Brit. J. prev. soc. Med. (1962), **16**, 189

A NEW WEIGHT-FOR-HEIGHT STANDARD BASED ON BRITISH ANTHROPOMETRIC DATA

BY

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It was concluded in a previous paper (Billewicz, Kemsley, and Thomson, 1962) that the ratio of observed to standard weight is the simplest and most reliable index of adiposity, provided that the standard is suitably chosen. This ratio has obvious advantages: it is easy to calculate, the values obtained do not depend on the units of measurement, and if the mathematical model presented in the previous paper gives a good approximation to reality the ratio should also yield results which are clinically and statistically consistent. The idea of using the ratio of observed to standard weight as an index to adiposity is, of course, not new. Indices of this type have been used in the past, though lately there has been a tendency to use instead various "formula" indices, notably the "Ponderal Index". We suspect that the reluctance of research workers to use standard weights stems from the difficulty of finding suitable standards and from the idea that the use of standards implies the acceptance of standards as "ideal" or "desirable" weights. In this paper we present British weight-for-height standards, examine the properties of the ratio of observed to standard weight, and consider the applicability of this ratio to a variety of situations.

The weight-for-height standard most commonly used in Britain is derived from the actuarial data collected in America towards the end of the 19th century (Medico-Actuarial Investigation, 1912). In the absence of generally-accepted standards based on British data, Davidson, Meiklejohn and Passmore (1959) recommended the continued use in Britain of this standard, in preference to more recent American actuarial data, on the grounds that it agrees more closely with recent British measurements.

These actuarial standards include the weight of clothing and the height of footwear, but the appropriate allowances for them are not usually specified. The data were derived from part of the American population, namely from those whose lives were proposed for insurance. They were, therefore, subject to some measure of self-selection, although it is not known whether or how far this has affected the standards, for example, by producing a bias towards certain income groups. In the latest set of American standards (Metropolitan Life Insurance Company, 1959) ranges of "desirable" weights are given for individuals of a given height and "frame" aged 25 years and over. It is clear from the text that the desirable weights are those associated with lowest mortality experience, but no definition of "large", "medium", or "small" frame is given.

PURPOSES OF A STANDARD

A set of standards may serve several purposes, and to avoid confusion it is first necessary to say something about the three main uses to which weight-for-height standards may be put. Examples are given towards the end of this paper.

(*i*) *As a reference base for comparisons or for regression analyses*

It may be desired, for example, to compare weights in two groups which differ appreciably in height. For this purpose, any statistic that describes the behaviour of weight in relation to height will serve to correct for the height differences. The mean or median weight at a given height is usually the most convenient, but there need not be an inference that the mean or median used refers directly to the population from which the subjects being studied are drawn. Thus, American data would serve perfectly well as the reference base in the analysis of British clinical data, even if the average American is (say) heavier than the average Briton, because American and British weight-for-height data appear to have the same general statistical properties.

(ii) As a "control" as well as a standard of reference

Here the standard must have the same statistical properties as the above, but it is also necessary to assume that the subjects form a sample drawn from the population from which the standard is derived. Thus, if an American standard based on a relatively heavier population is used in Britain, it cannot readily be used to conclude that a British sample is overweight or underweight, by comparison with the general population in Britain.

It is perhaps worth pointing out that such an American standard can be used indirectly to investigate whether a particular British sample is under- or overweight if a "control" sample is first drawn from the appropriate British population. The two samples may then be compared using the American standards as a reference base as in the use described as type (*i*). Though it will usually be better to use the standard proposed here rather than to adopt this roundabout approach, the device is worth considering when dealing with a sample from a restricted population, for example, a particular socio-economic group.

(iii) As "target" weights

The properties needed for the uses described in (*i*) and (*ii*) are purely statistical, and no value judgments are made or implied. But if the standards are stated or inferred to be "desirable" or "ideal" weights, there must be an external clinical or actuarial criterion. Such a criterion is, of course, explicit in the ranges of desirable weights published by insurance companies, and it may to some extent apply also to actuarial averages based upon life policies. How far the latter is the case will depend on the degree of self-selection and whether the averages are restricted to accepted proposals, and if so, how far the policy of the company in accepting life insurances is influenced by these figures of desirable weights.

The standards described below are essentially those of type (*i*) but, since they are based on fairly recent British data, they will also serve for some time to come as a guide in Britain for the uses described under type (*ii*). The ranges proposed are statistical; no direct conclusions can be drawn as to their uses and limitations as health standards, but a guide can be obtained through comparisons with actuarial data.

