Chula Med J Vol. 48 No. 5 May 2004

Ponderal index is better than body mass index in diagnosis of obesity in Thai male adolescents

Paravee Hiranrat *

Pisut Katavetin ** Pairoj Chotevitayatharakorn*

Hiranrat P, Katavetin P, Chotevitayatharakorn P. Ponderal index is better than body mass index in diagnosis of obesity in Thai male adolescents. Chula Med J 2004 May; 48(5): 289 - 98

Objective : *To study the correlations of weight-to-height indices and percent weight-for-height in Thai male adolescents.*

Methods : *Students grade 7-9 of Bangkok Christian College were measured body weight and height. Percent weight-for-height and weight-to-height indices (weight-to-height ratio, body mass index and ponderal index) were calculated. The correlations of weight-to-height indices and percent weight-for-height were analyzed with Pearson's correlations and the diagnostic properties of these indices were tested.*

Results : *One thousand and eighty-eight students, age 11-16 years, were recruited into this study. The prevalence of obesity (percent weight-for-height > 120) was 26.38 % (287 in 1088 students). Their ponderal index and body mass index are highly correlated with percent weight-for-height. The ponderal index of more than 14 and body mass index of more than 23 could be reliably used to identify Thai male adolescents who have percent weight-for-height more than 120 (accuracy 98.71 % and 93.20 %, respectively).*

* Department of Pediatrics, Faculty of Medicine, Chulalongkorn University

** Department of Medicine, Faculty of Medicine, Chulalongkorn University

Conclusions : *Ponderal index and body mass index are correlated with percent weight-for-height. Ponderal index has higher accuracy than body mass index in the diagnosis of obesity in Thai male adolescents.*

Keywords : *Ponderal index, Body mass index, Percent weight-for-height, Childhood obesity.*

Reprint request : Hiranrat P, Department of Pediatrics, Faculty of Medicine, Chulalongkorn University, Bangkok 10330, Thailand.

Received for publication: February 13, 2004.

ภารวี หิรัญรัตน์, พิสุทธิ์ กตเวทิน, ไพโรจน์ โชติวิทยธารากร. ดัชนีพอนเดอรัลเหนือกว่าดัชนีมวลกายในการวินิจฉัยภาวะอ้วนในวัยรุ่นชายไทย. จุฬาลงกรณ์เวชสาร 2547 พ.ค; 48(5): 289 – 98

วัตถุประสงค์ : *เพื่อศึกษาความสัมพันธ์ระหว่างดัชนีน้ำหนักต่อส่วนสูงกับร้อยละของน้ำหนักเมื่อเทียบกับน้ำหนักมาตรฐานที่ความสูงเดียวกัน ในวัยรุ่นชายไทย*

วิธีการศึกษา : *ทำการชั่งน้ำหนัก วัดส่วนสูง เด็กนักเรียนระดับชั้นมัธยมศึกษาตอนต้นของโรงเรียนกรุงเทพคริสเตียน เพื่อนำมาคำนวณหาร้อยละของน้ำหนักเมื่อเทียบกับน้ำหนักมาตรฐาน และดัชนีน้ำหนักต่อส่วนสูง ได้แก่ สัดส่วนของน้ำหนักต่อส่วนสูง ดัชนีมวลกาย และดัชนีพอนเดอรัล แล้วทำการวิเคราะห์ข้อมูลเพื่อหาความสัมพันธ์ระหว่างดัชนีน้ำหนักต่อส่วนสูงต่าง ๆ กับร้อยละของน้ำหนักเมื่อเทียบกับน้ำหนักมาตรฐาน โดยใช้ Pearson's correlations*

ผลการศึกษา : *ในเด็กนักเรียนที่เข้าร่วมการศึกษาจำนวน 1088 ราย อายุระหว่าง 11-16 ปี (อายุเฉลี่ย 13.1 ปี) พบว่ามีเด็กอ้วน จำนวน 287 ราย คิดเป็นร้อยละ 26.38 ดัชนีพอนเดอรัลและดัชนีมวลกายมีความสัมพันธ์อย่างมากกับร้อยละของน้ำหนักเมื่อเทียบกับน้ำหนักมาตรฐาน สามารถใช้ดัชนีพอนเดอรัลที่มากกว่า 14 และดัชนีมวลกายที่มากกว่า 23 ในการวินิจฉัยภาวะอ้วนได้อย่างถูกต้อง โดยมีความถูกต้องถึงร้อยละ 98.71 และร้อยละ 93.20 ตามลำดับ*

