girth tends to fall slightly with increasing stature in the same weight group.

The estimates of the standard deviations made for each group are very similar, with two exceptions probably attributable to sampling variation, and they have been averaged. The mean value is 0.0165 log in., and this estimate has been used as a measure of the variability in each sample. Clearly, the variability is considerable, and the upper end of the distribution of chest girth in one group overlaps considerably the lower end of the distribution in the next largest group, and so on. Trends in measurements of chest girth associated with changes in stature and body-weight may be expressed quantitatively by the partial regression coefficients derived from a multivariate analysis, and these have been calculated from the data for the social classes separately. Analysis shows that the coefficients for each class do not differ significantly but that the mean chest girths do so after standardizing for differences in stature and log-weight. The estimates of the coefficients may be pooled therefore, but the constants of the equations will differ from class to class.

The best estimates of the coefficients have been derived from the data for the pooled social classes:

The partial regression coefficient relating log chest girth and log-weight, keeping stature constant, is $b_{y1.2} + 0.38 \pm 0.01^*$.

The partial regression coefficient relating log chest girth and stature, keeping log-weight constant, is $b_{y1.2} - 0.0012 \pm 0.0001^*$.

The constant of the equation is:

Class 1.2	+ 0.79;
Class 3	+ 0.83;
Class 4	+ 0.79;
Class 5	+ 0.79;
Pooled classes	+ 0.80.

These statistics taken together establish the following relationship:

Log Chest Girth = Constant (depending upon social class) + 0.38 log-Weight - 0.0012 Stature (in.).

The partial regression coefficients indicate that chest girth increases at the rate of 0.38 log in. for each unit increase in weight expressed as log lb. in men with the same stature but with different weights. On the other hand, chest girth decreases at the rate of 0.0012 log in. for each unit increase in stature amongst men of the same weight but varying stature.

RELATIONSHIP OF LOG CHEST GIRTH TO STATURE, LOG-WEIGHT, AND AGE.—The relationship of log chest girth to the variables of stature, log-weight, and age taken together requires consideration. The technique of multivariate analysis, employed in the previous section to study variations associated with weight and stature, may be extended to include age as an extra variable. The partial regression coefficients of stature, weight, and age have been derived from the data for the pooled social classes, and all the coefficients are significant. An analysis of the data for Social Class 3 indicates that the second degree term for weight is significant, but this term has not been taken into account in the analyses of the main samples. The second degree term of age is not significant when the variables of stature and weight are taken into account.

The partial regression coefficient relating log chest girth and log-weight, keeping stature and age constant, is $b_{y1.23} = 0.37 \pm 0.01^*$.

The partial regression coefficient relating log chest girth and stature, keeping log-weight and age constant, is $b_{y2.13} = + 0.00034 \pm 0.00004^*$.

The partial regression coefficient relating log chest girth and age, keeping log-weight and stature constant, is $b_{y3.12} = - 0.00097 \pm 0.00013^*$.

These statistics taken together establish the following relationship:

Chest Girth (log in.) = 0.80 + 0.37 log-Weight (log lb.) + 0.00034 Age (yrs) - 0.00097 Stature (in.).

The multiple coefficient of correlation $R = 0.80$.

The partial regression coefficients given in the above equation express quantitatively the changes in chest girth attributable to each unit increase in the variables of weight, age, and stature.

GEOGRAPHICAL VARIATION.—Table II presents the mean chest girths of men for the regions and the social classes defined by the Registrar-General. As has already been observed, the largest mean chest girth in each social class occurs in the sample from the Northern Region. Such a finding in unstandardized data may simply reflect the geographical variation already determined from measurements of stature and weight, because chest girth is correlated with these variables. On the other hand, chest girth may vary independently of the other measurements. Before the facts can be established, the data on chest girth must be standardized so as to take into account

* Where y represents the variable of log chest girth.
 x_1 represents the variable of log weight.
 x_2 represents the variable of stature.
 x_3 represents the variable of age.

differences in the other known variables. In this analysis, tests of significance have been made by a covariance analysis taking stature, weight, and age into account. The examination shows that a general heterogeneity exists and that no homogeneous samples can be provided for the social classes by separating out areas with unusual chest girths. The actual extent of the difference between the means is very small, but the statistical tests are sufficiently sensitive, after carrying out the standardizing procedures, to differentiate one medical board from another within the same region. The finding may reflect a genuine variation from area to area; on the other hand the finding may represent a variation in the measuring technique between the boards. Clearly, the technique of measuring girths of the body must be rigorously standardized before differences between samples can be regarded seriously as indicating definite geographical variation.

SOCIAL CLASS.—The heterogeneity of the samples for geographical factors can be disregarded when examining the significance of differences between the social classes, if the assumption is justified that each medical board contributes a similar proportion of men to the different groups under examination. The distribution of men in the different social classes in the medical boards is not seriously heterogeneous, and a comparison between them is justified. The unstandardized mean values of the chest girth of men by region and social class are given in Table II. The mean values of the chest girth after being transformed into inches and standardized for stature 67 in., weight 2·1399 log lb. (138 lb.), and age 26 yrs, are as follows:

<i>Social Class</i>	<i>Standardized Mean Chest Girth (in.)</i>			
1.2	..	..	..	34·71
3	..	..	..	34·79
4	..	..	..	34·80
5	..	..	..	34·81

$P > 0\cdot01$

The mean measurements are all very similar and the differences are not significant. All the previous tests showed that the mean chest girths of men in various social classes differed significantly, but in these tests only one variable was standardized at a time, and in one other case two variables (log-weight and stature) were taken together. Clearly, if age is included with stature and weight, and the data are standardized, separation of data into social classes is unnecessary.