METHOD

The standards are based on measurements of 4,325 men and 10,423 women aged 20–29 years who were measured in Britain in 1943 (Kemsley, 1950). The subjects were measured clothed and usually wearing shoes or boots, but in constructing the standard the data were adjusted to approximate nude weight, and to height without footwear. For this purpose deductions of 10 lb. and 6 lb. were made from the weight of men and women respectively, and deductions of 1 inch and 1½ inches respectively from the height: these allowances were based on information collected during the course of the inquiry in 1943.

Further results from the same data were set out in a later paper (Kemsley, 1952), including a set of standards similar in some respects to those now proposed. However, the data have been recalculated and reduced to a simpler and more manageable form. The crude data were smoothed where necessary in order to eliminate obvious irregularities due to small numbers.

As is well known, weight tends to increase with age, and a case could be made for using different standards for different age groups, as is done in actuarial standards. But it is now generally agreed that, ideally, weight should not increase above that which is "normal" at about age 25 (National Research Council, 1958). For this reason, we have preferred to use the same standard, based on the measurement of young adults, for all adult age groups. An increasing ratio of observed to standard weight will then reflect the tendency towards corpulence in middle life which is indicated by experience. For some purposes, it is necessary to differentiate the amount of increase probably attributable to age from that attributable to disease. We have therefore calculated "adjustment factors" which will permit allowance to be made for the age effect, when required.

The central standard used is the median weight at each inch of height; to this we have added the quartile values. The upper quartile may be taken as an arbitrary lower limit of "overweight" and the lower quartile as an arbitrary upper limit of "underweight". The clinical values implicit in these terms will be discussed below.

RESULTS

Table I gives the standards. It has been shown in a previous paper (Billewicz, Kemsley, and Thomson, 1962) that indices of adiposity should not be correlated with height. Table II shows that the values of the ratio of observed weight to standard weight remain quite constant throughout the range of heights, at all percentiles (unsmoothed) of the weight distributions. The data on which Table II is based were derived from about 6,000 primigravidae measured in Aberdeen between 1949 and 1959; weights at the 20th week of pregnancy were corrected to pre-pregnant weights by subtracting 9 lb. (Thomson and Billewicz, 1961). The choice of the sample for this illustration does not affect the main point of Table II, which is to show that the application of the standards to a completely independent sample produces a set of indices fully consistent with the model described in our previous paper. Results similar to those in Table II have been obtained by using other measurements, including those of British men.

Ratios of observed to standard weight are quite closely associated with independent estimates of total body fat (based on measurements of body density), and can therefore be used with reasonable confidence as indices of relative adiposity. Using the data of Allen, Peng, Chen, Huang, Chang, and Fang (1956), the correlation coefficients for men and women are 0·72 and 0·79 respectively; while the data of Brockett, Brophy, Konishi, Marcinek, Grotheer, Michalowicz, Kashin and Grossman (1956) for men yield a coefficient of 0·60. The subjects of Allen and others' inquiry were the Chinese staff of Taiwan National University, and those of Brockett and others' inquiry were well-trained American infantrymen, probably of above average muscularity. In these data, the correlations between the ratios and height and between height and relative adiposity are so small as to be negligible.

As mentioned above, it may be convenient for some purposes to allow for the effect of age on adiposity. Table III provides the appropriate adjustments to the standard weights. For example, if we wish to allow for the effect of age, the standard for a woman aged 37 and 63 in. tall becomes:

$$118 + 5 = 123 \text{ lb.}$$

TABLE III

ADJUSTMENTS TO BE ADDED TO THE STANDARDS OF TABLE I TO ALLOW FOR AGE, BY SEX

Age (yrs)	Weight Adjustment (lb.)	
	Men	Women
30–34	5	5
35–39	5	5
40–44	10	10
45–49	10	15
50–54	5	15
55–59	5	15
60–64	5	15

TABLE I

STANDARD NUDE WEIGHTS FOR BRITISH ADULTS (lb.)

The low and high weights cut off approximately the lower and upper 25 per cent. of the weight distribution at each height

Sex		Height without Shoes (in.)																		
		56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74
Men ..	Low ..	—	—	—	—	102	105	109	112	115	119	122	126	129	133	136	140	143	146	150
	Standard..	—	—	—	—	**108**	**112**	**116**	**120**	**123**	**127**	**130**	**134**	**138**	**141**	**145**	**149**	**152**	**156**	**160**
	High ..	—	—	—	—	116	119	124	128	132	136	140	143	147	151	155	159	163	167	171
Women	Low ..	89	92	95	98	100	103	106	109	112	115	118	121	124	126	129	—	—	—	—
	Standard..	**96**	**99**	**102**	**105**	**108**	**111**	**114**	**118**	**121**	**124**	**127**	**130**	**133**	**136**	**139**	—	—	—	—
	High ..	104	108	111	114	118	121	124	128	131	134	138	141	145	148	151	—	—	—	—