สรุป : *ดัชนีพอนเดอรัลและดัชนีมวลกายมีความสัมพันธ์อย่างมากกับร้อยละของน้ำหนักเมื่อเทียบกับน้ำหนักมาตรฐาน ดัชนีพอนเดอรัลมีความถูกต้องในการวินิจฉัยภาวะอ้วนในเด็กวัยรุ่นชายไทยมากกว่าดัชนีมวลกาย*

คำสำคัญ : *ดัชนีพอนเดอรัล, ดัชนีมวลกาย, ร้อยละของน้ำหนักเมื่อเทียบกับน้ำหนักมาตรฐาน, ภาวะอ้วนในเด็กและวัยรุ่น*

Childhood obesity is an increasing public health problem worldwide.[1-3] Body mass index (BMI) is widely accepted as the standard method for clinical assessment of childhood obesity.[4-8] Because standardized percentile curves of body mass index for Thai children have not been established, percent weight-for-height is currently the gold standard for assessment of childhood obesity in Thailand. [9, 10] Obtaining percent weight-for-height is rather complicated and impractical a task, since it requires standard growth curves or weight-for-height curves of the child of same sex for determination of weight-for-height. Weight-to-height indices such as weight-to-height ratio, body mass index and ponderal index can be directly calculated from weight and height. These indices are more practical than percent weight-for-height for clinical assessment of childhood obesity.

We conducted this study to determine the correlations of weight-to-height indices and percent weight-for-height, and to assess the properties of these indices in the diagnosis of childhood obesity in Thai male adolescents.

Subjects and methods

Students grade 7-9 of Bangkok Christian College, academic year A.D. 2000, were measured body weight and height by using standard calibrated devices with accuracy within 0.1 kilogram and 0.1 centimeter, respectively. Percent weight-for-height [(actual weight / expected weight-for-height) x100] was calculated from individual weight and weight-for-height obtained from standard growth curve of Thai people. Weight-to-height ratio [weight / height], body mass index [weight / $(height)^2$] and ponderal index [weight / $(height)^3$] were directly calculated from individuals' weight and height

The best weight-to-height index: the best p

Weight-to-height indices can be generally written as an equation (Equation 1).

Equation 1 :

$$\text{Weight-to-height index} = \text{Weight} / (\text{Height})^{p}$$

When p = 1, it is weight-to-height ratio; when p = 2, it is body mass index; and when p = 3, it is ponderal index.

Weight-to-height indices are intended to adjust weight from different body size (height) into the same comparable indices and the best index should have no correlation with height (height-independent index). The best weight-to-height index is an index with the best p (Equation 2) that has constant value for weight-for-height or standard weight of any height (Equation 3).

Equation 2 :

$$\text{Weight-to-height index} = \text{Weight} / (\text{Height})^{\text{best p}}$$

Equation 3 :

$$\text{Constant} = \text{Weight-for-height} / (\text{Height})^{\text{best p}}$$

Equation 3 can be transformed to equation 4 as follows:

$$\text{Constant} = \text{Weight-for-height} / (\text{Height})^{\text{best p}}$$

$$\text{Log (Constant)} = \log [\text{Weight-for-height} / (\text{Height})^{\text{best p}}]$$

$$\text{Constant (C)} = \log (\text{Weight-for-height}) - \log (\text{Height})^{\text{best p}}$$

$$= \log (\text{Weight-for-height}) - [(\text{best p}) \times \log (\text{Height})]$$

Equation 4 :

$$\log (\text{Weight-for-height}) = [(\text{best p}) \times \log (\text{Height})] + C$$

Statistical analysis

Correlations of weight-to-height indices to percent weight-for-height and weight-to-height indices to height were analyzed with Pearson's correlations. Simple linear regression model was used to formulate the equations predicting percent weight-for-height from weight-to-height indices.

The best p was determined by the solution of equation 4 using simple linear regression model.[11] Diagnostic properties and appropriate cut-off point of each weight-to-height index in diagnosis of childhood obesity were determined by comparing receiver operating characteristic (ROC) curve, using percent weight-for-height of more than 120 as a gold standard.

Results

One thousand and eighty-eight male students, age 11-16 years with the mean age of 13.1 years, were recruited into this study. The prevalence of obesity which defined as percent weight-for-height of more than 120 was 26.38 % (287 in 1088 students).

Correlation of weight-to-height indices to percent weight-for-height

Weight-to-height ratio, body mass index and ponderal index had good correlation with percent weight-for-height (Table 1). The weight-to-height index that was best correlated with the percent weight-for-height was ponderal index (correlation coefficient, r = 0.997).

Table 1. Correlation of weight-to-height indices and percent weight-for-height.

