The human body is composed of two broad compartments: (i) active tissue mass (lean body mass or fat-free mass) and (ii) the fat mass which is the principal store of energy in the body. In steady state, an individual will maintain his body weight when the input of food energy is equal to the output of energy. Under these conditions, any change in body weight indicates a change in energy balance and, most probably, a change in fat (or energy) stores. Thus body weight is a proxy for steady state as well as reflecting the energy stores of the individual.

The body weight of an individual is, however, influenced by the stature of the individual and hence there is a need for a nutritional status indicator or index of acceptable body weight for height. This would enable comparisons of different individuals of varying heights and provide a measure of their energy status. A ‘weight for height’ index suitable for epidemiological purposes should be simple to calculate from the measurements made; should be highly correlated with the body weight and at the same time be independent of height. This implies that the numerical value derived should be the same for individuals of standard weight for that height at different heights. Such a nutritional index will reflect the relative weight of the individual or population while also reflecting the changes in energy stores of the individual or group.

WEIGHT FOR HEIGHT INDICES

There are two basic types of weight for height indices commonly used in assessing nutritional status of individuals or populations:

Relative weight: This is the ratio of an individual’s weight to a standard or expected weight for individuals of his/her height. Age may also be used as an additional standardising variable. Relative weight expresses the weight of a given subject as a percentage of the average weight of persons of the same sex, age and height. The standard or average weight is frequently derived from large population samples. However, differences between standards can be large across populations and hence relative weight, despite being a readily interpretable and an easily usable measure, is of limited use for international comparisons. It is also subject to error due to secular changes in heights of populations.

Power-type index: This is derived by the ratio of weight divided by height raised to the power ‘p’ where p has a value, usually between 1.0 and 3.0. There are three possible simple power type indices combining weight and height in use. They are weight/height (W/H), weight/height² (W/H²) and weight/height³ (W/H³) where p is equal to 1, 2 and 3, respectively. However, in order that these three power indices recommended for use in the literature at various times are evaluated, it is useful to remind ourselves that the most desirable quality of the power index for international use should be that it is maximally correlated with weight and is unbiased by height, that is, poorly or not at all correlated with stature in all populations. W/H consistently shows high correlations with weight but also correlates with height in adult populations¹. W/H² or Body Mass Index (BMI) also shows consistent high correlations² with weight and is consistently independent of height. W/H² or Ponderal Index, on the other hand, shows substantially lower correlations with weight but also shows negative correlations with height. A comparative analysis of these three power indices in several population groups showed that W/H had the highest correlation with height followed by W/H² and suggested that W/H² or BMI which is highly correlated with body weight and is relatively unbiased by height is the power index of choice for epidemiological purposes and for international use³.

BODY MASS INDEX (BMI)

It was the Belgian astronomer Adolphe Quetelet⁴ who in 1869 observed, ‘nous trouverons que les poids, chez les individus developpés et de hauteurs différentes, sont a peu pres comme les carres de tailles’ which meant that the body weight of adults of different heights is more or less constant to the square of the height. In 1972, Ancel Keys⁵ and colleagues christened this relationship between body weight of adults and the square of the height as the Body Mass Index (BMI) and ‘ungraciously’ replaced the term Quetelet’s Index⁶. The choice of BMI as the likely objective index for the assessment of nutritional status of adults was based on the observation that BMI was consistently highly correlated with body weight (a proxy for the available energy stored within the body) and was relatively independent of the height of the individual.

