

## Evaluation of Validity of Five Weight-Height Obesity Indices

OMURA, Minoru

Department of Hygiene, Faculty of Medicine, Kyushu University

ZINNO, Shozo

Department of Hygiene, Faculty of Medicine, Kyushu University

HARADA, Taishi

Department of Hygiene, Faculty of Medicine, Kyushu University

INOUE, Naohide

Department of Hygiene, Faculty of Medicine, Kyushu University

<https://doi.org/10.15017/7333682>

---

出版情報：福岡醫學雜誌. 84 (6), pp.305-310, 1993-06-25. 福岡医学会  
バージョン：  
権利関係：



---

---

原 著

---

---

## Evaluation of Validity of Five Weight-Height Obesity Indices

Minoru OMURA, Shozo ZINNO,  
Taishi HARADA and Naohide INOUE

*Department of Hygiene, Faculty of Medicine, Kyushu University 60,  
Fukuoka 812*

**Abstract** Validity of five weight-height obesity indices, Broca-Katsura index, weight/height ratio, BMI, Rohrer index and Benn index were evaluated as an obesity index in male medical students of Kyushu University. Validity of them was evaluated using the following three criteria : (1) it should be highly correlated with body weight and its distribution should be independent of height ; (2) it should be highly correlated with obese rate to the standard body weight of Japanese young men ; (3) it can accurately classify individuals as overweight or not overweight. BMI met all three criteria in this population. Benn index proved to be not only independent of body height but also highly correlated with body weight and obese rate, though we could not evaluate this obesity index using criterion (3) because there is no generally-accepted cut-off point of overweight of it. Broca-Katsura index, weight/height ratio and Rohrer index were not independent of body height. From these results, it is concluded that BMI is the best weight-height obesity index in this population.

### Introduction

Many epidemiological studies have suggested that obesity is an important risk factor for hypertension, coronary heart disease, and diabetes mellitus<sup>10)12)13)15)19)</sup>. In Japan, average skinfold thickness, one of obesity indices, has not increased for young adult according to the national nutrition survey ('Kokumin Eiyo Chosa')<sup>17)</sup>, but secular increase in obesity was found among university students<sup>5)14)</sup>. Therefore, it seems important for Japanese young adult to control their body weight to prevent those diseases.

Accurate identification of obesity is important for weight control. Direct measures of total body fat, <sup>40</sup>K counting for example, are accurate, but inappropriate for routine clinical practice. Weight-height obesity indices are commonly used for this purpose because they

are easily measured. Among many weight-height obesity indices, body mass index (BMI) is generally recommended as an obesity index for adult, but the ratio of a body weight to Broca-Katsura standard body weight ( $(Ht(cm)-100) \times 0.9(kg)$ ) is also used for clinical practice in Japan (we call this ratio Broca-Katsura index in this paper) and some researchers reported usefulness of Benn index ( $Wt/Ht^P$ )<sup>6)9)16)</sup>.

We have been recording anthropometric dimensions of medical students in Kyushu University by Martin's method<sup>11)</sup> since 1936. Our data are very unique because there are few studies which record anthropometric dimensions of young adults in detail so long as ours. Using this data source from 1961 to 1992, we evaluate a validity of following five weight-height obese indices as an obesity index in young men ; Broca-Katsura index, weight/height ratio, BMI, Rohrer index, Benn index.

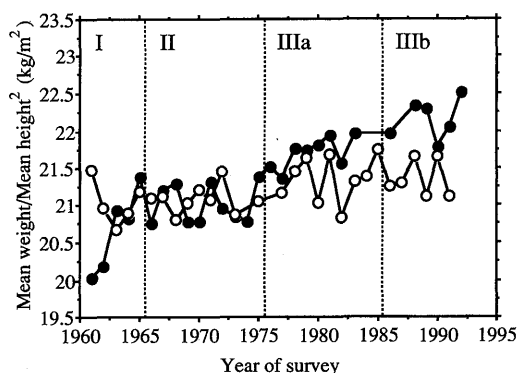
## Data Source and Methods

### Data Source

Anthropometric measurements have been taken annually since 1936 on all third-or fourth-year medical students. The data used in this study were collected from 1961 to 1992. We could not use the data in 1984, 1986, and 1987 because these data were lost. Excluding female students and foreign students, 2253 male students were included in this study. Body height was measured without shoes using Martin's metal anthropometer<sup>11)</sup>. Body weight was measured in light clothing on a weighing balance. Those measurements were performed by students between 9:00 AM and 12:00 AM.