DIFFERENCES BETWEEN MEN CLASSED AS FIT AND UNFIT FOR MILITARY SERVICE.—Assuming that the proportion of fit to unfit men is much the same in each medical board, and in this way disregarding the heterogeneity of the samples for the geographical factor, analysis shows that fit men have a greater chest girth than unfit men, although the actual difference is very small in amount. The standardized mean chest girth in inches after conversion from the transformed data is:

<i>Class</i>	<i>Mean Chest Girth (in.)</i>			
Fit	..	..	..	34·85
Unfit	..	..	..	34·64
Unclassified	..	..	..	34·97

$P < 0\cdot01$

DISCUSSION

A considerable variation exists in measurements of chest girth in men with similar statures and body-weights. For example, in the group of men with a stature of from 63 to 64·9 in. and a weight of from 2·05 to 2·09 log lb. (112–124 lb.), 10 per cent. have a chest girth of 31·6 in. or less, and 10 per cent. a chest girth of 34·9 in. or more. The chest girth of 55·6 per cent. of individuals in the next heaviest group, men weighing from 2·10 to 2·14 log lb. (125–139 lb.), in the same stature group, is less than 34·9 in.

How much of the variance existing in the measurement of chest girth is attributable to constitutional factors, and how much to variations in nutrition is not known, but frequently these two factors are confused. Sometimes anthropometric measurements, such as, for example, the relationship of weight and stature, are employed as indices of nutrition, and at other times as a means of classifying men into physical types.

Sheldon, Stevens, and Tucker (1940) employed the ratio of chest girth to stature to distinguish between their factors of mesomorphy (muscle) and endomorphy (body fat), and found that men with a high factor of endomorphy tended to have the higher index. It may therefore be supposed that men with a larger chest girth for the same weight have a higher factor of endomorphy than men with smaller chest girths. It was noted earlier that the mean chest girth increases more rapidly in both light-weight and heavy-weight groups than in the medium-weight groups. This observation may indicate that the changes in weight at either end of the weight distribution are mainly associated with changes in the fatty tissue.

The separation of men into groups each comprising men with much the same stature and weight (such, for example, as the groups in Table VI) provides a convenient framework within which to study body constitution. Variations in human physique have been studied recently by means of factor analysis (Burt and Banks, 1947; Hammond, 1942) and a general factor for size was defined first. The regression line relating stature and log weight indicates that, on the average, an increase in stature is accompanied by an increase in weight. Bigness in one dimension is associated with bigness in another. In other words, the regression has much the same biological interpretation as the general factor, and both express the principle of isogonic growth (Huxley, 1932). The variance from the regression line relating log weight and stature distinguishes between men of spare and stout physique, and the first bipolar factor defined by factor analysis achieves the same object. The second factor, according to Burt and Banks, separates measurements of girth into two groups; in their analysis, abdomen and hip girths were separated from shoulder girth and weight. The variance of chest girth within the groups of equal stature and weight may possibly be related to this factor.

The regression coefficients of chest girth on weight determined for men in the various social classes in Scotland do not differ significantly, and the same stability of coefficients is found in those relating chest girth to stature to stature and age respectively. There can be little doubt that most regression coefficients relating anthropometric measurements do not vary within a wide range of conditions. This stability is of considerable practical importance, because when once a relationship has been established it can be applied confidently to other sections of the same community. On the other hand the factors which may be associated with different regression relationships will be of great biological interest.

SUMMARY

(1) Statistics on the chest girth of men living in Scotland have been derived from a sample of records of the medical examinations made by the Ministry of Labour and National Service in 1941.

(2) Measurements of chest girth have a skew distribution, but a more satisfactory distribution for analysis is obtained by transforming the measurements into logarithms to base 10.

(3) Chest girth is related to other variables by the following regression equations:*

(a) To Weight:

$$\text{Log Chest Girth} = 0.80 + 0.35 \log\text{-Weight} \\ (\text{or more accurately}) = 0.95 + 0.18 \log\text{-Weight} \\ + 0.043 (\log\text{-Weight})^2.$$

(b) To Stature:

$$\text{Log Chest Girth} = 1.32 + 0.0034 \text{ Stature}.$$

(c) To Age:

$$\text{Log Chest Girth} = 1.45 + 0.0061 \text{ Age} - 0.000099 (\text{Age})^2.$$

(d) To Weight, Stature, and Age together:

$$\text{Log Chest Girth} = 0.80 + 0.37 \log\text{-Weight} - 0.00097 \text{ Stature} + 0.00034 \text{ Age}.$$

(4) The mean chest girths of men by age groups show an upward trend until about 30 years of age, which is succeeded by a slow downward trend.

(5) The material has been standardized for differences in stature, weight, and age, and the following facts have been established:

(a) In the samples for each social class, the mean chest girths of men measured by different medical boards differ significantly. Whether the finding should be attributed to differences in measuring technique or to real geographical differences is not known.

(b) The mean chest girths of men in different social classes do not differ significantly.

(c) The mean chest girth of the sample of fit men is 0.21 in. greater than that of unfit men.

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* Log Chest Girth is measured in log in.
 Log-Weight is measured in log lb.
 Stature is measured in linear inches.
 Age is measured in years.