TABLE II

OBSERVED/STANDARD WEIGHT RATIOS AT VARIOUS PERCENTILES OF THE DISTRIBUTIONS OF BODY WEIGHT IN 6,627 WOMEN

Percentile	Height (in.)										
	–58	58–	59–	60–	61–	62–	63–	64–	65–	66–	67–
10	86	87	85	91	87	87	88	88	90	88	91
25	92	93	92	93	93	94	94	94	94	94	96
50	100	99	99	100	100	101	100	101	101	102	102
75	109	107	107	107	108	109	108	109	109	109	111
90	120	115	115	118	117	118	117	118	117	117	121
Numbers	109	183	403	809	1,046	1,224	1,077	838	511	268	159

To adjust low and high weights for age, Table IV has been provided; this gives the ratios of the lower and upper quartiles to the median for each age group, because these values are best calculated by first finding the median for the required age and then applying the appropriate multiplier. For example, the lower and upper quartiles, that is the low and high weights, for a woman of 37 and height 63 in. are respectively:

112 lb. (=123 × 91/100) and 137 lb. (=123 × 111/100)

TABLE IV

MULTIPLIERS TO CONVERT STANDARDS TO LOW AND HIGH WEIGHTS

(Lower and upper quartiles as percentage of median)

Age (yrs)	Men		Women	
	Low	High	Low	High
30–34	94	107	92	110
34–39	94	107	91	111
40–44	94	108	90	112
45–49	94	109	90	113
50–54	94	109	89	114
55–59	94	110	89	114
60–64	94	110	89	114

DISCUSSION

The standards described above are based on measurements made in Britain during the Second World War. To what extent are they likely to have been influenced by the absence of many servicemen overseas, and by the imposition of rationing?

The 1943 anthropometric survey was continued in a restricted form until 1950, repeat measurements being made on many of the same individuals (Kemsley, 1950). The results showed a slight increase in average body weight in the age group 20 to 29 yrs, less than 1 lb. for men and less than 3 lb. for women. This suggests that the effect of wartime rationing on body weight was trivial. In samples of men measured by the Ministry of Labour in 1941 before they were called up for national service, average weights at each height were a pound or two greater than the standards shown in Table I. The same is true of a comparison between the standards and more recent measurements of Army recruits (Rosenbaum, 1954). It therefore appears that our standards are little affected by wartime conditions. The standards for women agree remarkably well with recent (corrected) measurements of pregnant women in Aberdeen.

The continuation of the 1943 anthropometric survey indicated greater increases of weight-for-height at older ages than in the age group 20 to 29 yrs (Kemsley, 1953).

The figures in Table III include an allowance for the post-war change, and have been rounded to the nearest 5 lb., partly because the extent of the increase in weight is not known exactly and partly because there may have been further changes since 1950. All the data collected since 1943 indicate that the shape of the distribution curve of weight has not changed, and it is best to compute "high" and "low" weights at older ages directly from the median for the appropriate age by using the multipliers given in Table IV. Strictly speaking, these age adjustments should also vary with height, because the regression of weight on height is not quite invariant with age. But the effect is slight and, in view of the approximate nature of the data in Table III, may be ignored.

We believe that the standards can be used with reasonable confidence as "control" weights for current British samples (purpose (*ii*) as described on p. 190 above). As time passes, the standards may become obsolete from this point of view, especially if food remains plentiful and mechanization continues to increase. But, from trends in earlier British data and in American actuarial standards over the past 60 years, it would appear that secular changes are likely to be slow in developing.

Our standards for women correspond quite well with actuarial standards for American women, both at the end of the 19th century (Medico-Actuarial Investigation, 1912) and more recently (Hathaway and Foard, 1960; Metropolitan Life Assurance Company, 1959). It appears that American women show much the same weight-for-height characteristics as British women, and that there has been little change during the past half-century. But the older American standards for men are about 5 lb. greater at each height, and weight-for-height has continued to increase, so that American men are now 10–15 lb. heavier than British men, at each height.

Despite such secular and international differences, it appears that our standards—and any other standard derived and constructed in a similar way—can be reliably used as a statistical reference base (Purpose (*i*), above) without regard to obsolescence or race.