### Study Period

Figure 1 shows the time trend in mean body weight(kg) / mean body height(m)<sup>2</sup>(Wt/Ht<sup>2</sup>) of male medical students in Kyushu University



**Fig. 1** Changes in mean weight/mean height<sup>2</sup> of male medical students (●) and the Japanese young men (○) between 1961 and 1992.

and Japanese young men aged 22 years<sup>17)</sup> from 1961 to 1992. Although Wt/Ht<sup>2</sup> has not remarkably changed for Japanese young men, Wt/Ht<sup>2</sup> of these students has been gradually increasing and the study period can be divided into the following four periods according to the trend in Wt/Ht<sup>2</sup> of these students :

Period I (1961-1965)

Wt/Ht<sup>2</sup> of male medical students was increasing, though below that of Japanese young men.

Period II (1966-1975)

Wt/Ht<sup>2</sup> of male medical students did not remarkably change and was almost equal to that of Japanese young men.

Period IIIa (1976-1985), IIIb (1986-1992)

Wt/Ht<sup>2</sup> of male medical students was increasing beyond that of Japanese young men.

Validity of five weight-height obesity indices was evaluated in each period. Number, mean age, mean body height, mean body weight of male medical students in each period are shown in Table 1.

### Weight-Height obesity indices

Broca-Katsura index (%) : The ratio of a body weight to Broca-katsura standard body weight ((Ht(cm)-100)×0.9(kg)).

Weight/height ratio (kg/m) : Wt(kg)/Ht(m)

BMI(kg/m<sup>2</sup>) : Wt(kg)/Ht(m)<sup>2</sup>

Rohrer index (kg/m<sup>3</sup>) : Wt(kg)/Ht(m)<sup>3</sup> × 10

Benn index (kg/m<sup>P</sup>) : Wt(kg)/Ht(m)<sup>P</sup>

**Table 1** Body height and body weight of male medical students from 1961 to 1992.

|       | Period*   | n   | Age(years)<br>(mean±SD) | Body height(cm)<br>(mean±SD) | Body weight(kg)<br>(mean±SD) |
|-------|-----------|-----|-------------------------|------------------------------|------------------------------|
| I     | 1961-1965 | 360 | 22.9±1.9                | 167.01±5.07                  | 57.60±6.15                   |
| II    | 1966-1975 | 757 | 22.5±1.2                | 168.77±5.20                  | 59.94±6.34                   |
| III a | 1976-1985 | 677 | 23.1±2.0                | 170.24±5.28                  | 62.90±7.13                   |
| III b | 1986-1992 | 459 | 22.8±2.7                | 171.38±5.49                  | 64.94±7.87                   |

\*Data could not be available in 1984, 1985, and 1987.

P value of Benn index is calculated from the following equation<sup>1)</sup>,

$$P = B \times (H/W)$$

where B is a regression coefficient of body weight against body height, H is a mean body height, and W is a mean body weight of the population. P values of Benn index in the four periods of this study were 1.838 (period I), 1.882 (period II), 1.824 (period IIIa) and 1.995 (period IIIb), respectively.

#### Validity of obesity indices

Validity of five weight-height obesity indices was evaluated using the following three criteria:

1) It should be highly correlated with body weight and its distribution should be independent of height.

2) It should be highly correlated with the ratio of a body weight to the standard body weight of Japanese young men (we call this ratio obese rate in this paper).

3) It can accurately classify individuals as overweight or not overweight.

Evaluation of criterion 3) was performed by calculating sensitivity and specificity. In the present context, sensitivity is the proportion of truly overweight students who are identified as such by obesity indices and specificity is the proportion of truly *not* overweight students who are identified as such by obesity indices.

The following cut-off points were used for evaluating overweight in this study: obese rate  $\geq 10\%$ , Broca-Katsura index  $\geq 10\%$ , BMI  $\geq 24 \text{ kg/m}^2$ , Rohrer index  $\geq 140 \text{ kg/m}^3$ . Weight/height ratio and Benn index were not included in the evaluation of criterion 3) because there is no generally-accepted cut-off point of these two obesity indices for evaluating overweight.

