Original Research Communications—methods

Relative merits of the weight-corrected-for-height indices[1-3]

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ABSTRACT Based on weight and height data on 35,523 subjects representing both sexes, ages 18 yr and over, and five diverse ethnic populations, the obesity index W/H^p (p is derived from the observed weight-height data) was compared with the traditional obesity indices (W/H, W/H^2, W/H^3, and $H/W^{1/3}$) in terms of maximum correlation with weight and minimum correlation with height (i.e., unbiased by height). Of the traditional indices, W/H and W/H^2 were highly correlated with weight, but W/H^3 and $H/W^{1/3}$ were only moderately correlated with weight in each ethnic-sex-specific population. The indices W/H^3 and $H/W^{1/3}$ were substantially more biased by height than were W/H and W/H^2 in each population. Of the two latter indices, W/H^2 was less height-biased in the male populations whereas W/H was less height-biased in the female population. However, all four indices, except W/H^2 in Chinese males, were significantly correlated with height ($p < 0.05$) in each population. The index W/H^p was highly correlated with weight and virtually independent of height in each ethnic-sex specific population. More importantly, W/H^p was also independent of height in an admixture of heterogeneous populations. This independence of height in pooled data makes the index invaluable for use in epidemiological and nutritional studies, where a single index must be used for comparing obesity among different populations. The relationship of each obesity index with weight and height did not materially change with age adjustment. The statistical results showed W/H^3 and $H/W^{1/3}$ to be the least satisfactory indices of obesity, W/H and W/H^2 to be acceptable only in specific populations, and W/H^p to be decidedly the most suitable index in all populations. W/H^p should be routinely adopted as a weight-height-derived index of obesity. *Am. J. Clin. Nutr.* 34: 2521–2529, 1981.

KEY WORDS Weight-corrected-for-height indices, obesity indices, power-type weight-height indices, bias in comparison studies, adiposity, relative weight

Introduction

Many nutritional and epidemiological studies are concerned with comparing obesity indicators among different study populations. Although obesity should ideally be assessed by direct measures of the degree of fatness, such as skinfold thickness or other more elaborate laboratory methods such as somatotyping and hydrostatic determinations of density, these measurements are generally impractical to collect in large-scale nutritional and epidemiological investigations. Accordingly, a weight-corrected-for-height index derived from body weight (W) and height (H) data is used for measuring, although indirectly, obesity among study subjects. The underlying assumption in using the weight-corrected-for-height index is that body weight, after correc-

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tion for height, is highly correlated with a direct measure of obesity. But in the absence of a direct measure of obesity for comparison, a weight-height derived index should at least be consistently highly correlated with body weight and independent of height in diverse populations.

There are two distinct types of weight-corrected-for-height index, or simply "obesity index." The first, known as the relativve weight index, expresses weight of a given subject as a percentage of the average weight of persons of the same height. The general characteristics of this index and its effectiveness in assessing obesity have been examined by a number of investigators (1–3). The second type of obesity index, referred to as the power-type index, either expresses weight relative to some power function of height or height relative to some power function of weight. The traditional power-type indices include the weight-height ratio (W/H), Quetelet's index (W/H^2), and the ponderal index ($H/W^{1/3}$). Because the ponderal index has the disadvantage of being negatively related to body weight, Khosla and Lowe (4) proposed an index in the form of W/H^3 which they claimed to be an equivalent expression for the ponderal index except that their index is positively related to body weight.

Since there are several competing power-type indices that are purported to measure obesity and that have been used to varying extents by different investigators, it is extremely important that the relative merits of these indices be examined. The most desirable obesity index should be one that is maximally correlated with weight but minimally correlated with height (i.e., unbiased by height) in all populations.

Over the past decade or so, a number of investigators have examined the correlation of these indices with weight and height in diverse populations (**Table 1**). In the adult populations (4–9), W/H and W/H^2 are consistently highly correlated with weight, although W/H correlates with weight slightly better than does W/H^2. However, W/H^3 and $H/W^{1/3}$ are only moderately correlated with weight. Killeen et al. (10) investigated the relative desirability of these indices for subjects aged 6 to 17 yr, but they did not report correlations with weight. Therefore, it is not known whether these indices show similar correlation with weight for subjects in their growing years as they do for adult populations.