The Figure (opposite) shows some regressions of weight on height for several nationalities and races. The lines are very nearly parallel. No attempt has been made to adjust the data for weight of clothing and height of shoe heels, so that the vertical positioning of the lines does not necessarily reflect real differences of weight. But since the slopes of the lines are so similar, the regression of weight on height can be regarded as fairly constant under all

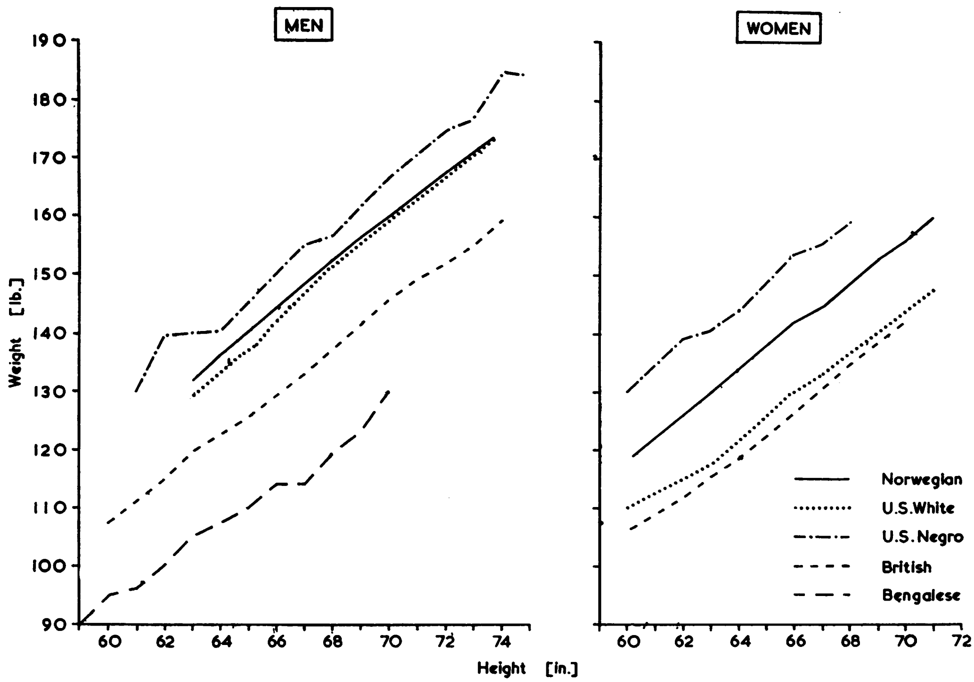

FIGURE.—Comparison of slopes in weight for height data.
Bengalese —Majumdar and Rao, 1958.
British —Standards from Table I of this paper.
Norwegian —Lindberg and others, 1956.
U.S. (White)—Hathaway and Foard, 1960 (Table 80).
U.S. (Negro)—Hathaway and Foard, 1960 (Tables 44 and 45).

the conditions for which data are available. Though the standards in Table II can be used as a basis for the statistical analysis of anthropometric data in countries other than Britain, the age adjustments in Table III should be used only if it is known that they are of a similar order in the population being studied.

It is also relevant to inquire whether the use of the standards may be affected by social class differentials in the weight-height relationship. Educated women may, for example, be relatively more susceptible to propaganda which describes obesity as unfashionable or undesirable; and wealthy men may be relatively more exposed to a way of life that leads to obesity. We cannot at present answer this question directly, but we know of no data that demonstrate the presence of a significant social class difference in the relationship of weight to height. In an unselected population of more than 4,000 primigravidae from all social strata in Aberdeen, the shapes of the weight distribution curves were similar throughout the range of heights; though the variance of weight increased with height, the coefficients of variation were similar throughout. Tentatively, therefore, we think that the standards can be accepted as a relevant reference base for all social groups, in Britain at least.

As already mentioned, the adoption of quartile values to represent the limits of "underweight" and "overweight" is entirely arbitrary. These correspond to ratios of observed to standard weight of about 94 and 107 per cent. respectively for men and of about 93 and 109 per cent. for women. These percentages can be deduced from Table I, and they are also consistent with the trends shown in Table IV; incidentally, the ratios for the Aberdeen sample are also similar (Table II). It is not uncommon in the literature to find that 10 per cent. above or below standard weight has, quite arbitrarily, been assigned as the dividing point for over- or under-weight. These limits may be unnecessarily extreme, particularly for underweight individuals, since they ignore the skewness of the weight distribution. Moreover, our quartile values agree reasonably well with the limits of desirable weight for men and women of "medium frame", as specified by the Metropolitan Life Assurance Company (1959).

Again, quartile values were used by Hathaway and Foard (1960) to connote "high" and "low" weights at each height. There is, accordingly, a *prima facie* case for supposing that the limits of "high" and "low" weights given in Table I, though based entirely on statistical parameters, may also serve as crude limits of "underweight" and "overweight" in the clinical sense.