As a standard body weight of Japanese young men, height-considered standard weight of Japanese young men aged between 20 and 29 years was used<sup>18)</sup>.

#### Statistical analysis

The statistical significance of independence

of height was determined by t-test.

### Results

#### Correlation with body weight

Table 2 shows correlation coefficients of five weight-height obesity indices with body weight in each period. Weight/height ratio showed the highest correlation with body weight and Broca-Katsura index, BMI and Benn index also showed high correlation, though Rohrer index showed relatively low correlation.

#### Independence of body height

Table 3 shows correlation coefficients of five weight-height obesity indices with body height in each period. Correlation coefficients of BMI and Benn index were nearly zero and supposed to be independent of body height. Other three obesity indices were *not* independent of body height and that was statistically significant ( $p < 0.05$ ).

#### Correlation with obese rate

Table 4 shows correlation coefficients of five

**Table 2** Correlations of five weight-height obesity indices with body weight.

| Index               | Period |      |       |       |
|---------------------|--------|------|-------|-------|
|                     | I      | II   | III a | III b |
| Broca-Katsura index | .709   | .699 | .755  | .772  |
| Weight/height ratio | .961   | .959 | .964  | .967  |
| Body mass index     | .819   | .807 | .836  | .847  |
| Rohrer index        | .595   | .566 | .637  | .649  |
| Benn index          | .849   | .831 | .865  | .848  |

**Table 3** Correlations of five weight-height obesity indices with body height.

| Index               | Period |        |        |        |
|---------------------|--------|--------|--------|--------|
|                     | I      | II     | III a  | III b  |
| Broca-Katsura index | -.226* | -.212* | -.187* | -.128  |
| Weight/height ratio | .269*  | .292*  | .252*  | .296*  |
| Body mass index     | -.059  | -.049  | -.054  | -.002  |
| Rohrer index        | -.370* | -.376* | -.346* | -.299* |
| Benn index          | -.004  | -.007  | -.001  | -.000  |

\*Not independent of height ( $P < 0.05$ ).

weight-height obesity indices with obese rate in each period. All obesity indices showed high correlation with obese rate ( $r > 0.9$ ). Particularly, Broca-Katsura index, BMI and Benn index showed very high correlation.

#### Sensitivity and specificity of obesity indices

Table 5 shows sensitivity and specificity of Broca-Katsura index, BMI and Rohrer index at identification of overweight in each period. All three indices showed relatively high sensitivity, about 90 %. Broca-Katsura index and BMI showed very high specificity, nearly 100 %, though Rohrer index showed lower specificity than others.

From these results, the following conclusion was obtained about the validity of five weight-height obesity indices in the male medical students of Kyushu University: BMI met three criteria of obesity indices and proved to be a good obesity index in this population. Benn

index proved to be not only independent of body height but also highly correlated with body weight and obese rate in this population. Broca-Katsura index, weight/height ratio and Rohrer index proved to be not independent of body height. Therefore it is supposed that these three weight-height obesity indices are inappropriate as an obesity index in this population.

#### Discussions

The following criteria are commonly proposed for a good obesity index<sup>1)3)6)7)16)</sup>: (1) it should be highly correlated with body weight and its distribution should be independent of height; and (2) it should be highly correlated with total body fat. In the present study, one more criterion was added to these two criteria, which was (3) it can accurately classify individuals as overweight or not overweight; because the former two criteria can not describe the extent of misclassification (classifying overweight as not overweight, or not overweight as overweight) resulting from use of specific cut-off values. Concerning criterion (2), obese rate was used instead of skinfold thickness which is a more direct measure of total body fat. Although we have a record of skinfold thickness of this population, we could not be confident of the accuracy of skinfold values measured by students because of difficulty of this

**Table 4** Correlations of five weight-height obesity indices with obese rate.

| Index               | Period |      |       |       |
|---------------------|--------|------|-------|-------|
|                     | I      | II   | III a | III b |
| Broca-Katsura index | .981   | .984 | .990  | .992  |
| Weight/height ratio | .948   | .942 | .952  | .953  |
| Body mass index     | .999   | .999 | .999  | .999  |
| Rohrer index        | .944   | .941 | .955  | .955  |
| Benn index          | .998   | .999 | .998  | .999  |