The indices W/H^3 and $H/W^{1/3}$ are more highly correlated with height than are W/H and W/H^2. Of the latter two indices, W/H^2 is on the whole slightly less biased by height than is W/H, but there are exceptions. For example, Florey (6) found W/H^2 to be less biased than W/H in males but not in females, and Watson et al. (9) showed W/H to be less biased than W/H^2 in both sexes. Generally, all four indices are considerably height-biased in subjects aged 6 to 17 yr (10).

Based on all of these reports, W/H^3 and $H/W^{1/3}$ appear to be undesirable obesity indices, since they are only moderately correlated with weight, and more importantly, are markedly biased by height. Although W/H and W/H^2 are highly correlated with weight, neither index is consistently independent of height in all populations. In adult populations, the correlation of W/H with height varies from 0.01 to 0.51 and that of W/H^2 from 0 to 0.25.

Billewicz et al. (1) noted that an obesity index that is correlated with height, even moderately, cannot be safely used in comparison studies, since it could potentially produce misleading results. On this basis, none of the four power-type obesity indices appears to be consistently satisfactory for all populations.

More recently, Benn (11) demonstrated mathematically that a power-type index, W/H^p, where p is derived from any given set of weight-height measurements, is independent of height provided weight and height are linearly related. Hence, W/H^p would appear to be the most ideal index of obesity. Benn (11) also showed that the index is maximally related to body weight (a correlate of obesity), provided weight is independent of height. Since weight is invariably correlated with height, however, this index may not in actuality be as highly correlated with weight as is one or more of the traditional obesity indices. The crucial question, then, is: To what extent is the correlation with weight attenuated in this index in order to achieve independence of height? (Naturally, any serious attenuation of the correlation with weight would weaken the usefulness of W/H^p even

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TABLE 1
Zero-order correlation of obesity indices with W and H as reported by other investigators

Investigators	Population	W/H with W	W/H with H	W/H^2 with W	W/H^2 with H	W/H^3 with W	W/H^3 with H	$H/W^{1/3}$ with W	$H/W^{1/3}$ with H
Khosla and Lowe, 1967 (4)	Males*	0.96/0.97†	0.19/0.37	0.83/0.86	−0.10/0.08	0.60/0.68	−0.36/−0.24		
Evans and Prior, 1969 (5)	Males‡	0.97/0.98	0.25/0.33	0.88/0.92	0.02/0.05	0.69/0.90	−0.21/−0.18		
	Females	0.98/0.99	0.10/0.29	0.92/0.95	0.02/0.12	0.82/0.88	−0.08/−0.01		
Florey, 1970 (6)	Males§	0.96	0.22	0.83	−0.08			−0.64	0.36
	Females	0.97	0.03	0.90	−0.20			−0.77	0.41
Keys et al., 1972 (7)	Males‖		0.17/0.51		0/0.25				0.10/0.47
Goldbourt and Medalie, 1974 (8)	Males¶	0.96	0.28	0.83	−0.03			−0.64	0.31
Watson et al., 1979 (9)	Males**	0.95	0.13	0.80	−0.20	0.58	−0.47	−0.61	0.44
	Females	0.98	0.01	0.93	−0.17	0.84	−0.35	−0.82	0.36
Kileen et al., 1978 (10)	Males††								
	White		0.36/0.63		0.11/0.38		−0.17/−0.05		
	Black		0.51/0.71		0.14/0.43		−0.36/−0.02		
	Females								
	White		0.21/0.63		−0.01/0.32		−0.23/0.18		
	Black		0.27/0.63		0.06/0.38		−0.15/0.06		

* British subjects age 15 to 64.
† Values to the left and right of diagonal line are the lowest and highest values, respectively.
‡ Two Polynesian populations.
§ The Framingham Study group.
‖ Twelve diverse populations.
¶ Israeli Ischaemic Heart Disease Project.
** Adult New Zealanders.
†† Subjects 6 to 17 yr of age from the United States Health Examination Survey.