TABLE V
WEIGHT INDICES FOR BUS DRIVERS AND CONDUCTORS

Age-adjusted Index	Bus Drivers		Bus Conductors	
	No.	Per cent.	No.	Per cent.
109+	21	49	9	28
93–108	13	30	15	47
-92	9	21	8	25
Total	43	100	32	100

EXAMPLES ILLUSTRATING SOME USES OF THE STANDARDS

The method of using the standards depends upon the question to be answered. The following examples may help to clarify the general principles.

We may wish to know whether overweight is characteristic of patients suffering from myxoedema. Since many of such patients are middle-aged, age as well as height should be taken into account. In eight cases of myxoedema described by Muldowney, Crooks, and Wayne (1957), the mean index of observed to standard weight, after adjusting for age, was 117 (S.E. 3·5). The result is significantly greater than 100, and suggests that the patients were, on average, significantly overweight.

With larger groups, it may be helpful, after calculating values of the index for each subject, to divide them into three index groups: 92 and under, 93–108, and 109 and over; the boundaries correspond approximately to a 25 : 50 : 25 division of a "normal" population. Heady, Morris, Kagan, and Raffle (1961) have shown that London bus drivers, who have a relatively higher rate of death from coronary heart disease than bus conductors, are also older, taller, and heavier, and have a greater waist girth; the ponderal index indicates that conductors are, on average, lighter than the drivers. Their paper does not show whether drivers are relatively overweight compared with a normal standard, but we have been given access to some of the original data so that we could examine this problem. Table V shows the distribution of index values (corrected for age) in drivers and in conductors; it appears that overweight is unduly frequent among drivers, while the weights of conductors are about normally distributed.

The significance of the difference between two frequency counts, such as those shown in Table V, is easily assessed by means of the χ^2 test; in this example, the difference is not significant. It should be noted that the test is designed to find out whether the two samples could have been drawn from a population defined by the combined samples, not whether either sample differs from the standard population. Furthermore, since the χ^2 test takes no account of the "direction" of differences, it is rather insensitive, and a test based on scores (Armitage, 1955) is likely to be more appropriate. If we want to compare each group with the standard, then the ordinary t-test on indices with $\mu = 100$ is applicable to each group and shows that the bus drivers have a mean index of 109·3 (S.E. 2·7), which yields a value of t significant at 1 per cent., indicating that bus drivers have higher index values (*i.e.* weight-for-height) than those specified by the standards.

Such tests of significance are valid irrespective of whether or not the reference base is actually applicable to the group under investigation provided that, as mentioned before, the slope of the regression of weight on height and the age corrections apply reasonably well to the group being studied.

While we have stated, above, that the "high" and "low" standards in Table I may serve as crude guides to "overweight" and "underweight" in the clinical sense, it should be noted that the evidence is highly tenuous and indirect. It might, therefore, be misleading to conclude from Table V that, for example, about half the bus drivers were overweight to an unhealthy degree. This would have to be proved, by using some external criterion of health.

Finally the use of the standards in regression analyses may be illustrated from data published by Crooks, Bluhm, and Muldowney (1959). These authors found that a better estimate of total exchangeable sodium (Na^e) is obtained from a regression on lean body weight than from one on total body weight. Since the estimation of lean body mass from determinations of total body water is time-consuming, it seemed worthwhile to inquire if the regression of Na^e on body weight and an index of adiposity would yield a satisfactory estimate of Na^e. In this example, we want to correct for body fat, irrespective of age, and the use of the standards in Table I is indicated without correction for age. From the published data, we have found by regression analysis that an estimate of Na^e based on total weight and the ratio of observed to standard weight gives estimates of Na^e as precise as those based by the authors on lean body mass. Since the average relative adiposity of males is different from that of females, two regression equations must be obtained. These lead to multiple correlations of 0·62 and 0·89 for males and for females respectively, which are almost identical with the correlations between lean body mass and Na^e obtainable for the two sexes from Table I of the above mentioned paper. In this example, there is no implication that the standards represent "ideal" weights, and age was disregarded. It would be equally possible to ascertain the effects of age and adiposity separately by using age and the unadjusted standards as variables in a regression analysis.

SUMMARY

(1) New weight-for-height standards based on British data are described.

(2) The validity of the standards is examined and established and comparisons are made with other data.

(3) The standards are supplemented with figures which provide a working definition of underweight and overweight.

(4) Various uses of the standards are described and illustrated by examples.

We wish to thank Dr. J. N. Morris and Mr. J. A. Heady for providing information on some of the bus drivers and conductors studied by them, and Dr. J. Crooks for advice and criticism.

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