**Table 5** Sensitivity and spesificity of three weight-height obesity indices to diagnose overweight of male medical students.

|                | Index               | Period |        |       |        |
|----------------|---------------------|--------|--------|-------|--------|
|                |                     | I      | II     | III a | III b  |
| Sensitivity(%) |                     | n=21   | n=60   | n=89  | n=66   |
|                | Body mass index     | 95.24  | 93.33  | 88.79 | 89.01  |
|                | Broca-Katsura index | 90.48  | 93.33  | 88.76 | 91.21  |
|                | Rohrer index        | 90.48  | 85.00  | 91.01 | 84.62  |
| Spesificity(%) |                     | n=66   | n=186  | n=227 | n=152  |
|                | Body mass index     | 100.00 | 100.00 | 99.56 | 100.00 |
|                | Broca-Katsura index | 95.45  | 95.70  | 97.36 | 98.68  |
|                | Rohrer index        | 75.76  | 86.02  | 88.50 | 93.42  |

measurement.

Billewicz et al.<sup>2)</sup> evaluated a validity of weight/height ratio, BMI, Rohrer index and Ponderal index ( $Ht/Wt^{1/3}$ ) as a obesity index of adult population and recommended BMI as the best obesity index. Many investigators demonstrated that BMI is independent of body height and a good obesity index of adult population<sup>3)4)7)8)</sup>. In the present study, BMI was supposed to be independent of body height, and highly correlated with body weight and obese rate. BMI could accurately classify individuals as obese or not obese, too. It was demonstrated that BMI is a good obesity index in the male medical students of Kyushu University.

Benn index ( $Wt/Ht^P$ ) was proposed by Benn<sup>1)</sup> as a weight-height obesity index which was independent of body height in any population group. Lee et al.<sup>9)</sup> evaluated a validity of weight/height ratio, BMI, Rohrer index and Benn index as a obesity index of peoples 18 year of age and older belonging to the five major ethnic groups in Hawaii (Caucasian, Japanese, Chinese, Filipinos and Hawaiians/part-Hawaiians). He concluded that only Benn index is uniformly independent of body height and always produced unbiased results. In the present study, Benn index proved to be not only independent of body height but also highly correlated with body weight and obese rate, though we could not evaluate sensitivity and specificity of this obesity index because there is no generally-accepted cut-off point of overweight of it. Benn index is inappropriate as a obesity index if sample size is small because the multiplier P can be a wide range of value in this case<sup>6)</sup>. Benn suggested that more than 1900 samples are needed to use Benn index as a obesity index and he recommended BMI as a best weight-height obesity index when sample size was small<sup>1)</sup>.

Broca-katsura index is widely used for clinical practice in Japan. In the present study, Broca-Katsura index showed high correlation with body weight and obese rate and also

showed high sensitivity and specificity. But Broca-Katsura index was not independent of body height like weight/height ratio and Rohrer index in this population. Therefore it supposed that Broca-Katsura index is inappropriate as a obesity index in this population.

### Acknowledgement

The present study was performed with co-authors Mr. Zinno and Mr. Harada in the Laboratory Course in Faculty of Medicine, Kyushu University in 1992. And the authors wish to thank Dr. S. Tokunaga of the Department of Public Health, Faculty of Medicine, Kyushu University for his advice about statistical analysis.