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though it is unbiased by height.) To our knowledge, this question has never been examined using actual weight-height data collected from diverse population groups.

This report attempts to evaluate empirically the usefulness of Benn's index relative to the traditional indices, based on the correlations with weight and height in several different populations. We hope this report will encourage the reader to be judicious in the selection of an appropriate obesity index for statistical analysis.

Data source

In 1975, the Epidemiology Program of the Cancer Center of Hawaii, in collaboration with the Hawaii State Department of Health, began to collect data from an annually selected representative sample of 5000 households throughout the State. Information on a series of personal, socioeconomic, and health-related variables was obtained from each subject. The present report is based on the weight, height, and age data collected by the end of 1979 from male and female subjects 18 yr of age and older belonging to the five major ethnic groups in Hawaii (Caucasians, Japanese, Chinese, Filipinos, and Hawaiians/part-Hawaiians). Of the 36,457 subjects in this group, 934 had missing information on one or more variables. Hence, this report is based on the remaining 35,523 subjects.

Statistical methods

The following computations were performed on the data from each of the 10 ethnic-sex-specific sample, as well as on the pooled data from all samples: *1*) linear regression analysis of weight (dependent variable) on height (independent variable) was carried out in order to determine the regression coefficient $\hat{\beta}$. The exponent p for Benn's index was then computed as $\hat{\beta}(\bar{H}/\bar{W})$, where $\bar{H}$ and $\bar{W}$ are mean height and mean weight, respectively. *2*) Zero-order correlation coefficients for each of the five obesity indices on weight and height were determined by the usual linear correlation analysis. *3*) Partial correlation coefficents for each of the five obesity indices on weight and height, statistically controlling for age, were determined by the usual partial linear correlation analysis.

Results

Relationship between weight and height

Mean weight and height, the regression statistics and the exponent p for Benn's index for each ethnic-sex specific and combined samples are shown in **Table 2**.

Mean weight and height vary considerably among the ethnic groups in both sexes. Hawaiians (including part-Hawaiians) and Caucasians are, on average, substantially heavier and taller than the other ethnic groups. Differences in weight and height among Japanese, Chinese, and Filipinos are less pro-

TABLE 2
Mean weight and height, coefficient of determination (r^2), regression coefficient ($\hat{\beta}$) of weight (kg) on height (cm), Y-intercept ($\hat{\alpha}$) and the exponent (p) for each of the 10 ethnic-sex groups

Ethnic-sex group	No. of subjects	Mean wt	Mean ht	r^2	$\hat{\beta}$*	$\hat{\alpha}$	p†
		kg	*cm*				
Males							
Caucasian	6081	77.19	177	0.23	0.72	−50.5	1.65
Japanese	5419	66.49	167	0.28	0.81	−68.7	2.03
Chinese	818	67.11	170	0.28	0.83	−73.3	2.09
Filipino	2693	65.02	165	0.20	0.67	−45.2	1.69
Hawaiian	2646	81.55	174	0.17	0.91	−77.5	1.95
Females							
Caucasian	5895	60.50	163	0.07	0.44	−11.1	1.18
Japanese	5848	52.96	155	0.12	0.47	−20.3	1.38
Chinese	795	53.10	158	0.12	0.45	−17.8	1.33
Filipino	2341	54.46	155	0.09	0.42	−10.2	1.19
Hawaiian	2987	66.90	162	0.09	0.66	−39.6	1.59
All groups combined	35523	65.07	165	0.41	0.91	−85.6	2.31

* All the values are significantly different from 0 ($p < 0.001$).
† The exponent p for Benn's index is computed by $\hat{\beta}$ (mean height/mean weight).