Overweight and obesity is normally assumed to indicate an excess of body fat. BMI is used as an indicator of choice to diagnose obesity in adults and Garrow’s earlier classification of obesity⁷ has been replaced following its universal use by the international criteria developed and endorsed by the World Health Organisation (WHO). Recent WHO⁸ recommendations include the suggestion that a BMI of between 18.5 -24.9 in adults be considered appropriate weight for height. A BMI between 25-29.9 is indicative of overweight and possibly a pre-obese state while obesity is diagnosed at a BMI >30.0 (further classified as 30.0-34.9 moderate, 35.0-39.9 severe and >40.0 very severe obesity). The need for a simple objective method to assess undernutrition in adults, a question deliberated at the first meeting of the International Dietary Energy Consultancy Group which met in Guatemala in 1987 resulted in BMI being recommended as the suitable indicator⁹. BMI was subsequently accepted by FAO¹⁰ as a simple, responsive and useful indicator of nutritional status of adults to serve as an important and valuable tool for monitoring nutritional status of populations⁶. Thus BMI has now become a very valuable nutritional assessment and monitoring tool that is useful to assess the continuum of undernutrition, normal range and over-nutrition (that is, the spectrum from deficiency to excess) in the community.

BMI provides for a most useful epidemiological tool in estimating the prevalence of obesity and chronic undernutrition and the increased risk of morbidity and mortality associated with these nutritional states. However, it does not account for the wide
Abdominal accumulation of fat can vary markedly for the same per cent body fat or BMI. It is now well accepted that waist circumference as well as waist-hip ratio (WHR) is a good indicator of abdominal obesity which increases risk of obesity-related co-morbidities. However, populations differ in their level of risk associated with abdominal obesity—a good example being South Asians who show a disproportionate increase in risk\(^2\). All this has prompted the need to re-evaluate the recommended cut-offs for obesity and has raised the sceptre of the need for population specific cut-offs for obesity\(^1\). The eagerly awaited report of the recent WHO Expert Consultation on ‘Appropriate BMIs for Asian populations and its implications for policy and intervention strategies’ held in Singapore in July 2002 will certainly make helpful recommendations and throw more light on this topic.

### BMI OR BENN INDEX?

In an attempt to provide a unified alternative to the three power indices in their universal applicability, Benn\(^{17}\) proposed the use of \(W/HP\) where the power function \(p\) is derived specifically for each population group. The value of \(p\) would be chosen in such a manner that the index would be fully independent of height. The power \(p\) has to be specifically derived for the population to be studied from any given set of weight-height measurements and would hence be population specific. Benn also showed that the index is maximally related to body weight, provided weight is independent of height. However, since weight is invariably correlated with height, the Benn index may not in actuality be as highly correlated with weight as the other weight-height power indices. It is, therefore, important to know to what extent the correlation with weight is attenuated or reduced in the Benn index in order that it is totally independent of height. Hence serious attenuation of the correlation with weight would reduce the usefulness of \(W/HP\) in comparison with other weight-height indices although unlike the latter the Benn index may be unbiased by height.

The relative usefulness of the Benn index has been evaluated by Lee et al\(^{18}\) in a sample size of 35,523 subjects of both sexes and ages over 18 years in five diverse ethnic groups (Caucasians, Japanese, Chinese, Filipinos and Hawaiians). They were able to show that \(W/HP\) showed the highest correlation with weight, followed by \(W/HP^2\) but \(W/HP^2\) remained minimally correlated with weight. \(W/HP^2\) was the most invariant of height \((r = -0.02)\) followed by \(W/HP^2\) \((r = 0.10)\); hence invariance with height is a positive feature of \(W/HP\) as compared to \(W/HP^2\) or other weight-height indices. \(W/HP\) was highly correlated with weight in all the ethnic-sex groups, but was relatively unbiased by height only in certain groups. There was a distinct sex difference in their study with \(W/HP\) being generally less height-biased for males than for females. The Benn index, on the other hand, was consistently unbiased by height and was also highly correlated with weight in all the ethnic-sex specific groups and remained virtually uncorrelated with height in the pooled data from diverse populations. An assessment of relative weight, BMI and Benn index based on the analysis of data on 10,606 men and women aged 18-74 years obtained during NHANES II survey has reported\(^{20}\) that the value for the exponent \(p\) for women among the different age ranges varied from 1.16 to 1.62 while that for men were fairly similar and ranged from 1.69 to 1.86. The Table summarises the analysis carried out by Flegal to show that the power function \(p\) varies with the ethnic group and with sex and also with age (not shown in Table). Flegal's analysis showed that relative weight was still superior to both and had a distinct advantage in that relative weight was perfectly invariant with height while the power type index varied with height in a curvilinear fashion.