### References

- 1) Benn RT: Some mathematical properties of weight-for-height indices used as measure of adiposity. *Brit. J. Prev. Med.*, 25: 42-50, 1971.
- 2) Billewicz WZ, Kemsley WF and Thompson AM: Indices of adiposity. *Brit. J. Prev. Soc. Med.*, 16: 183-188, 1984.
- 3) Garrow JS and Webster J: Quetelet's index ( $W/H^2$ ) as a measure of fatness. *Int. J. Obesity*, 9: 147-153, 1985.
- 4) Goldbourt U and Medalie JH: Weight-height indices. *Brit. J. Prev. Soc. Med.*, 28: 116-126, 1974.
- 5) Kawara A, Doi K, Baba S and Nagai I: Changing distribution of obesity index in freshmen students of Kobe University from 1975 to 1985. *Diabetes Res. Clin. Pract.*, 10, Suppl. 1: S61-S64, 1990.
- 6) Kawashima T, Hashimoto M and Tokunaga R: BMI and Benn index for evaluation of six years' health condition of medical students, *Jpn. J. Hyg.*, 47: 377, 1992.
- 7) Keys A, Fidanza F, Karvonen MJ, Kimura N and Taylor HL: Indices of relative weight and obesity. *J. Chron. Dis.*, 25: 329-343, 1972.
- 8) Khosla T and Lowe CR: Indices of obesity derived from body weight and height. *Brit. J. Prev. Soc. Med.*, 21: 122-128, 1967.
- 9) Lee J, Kolonel LN and Hinds MW: The use of an inappropriate weight-height derived index of obesity can produce misleading results. *Int. J. Obesity*, 6: 233-239, 1982.
- 10) Licciardone JC, Hagan RD, Weiss S, Kaman RL, Taylor SC and Woodworth RM: Projected incidence of cardiovascular disease in male firefighters based on current risk factor prevalence. *J.*

Am. Osteopath. Assoc., 89: 1293-1301, 1989.

11) Martin R: Lehrbuch der Anthropologie, Gustav Fisher Jena, 1928.

12) Naser WB, Thomas J, Semanya K, Thomas DJ and Gillum RF: Obesity and hypertension in a longitudinal study of black physicians: the Meharry Cohort Study. J. Chronic Dis., 39: 105-113, 1986.

13) NIH Technology Assessment Conference Panel: Methods for voluntary weight loss and control. Ann. Intern. Med., 116: 942-949, 1992.

14) Ohe K, Hachiya Y, Takahashi Y, Oda S and Takahara K: The significance of obesity in UOEH medical students-Multiple regression analysis of the annual physical checkup data in 1991-. J. UOEH, 14: 279-288, 1992.

15) Strata A, Zuliani U, Caronna S, Magnati G, Pugnoli C and Tirelli F: Epidemiological aspects

and social importance of obesity. Int. J. Obesity, 1: 191-206, 1977.

16) Suzuki M, Tatsumi M and Tsunoda H: On the usefulness of the Benn index for obesity of school children compared to the Kaup index and the Rohrer index. Jpn. J. Hyg., 44: 863-868, 1989.

17) The Ministry of Health and Welfare: Kokumin eiyo no genzyo, Daiichi shuppan, Tokyo, 1958-1991.

18) The Ministry of Health and Welfare: Himan to yase no hanteihyo zu, pp. 3, Daiichi Shuppan, Tokyo, 1986.

19) Tokunaga K, Matsuzawa Y, Kotani K, Keno Y, Kobatake T, Fujioka S and Tarui S: Ideal body weight estimated from the body mass index with lowest morbidity. Int. J. Obesity, 15: 1-5, 1991.

(Received for publication March 22, 1993)

(和文抄録)

## 青年男子の肥満指標としての各種体格指数 の有用性の評価

九州大学医学部衛生学教室

大村 実・神野尚三・原田大志・井上尚英

Broca-桂指数, 比体重, BMI, Rohrer 指数, ベン指数の五つの体格指数の, 青年男子の肥満指標としての妥当性について, 1) 体重とは高い相関を持つが身長とはできるだけ独立であること, 2) 標準体重による肥満度と高い相関を持つこと, 3) 各体格指数の判定基準で過体重の有無を正しく判定できること, の三条件を設定し, 九州大学医学部男子学生の 1961 年~1992 年の身体計測データを用いて評価を行った。その結果, BMI はこの三条件をいずれも満たしており, 優れた肥満指標であることが示された。ベン指数は身長に対し

て独立であるだけでなく体重や Obese rate とともに高い相関を示すことが示されたが, この指数での確立された過体重の判定基準がないため, 条件 3) に関する検討を行うことができなかった。比体重, Rohrer 指数, Broca-桂指数は身長に対して独立でなく, 今回の研究対象における肥満指標としては適当でないと考えられた。

なお本研究は, 九州大学医学部の平成 4 年度学生基礎配置において, 共同執筆である神野尚三君, 原田大志君の両学生らとともにまとめたものである。