	Correlation coefficient	p value
Weight-to-height ratio	0.874	< 0.001
Body mass index	0.968	< 0.001
Ponderal index	0.997	< 0.001

The equations predicting percent weight-for-height from weight-to-height ratio or body mass index or ponderal index were formulated as follows:

Percent weight-for-height
= (2.554 X weight-to-height ratio) + 23.208
or
= (5.043 X body mass index) + 4.979
or
= (8.566 X ponderal index) + 0.296

Correlation of weight-to-height indices and height

Weight-to-height ratio, body mass index and ponderal index had poor correlation with height (Table 2). The weight-to-height index that was the least correlated with height was ponderal index (r = 0.096).

Table 2. Correlation of weight-to-height indices and height.

	Correlation coefficient	p value
Weight-to-height ratio	0.432	< 0.001
Body mass index	0.193	< 0.001
Ponderal index	0.096	0.002

The best p

The best p in this population was 2.842 (Figure 1), and the best weight-to-height index was weight / (height)$^{2.842}$.

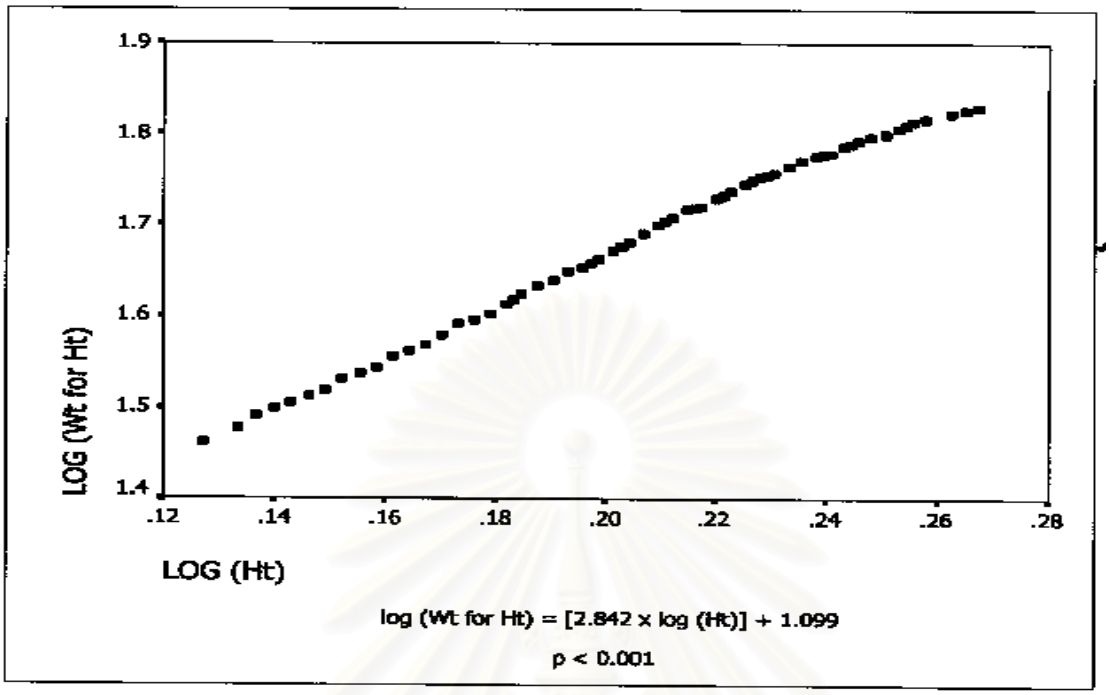

Figure 1. Scatter plot of log (weight-for-height) and log (height) with regression equation.

Diagnostic properties of weight-to-height indices

Ponderal index, which had the largest area under ROC curve (AUC=0.999), was the best weight-to-height index in the diagnosis of obesity in this population (Figure 2). However, body mass index which is widely used in adult and more familiar to most pediatricians was also a good index in the diagnosis of obesity (AUC = 0.983).

The cut-off points for diagnosis of obesity which had the highest accuracy were body mass index of 23 (93.20 %) (Table 3) and ponderal index of 14 (98.71 %) (Table 4).

Table 3. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of body mass index cut-off points in diagnosis of obesity.

Cut-off point*	Sensitivity	Specificity	PPV	NPV	Accuracy
20	100	67.67	52.56	100	76.19
21	98.26	80.90	64.83	99.23	85.48
22	93.38	91.26	79.29	97.47	91.82
23	85.02	96.13	88.73	94.71	93.20
24	71.43	100	100	90.71	92.46

*Obesity was diagnosed when the values were higher than the cut-off points.