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TABLE 3
Zero-order (top) and age-adjusted partial (bottom) correlation coefficients of obesity indices with W and H

Ethnic-sex group	W/H with		W/H^2 with		W/H^3 with		$H/W^{1/3}$ with		W/H^p with	
	W	H	W	H	W	H	W	H	W	H
Males										
Caucasian	0.96	0.21	0.81	−0.12	0.59	−0.41	−0.60	0.39	0.87	0*
	0.96	0.22	0.82	−0.10	0.60	−0.40	−0.61	0.38	0.88	0
Japanese	0.97	0.30	0.85	−0.01	0.64	−0.30	−0.64	0.28	0.84	−0.01
	0.97	0.26	0.86	−0.03	0.67	−0.31	−0.67	0.29	0.85	−0.03
Chinese	0.97	0.28	0.85	0	0.65	−0.30	−0.63	0.32	0.84	0
	0.97	0.29	0.86	0	0.67	−0.28	−0.65	0.30	0.85	0
Filipino	0.96	0.20	0.84	−0.10	0.65	−0.37	−0.64	0.37	0.88	−0.01
	0.97	0.18	0.85	−0.11	0.68	−0.36	−0.67	0.36	0.89	−0.02
Hawaiian	0.98	0.21	0.90	−0.02	0.77	−0.24	−0.76	0.25	0.91	0
	0.98	0.22	0.90	−0.01	0.77	−0.24	−0.76	0.24	0.90	0
Females										
Caucasian	0.97	0.04	0.88	−0.20	0.76	−0.40	−0.73	0.42	0.96	0
	0.97	0.07	0.88	−0.18	0.75	−0.39	−0.72	0.41	0.96	0.02
Japanese	0.96	0.10	0.85	−0.18	0.68	−0.43	−0.69	0.41	0.93	−0.01
	0.97	0.12	0.86	−0.15	0.70	−0.39	−0.71	0.38	0.93	0.01
Chinese	0.97	0.09	0.86	−0.18	0.70	−0.42	−0.68	0.43	0.94	0
	0.97	0.12	0.87	−0.15	0.71	−0.39	−0.69	0.41	0.94	0.02
Filipino	0.96	0.04	0.86	−0.23	0.68	−0.46	−0.69	0.46	0.95	−0.01
	0.97	0.06	0.86	−0.21	0.69	−0.44	−0.70	0.44	0.95	0.01
Hawaiian	0.98	0.11	0.92	−0.09	0.82	−0.28	−0.80	0.29	0.96	0
	0.98	0.13	0.92	−0.08	0.81	−0.28	−0.80	0.28	0.95	0
All groups	0.96	0.43	0.82	0.10	0.55	−0.26	−0.55	0.26	0.74	−0.02
combined	0.97	0.43	0.82	0.11	0.57	−0.24	−0.57	0.24	0.75	0

* A coefficient indicated by 0 is less than |0.01|. A coefficient less than or equal to |0.01| is not significantly different from 0 ($p < 0.05$).

nounced. The ranking of mean weights does not correspond exactly with the ranking of mean heights for the ethnic groups in either sex (e.g., Hawaiians are heavier than Caucasians but the latter are taller). This may reflect differences in body build characteristics, such as the ratio of leg length to the total height, among these ethnic groups.

Bivariate scattergrams (not shown here) revealed that weight was approximately linearly related to height for each ethnic-sex-specific sample as well as for the combined sample. Hence, the weight and height data were subjected to linear regression analysis. As revealed by both the regression coefficient and the coefficient of determination, the weight-height relationship varies among ethnic-sex groups. Both coefficients are consistently and discernably higher for males than for females in each ethnic group. For male subjects, the regression coefficient is highest for Hawaiians (with an expected increase of 0.91 kg in body weight per cm increase in height), followed in order by Chinese, Japanese, Caucasians, and Filipinos. For female subjects, the regression coefficient is again highest for Hawaiians. However, the regression coefficients are similar in the other four ethnic groups. The regression coefficient for the combined population is 0.91.