If the Benn index was intended as a practical tool then its limitations should also be recognised. Mechanical application of the formula will not

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**TABLE**

Zero-order Correlation Coefficients of BMI and Benn Index and Power Function (p) with Body Weights and Heights in Males (n=17,657) and Females (n=17,866) of Five Different Ethnic Groups

<table>
<thead>
<tr>
<th></th>
<th>BMI</th>
<th>Benn Index</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wt</td>
<td>Ht</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>F</td>
<td>M</td>
</tr>
<tr>
<td>Caucasian</td>
<td>0.81</td>
<td>0.88</td>
<td>-0.12</td>
</tr>
<tr>
<td>Japanese</td>
<td>0.85</td>
<td>0.85</td>
<td>-0.01</td>
</tr>
<tr>
<td>Chinese</td>
<td>0.85</td>
<td>0.86</td>
<td>0</td>
</tr>
<tr>
<td>Filipino</td>
<td>0.84</td>
<td>0.86</td>
<td>-0.10</td>
</tr>
<tr>
<td>Hawaiian</td>
<td>0.90</td>
<td>0.92</td>
<td>-0.02</td>
</tr>
</tbody>
</table>

automatically provide the best weight-height index in all situations. Since \( W/H^p \) has a non-linear, curvilinear association with height, which becomes more pronounced the greater the range of heights, then this argues against the proposed use of this index in a mixture of heterogeneous populations that vary considerably in height. The original choice of \( W/H^p \) was made on the criterion that an ideal weight-height index should be independent of height. This criterion is based on the assumption that relative adiposity or fat mass is independent of height, an assumption that may not always be valid. Earlier studies have shown a better correlation of skin-fold thickness with BMI rather than Benn index\(^9\). Weight-height indices are only approximate indicators of relative weight or optimal or acceptable weight for height and of body energy stores. Practical considerations such as ease of computation is also an important criterion. BMI is more readily computable than \( W/H^p \). Benn recommended use of either relative weight or a power-type index with \( p \) rounded to the nearest whole number to make computation easy.

From an operational point of view, it may be concluded that the closest integer of \( p \) is 2 and hence it may be concluded that \( W/H^p \) is possibly the best index of the type \( W/H^p \) in populations and thus the most useful in practice. However, given that we are beginning to question the appropriateness of BMI and considering the need to re-evaluate the recommended cut-offs based on variation of risk among different population groups, this may indeed be an opportunity to evaluate once again whether the use of a population specific power index may actually help us assess the risk of obesity and its co-morbidities better than we have been able to do so far.

The author is Senior Officer in the Food and Nutrition Division of FAO.

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The Annual Foundation Day of the Nutrition Foundation of India will be celebrated on November 25. Dr N.K. Ganguly, Director General, Indian Council of Medical Research, will give the C. Ramachandran Memorial Lecture on that occasion.

NUTRITION NEWS

- Eighth Annual Conference of the Indian Society for Parenteral and Enteral Nutrition (ISPEN) will be held from December 6-8, 2002, in Hyderabad at Hotel Viceroy. The Scientific Programme will include actual clinical case capsules for interactive discussions, controversies in clinical nutrition in addition to guest lectures, symposia and free papers. The first date of registration is November 15, 2002 and the deadline for submission of abstracts is November 10, 2002.

- PENSA 2003: India will be hosting the IX Annual Conference of the Parenteral and Enteral Nutrition Society of Asia (PENSA) at Goa from
• The annual meeting of the European Society for Parenteral and Enteral Nutrition (ESPEN 2002) was held from August 31-September 4, 2002 at Glasgow, Scotland. It was attended by over 2,000 delegates. The Scientific Programme of the Congress included a diverse range of topics such as ‘Nutrition in space’ and ‘Geo-gravity’. The current status regarding potential benefit of some immunonutrients was discussed and the available scientific evidence was acknowledged.