As indicated by the coefficient of determination, the percentage of the variance in body weight that is attributable to the variance in height for male subjects ranges from 17% for Hawaiians to 28% for Japanese and Chinese. For female subjects, this percentage ranges from 7% for Caucasians to 12% for Japanese and Chinese. Hence, even though weight and height are statistically related ($p < 0.001$), the strength of the relationship is only modest for each ethnic-sex specific-population. Pooling the data from all ethnic-sex groups increased the r^2 to 0.41.

The exponent, p, for Benn's obesity index (W/H^p) also varies considerably among ethnic-sex groups. The p value is markedly higher for males than for females in each ethnic sample but the variation is less pro-

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nounced among ethnic groups of the same sex. The p value for the pooled data is 2.31.

Zero-order correlation of obesity indices with height

The zero-order correlation coefficient of each of the five obesity indices with height and weight for the respective ethnic-sex groups is presented in the upper figure of **Table 3**. (W/H^p was computed based on the corresponding p values shown in Table 2.) Of the traditional indices, W/H^3 and $H/W^{1/3}$ are markedly more height-biased than are W/H and W/H^2 in all groups.[7] Even though W/H and W/H^2 are only moderately correlated with height, all the correlation coefficients are significantly different from 0 ($p < 0.05$), except W/H^2 in Chinese males. Note that W/H is consistently less height-biased than is W/H^2 in the female groups but W/H^2 is less height-biased than is W/H in the male groups. The index W/H^p is negligibly correlated with height for every ethnic-sex group. None of the correlations of W/H^p with height is significantly different from 0 ($p > 0.05$) despite the very large sample sizes.

Based on the combined data, W/H showed the highest correlation with height, followed by W/H^3 and then by W/H^2, but W/H^p remained minimally correlated with height even though the relationship is statistically significant ($p < 0.05$).

Although the correlation of W/H^p with height is substantially lower than that of any of the traditional indices, the results do not necessarily indicate W/H^p to be the most invariant of height (it is the invariance of height that makes the obesity index desirable). Since the correlation coefficient only quantifies the extent of linear relationship of the index with height, a low correlation implies either the index is approximately invariant of height or that the two variables are not linearly related. For this reason, the trend of each obesity index with height based on the combined data is depicted in **Figure 1**. (Note: values on the Y-axis of Fig. 1 are means of the respective index for each height interval expressed as a percent deviation from the overall mean.) It is apparent that none of the obesity indices is linearly related with height, but the nonlinearity is largely contributed by subjects whose height is below 150 or above 190 cm. (It should be noted that only 1.6% of the subjects in our study sample were either below 150 or above 190 cm in height). Within the height range of 150 to 190 cm, the relationship is nearly linear for each index and the degree of invariance of height is related to the magnitude of the correlation of the index with height. That is, W/H^p is most invariant of height ($r = -0.02$), followed by W/H^2 ($r = 0.10$), and W/H^3 ($r = -0.26$), with W/H least invariant of height ($r = 0.43$). We also examined the trend of each obesity index with height for the respective ethnic-sex-specific samples and W/H^p was consistently the most invariant of height. The extent of invariance of height for the other indices depended on the particular ethnic-sex sample. (It should be noted that the more closely the exponent in the traditional index approximates the p value in W/H^p, the more invariant of height that traditional index will be. For example, the p value for Caucasian females is 1.18 and the correlations of W/H, W/H^2, and W/H^3 with height are 0.04, −0.20, and −0.40, respectively. The p value for Japanese males is 2.03 and the correlation of W/H, W/H^2, and W/H^3 with height are 0.30, −0.01, and −0.30, respectively.)

Zero-order correlation of obesity indices with weight

The correlation of W/H^3 with weight is markedly lower than that for W/H, W/H^2, and W/H^p in all ethnic-sex-specific samples as well as in the combined sample (Table 3). Hence, W/H^3 is unquestionably the least desirable index of obesity since it is not only substantially more height-biased but also is less related to weight than are the other indices. The indices W/H, W/H^2, and W/H^p are all highly correlated with weight, but either W/H or W/H^2 shows a stronger relationship with weight than does W/H^p in all populations.