• IX Asian Congress of Nutrition

Arrangements for the Congress which is to take place between February 23-27, 2003 at Hotel Ashok, New Delhi are proceeding satisfactorily.

The Prime Minister of India, who is the Patron of the Congress, has kindly agreed to inaugurate the Congress. A comprehensive scientific programme consisting of 6 Plenary Lectures, 6 Plenary Sessions, 30 Symposia, 10 Free Communication Sessions and daily Poster Sessions is being organised.

The Plenary Sessions will address the following areas:

● Changing nutrition scene in Asia,
● Newer technologies for augmenting food production in the 21st century,
● Diet and genes: nutrigenetics/nutrigenomics, and
● Traditional health promoting foods of Asia.

In addition there will be the following two innovative programmes.

● Meet the Professors session with the theme ‘Role of Industry in the Advancement of Nutrition Science’ led by Director-General, CSIR, Dr R.A. Mashelkar and Dr Florentino Solon with other participants being Mr. Poddar and Mr. R.C. Venkateish to be followed by general discussion.

The Congress has aroused wide interest among scientists of all Asian countries as also of Europe, America and Africa. The Organising Committee of Congress is keen that a large number of delegates, especially from Asian countries, should participate. To encourage participation of foreign delegates the Organising Committee has decided the following arrangement:

Special concession rate of $250 on Registration Fee will be available for groups participating from each country in numbers of Six or more sponsored by the official nutrition society of the country or any other recognized institution. For student delegates participating in groups of Six or more the Registration Fee will be $150 each. The students have to furnish a letter in this regard from a recognised university or institution. The details regarding the name, designation of the delegates in the group and total sum of Registration Fee of all the delegates in the group should be sent in advance before October 15, 2002 to the Congress Secretariat.

In response to the request made by Congress Organisers, the authorities of Hotel Ashok (the Congress venue) and Hotel Samrat (adjoining the Congress venue) have reduced the room tariff for the period of Congress to US$ 84 per day for Hotel Ashok, the Congress venue and US$ 64 per day for the adjoining Hotel Samrat.

The details of the Congress are also available on the website: www.acn2003india.net.

The United Nations System Standing Committee on Nutrition (SCN) 30th Session, including a one-day Symposium on ‘Mainstreaming Nutrition to Improve Development Outcomes’ will take place in Chennai, India, hosted by Professor M.S. Swaminathan, March 3-7, 2003.

Registration and programme details will be available on the SCN website: www.unsystem.org/scn from mid-October 2002.

The Nutrition Foundation of India is grateful to FAO and WHO for matching grants towards the cost of this publication.

DR THAMMU ACHAYA

Dr Thammau Achaya, former President of the Nutrition Society of India, passed away on September 5 and India lost a distinguished scientist. Dr Achaya started his scientific career as a specialist in oils and fats and had made important contributions in this area. In later years he distinguished himself as a versatile and erudite scholar in the broad field of Food Science. He was the author of widely-read bestsellers on the history of Indian foods and food practices. These valuable and well-researched publications could adorn any good library.

Dr Achaya was elected President of the Nutrition Society of India; his contributions during his term of office, towards strengthening the society, were widely appreciated. He was a genuine friend of the Nutrition Foundation of India and was greatly interested in its programmes. He had contributed several papers to the Bulletin of the Nutrition Foundation of India.

Dr Achaya’s interests extended far beyond science into the fields of music, arts and culture. He was a connoisseur of both Carnatic and Western classical music. He was a highly ‘civilised’ human being, always soft spoken and courteous; and was no seeker of power or publicity. It is to be hoped that the example he has set will be emulated. Nutrition scientists of India will gratefully remember his contributions. The legacy he has left behind will be deeply cherished.

C.G.