Thus, although W/H^p is the best obesity index in terms of its virtual independence of height in all populations, it is not optimal in

[7] Since the zero-order and partial correlation coefficients for W/H^3 and $H/W^{1/3}$ are virtually identical in magnitude, although opposite in sign, whatever conclusions drawn regarding one index apply to the other. For this reason, $H/W^{1/3}$ will be omitted from all subsequent discussions.

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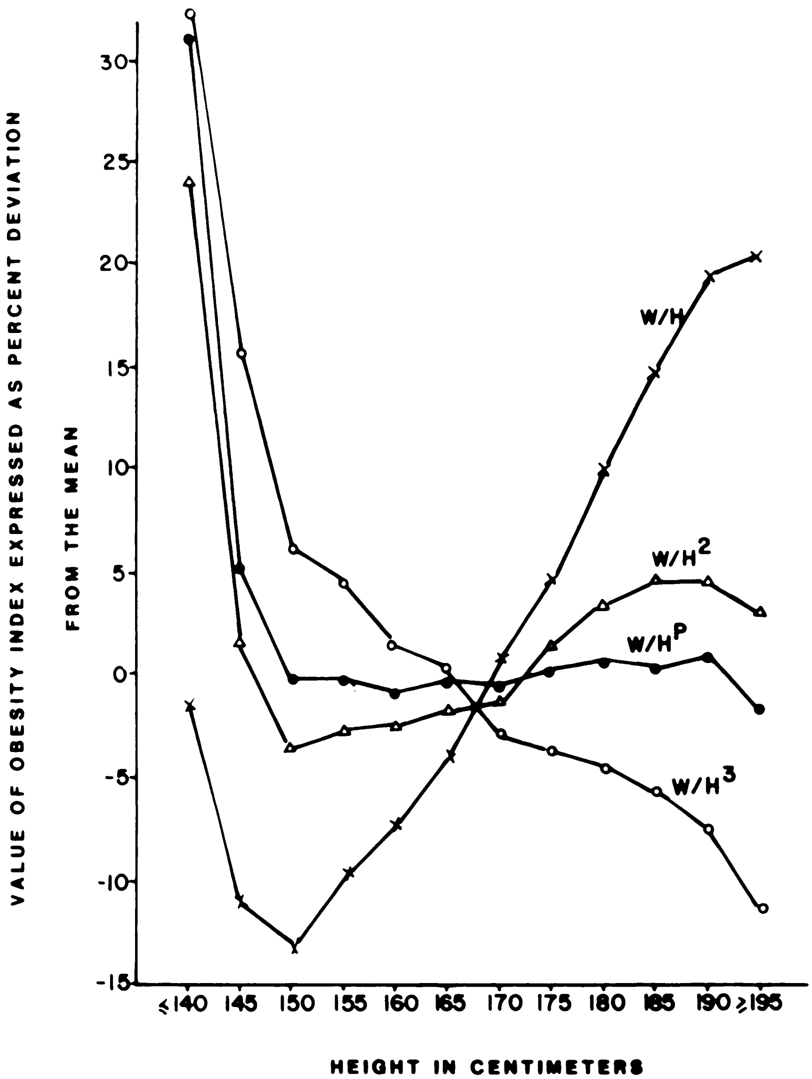

FIG. 1. Trend of obesity indices with height.

terms of its correlation with weight. This leads to the crucial question: To what extent has the correlation with weight been attenuated in order to achieve height independence? Table 3 shows that the correlation of the obesity index with weight decreases as the p value increases. Thus, W/H is consistently most highly correlated with weight, followed by W/H^2 and then by W/H^3. In most of the ethnic-sex groups, the correlation of W/H^p is intermediate between W/H and W/H^2 since the p value in W/H^p is between 1 and 2. So unless a population has a p value less than 1, W/H will show a higher correlation with weight than will W/H^p. Tables 2 and 3 show that the degree of attenuation of the correlation of the obesity index with weight in order to achieve height independence depends on the correlation of weight with height in the particular ethnic-sex sample. For example, among Japanese males where the weight-height correlation is 0.53 (Table 2), the correlation of $W/H^{2.03}$ on weight is 0.84, which is 0.13 lower than the correlation of W/H on weight. In contrast, among Caucasian females where the weight-height correlation is 0.26, the correlation of $W/H^{1.18}$ on weight is 0.96, which is only 0.01 lower than that for

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W/H. On the whole, attenuation does not seem to be serious in any of the ethnic-sex groups included in this study.

Age-adjusted partial correlation of obesity indices with weight and height

In order to examine the relationship of the obesity indices with weight and height controlling for age, the partial correlation coefficients were computed and are shown in the lower figure of Table 3. Since the partial correlations are generally similar to the zero-order correlations, the relationship of the obesity indices to weight and height does not change materially with age-adjustment. The only exception is the relationship of W/H^p to height which became statistically significant ($p < 0.05$) for four of the ethnic-sex groups after age-adjustment. However, the magnitude of the correlation coefficients increased only slightly with age-adjustment.

Discussion

Our results in Table 3 are in general accord with those reported previously (Table 1) for the traditional obesity indices; namely, that W/H^3 and $H/W^{1/3}$ are less correlated with weight and are substantially more biased by height than are W/H and W/H^2. Although W/H and W/H^2 were highly correlated with weight in all the ethnic-sex groups we examined, they were relatively unbiased by height only in certain groups. For example, W/H^2 was generally less height-biased for males and W/H was less height-biased for females. Thus, it is clear that none of the traditional indices is suitable in all situations.

The index W/H^p, on the other hand, was consistently unbiased by height and was also highly correlated with weight in all the ethnic-sex-specific groups. More importantly, W/H^p remained virtually uncorrelated with height in the combined sample (i.e., the pooled data from diverse populations). It should be emphasized that this virtual independence of W/H^p from height in an admixture of heterogeneous populations is an invaluable property of this index. Many nutritional and epidemiological studies are concerned with comparing mean obesity measures (weight-corrected-for-height) among different groups of subjects. In this situation, one cannot use group-specific p values to compute the respective means for W/H^p since any resulting differences would largely be due to the different p values used. In order for a common p value derived from the pooled data to be useful, however, W/H^p based on this p value would have to be uncorrelated with height. Otherwise the mean obesity values for the respective groups of subjects would be confounded by height. Since our analysis showed W/H^p to be virtually independent of height in an admixture of diverse populations, we think that this is the most desirable weight-height-derived index of obesity and should be routinely adopted as the obesity index of choice.

Although we have designated these indices derived from weight and height data as "obesity indices," we do not wish to imply that these are the most reliable indicators of true obesity or adiposity. These indices merely reflect relative body weights among different subjects or groups after correction for variations in height. Obesity or adiposity, on the other hand, refers to the proportion of an individual's body weight which is contributed by fat (12). However, since body weight-corrected-for-height is likely to be directly related to the degree of fatness in most individuals, this measure must at least be statistically correlated with adiposity at the aggregate level. Thus, a group of individuals with a higher mean value for a body weight-corrected-for-height index can be assumed to have, at least on the average, greater adiposity than a similar group of individuals with a lower mean value. Nevertheless, further investigations are needed to determine the extent of correlation between W/H^p and a more direct measure of obesity or adiposity.

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References

1. Billewicz WZ, Kemsley WFF, Thompson AM. Indices of obesity. Br J Prev Soc Med 1962;16:183–8.
2. Kemsley WFF, Billewicz WZ, Thompson AM. A new weight-for-height standard based on British anthropometric data. Br J Prev Soc Med 1962;16:189–95.
3. Seltzer CC, Stoudt HW, Bell B, Mayer J. Reliability

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of relative body weight as a criterion of obesity. Am J Epidemiol 1970;92:339–50.
4. Khosla T, Lowe CR. Indices of obesity derived from body weight and height. Br J Prev Soc Med 1967;21:122–8.
5. Evans JG, Prior IAM. Indices of obesity derived from height and weight in two Polynesian populations. Br J Prev Soc Med 1969;23:56–9.
6. Florey CDV. The use and interpretation of Ponderal Index and other weight-height ratios in epidemiological studies. J Chronic Dis 1970;23:93–103.
7. Keys A, Fidanza F, Karvonen MJ, Kimura N, Taylor HL. Indices of relative weight and obesity. J Chronic Dis 1972;25:329–43.
8. Goldbourt U, Medalie JH. Weight-height indices. Choice of the most suitable index and its association with selected variables among 10,000 adult males of heterogeneous origin. Br J Prev Soc Med 1974;28:116–26.
9. Watson PE, Watson ID, Batt RD. Obesity indices. Am J Clin Nutr 1979;32:736–7.
10. Killeen J, Vanderburg D, Harlan WR. Application of weight-height ratios and body indices to juvenile populations—the National Health Examination Survey Data. J Chronic Dis 1978;31:529–37.
11. Benn RT. Some mathematical properties of weight-for-height indices used as measure of adiposity. Br J Prev Soc Med 1971;25:42–50.
12. Van Itallie TB. Obesity: adverse effects of health and longevity. Am J Clin Nutr 1979;32:2723–33.

Appendix

The absolute values of the regression statistics of weight on height, as well as the mean and SD of a weight-height derived obesity index, depend on the scale of measurement of the weight and height data (i.e., whether in kg and cm or lb and in). There may be occasions when the statistics have been computed on one scale but the investigator wishes to convert them to the other.

Appendix Table 1 shows how to convert the pertinent statistics based on weight and height data in kg and cm (column 1) to the corresponding statistics based on lb and in (column 3). The conversion factors (column 2) are based on the following equivalences: 1 in = 2.54 cm; 1 lb = 0.45 kg. (To make the conversion in the reverse direction, simply divide by those factors marked "multiply" and multiply by the factors marked "divide".)

Appendix Table 1

Column 1	Column 2	Column 3
$\hat{\beta}$ (kg/cm)	Multiply by 5.588	$\hat{\beta}$ (lb/in)
$\hat{\alpha}$ (kg) $\bar{W}$ (kg) SD_W (kg)	Multiply by 2.2	$\hat{\alpha}$ (lb) $\bar{W}$ (lb) SD_W (lb)
$\bar{H}$ (cm) SD_H (cm)	Divide by 2.54	$\bar{H}$ (in) SD_H (in)
$\bar{I}$ (kg/cm^p) SD_I (kg/cm^p)	Multiply by $[2.2/(0.3937)^p]$	$\bar{I}$ (lb/in^p) SD_I (lb/in^p)

Notations: $\hat{\alpha}$ and $\hat{\beta}$ are the Y-intercept and regression coefficient, respectively, obtained from linear regression analysis of W on H. Mean and SD of W are denoted by $\bar{W}$ and SD_W, respectively. Mean and SD of the weight-corrected-for-height index (W/H^p) are denoted by $\bar{I}$ and SD_I, respectively.

Perhaps the conversion factor for $\bar{I}$ and SD_I needs some explanation. Since 1 kg is equal to 2.2 lb and 1 cm is equal to 0.3937 inches, then for a given subject,

$$\frac{W_{lb}}{(H_{in})^p} = \frac{2.2 \times W_{kg}}{(0.3937 \times H_{cm})^p} = \frac{2.2}{(0.3937)^p} \times \frac{W_{kg}}{(H_{cm})^p}$$

If we denote $W_{lb}/(H_{in})^p$ by I_B, $W_{kg}/(H_{cm})^p$ by I_M, and $2.2/(0.3937)^p$ by c (a constant), then $I_B = cI_M$. Since I_B and I_M are linearly related, then the mean of I_B is equal to c times the mean of I_M and the variance of I_B is equal to c^2 times the variance of I_M. Therefore, the standard deviation of I_B is equal to c times the standard deviation of I_M.

Note that the p value, the correlation coefficient of W on H, and the correlation coefficients of W/H^p on W and H are not affected by the scale of measurement. Hence, no conversion is needed.

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