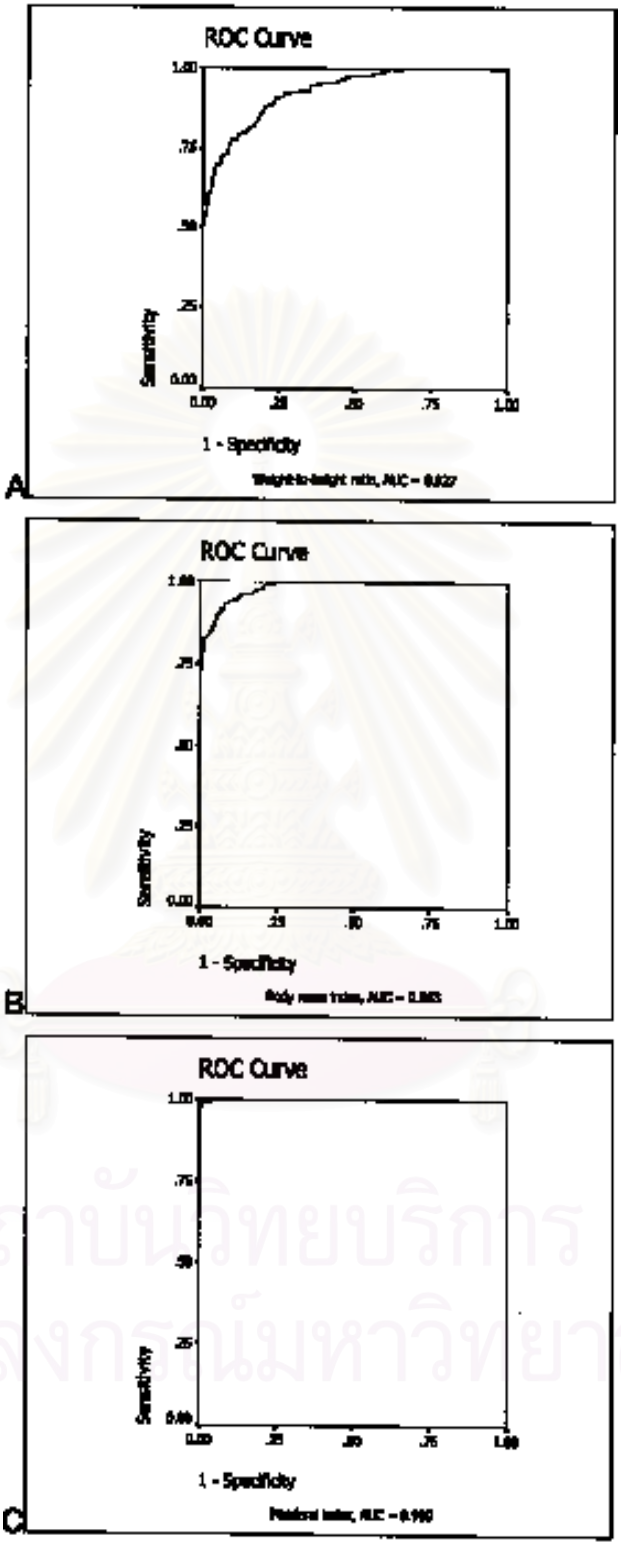

Figure 2. ROC curve of weight-to-height indices in diagnosis of childhood obesity: a) weight-to-height ratio, AUC = 0.927; b) body mass index, AUC = 0.983; c) ponderal index, AUC = 0.999.

Table 4. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of ponderal index cut-off points in diagnosis of obesity.

Cut-off point*	Sensitivity	Specificity	PPV	NPV	Accuracy
13	100	82.77	67.53	100	87.32
14	97.56	99.13	97.56	99.13	98.71
15	68.99	100	100	90	91.82

*Obesity was diagnosed when the values were higher than the cut-off points.

Discussion

In this study, about a quarter of the students had percent weight-for-height more than 120. Students grade 7-9 of Bangkok Christian College may represent Thai male adolescents with relatively high socioeconomic status, but this alarming high prevalence of obesity should not be overlooked.

All three weight-to-height indices have strong correlation with percent weight-for-height. Although ponderal index has the best correlation with percent weight-for-height, the equation predicting percent weight-for-height from body mass index is the most attractive. This equation, percent weight-for-height = (5.043 X BMI) + 4.979, may be simplified to percent weight-for-height = 5 BMI + 5.

The simplified equation is very easy to remember. Anyone can easily calculate predicted percent weight-for-height and use this predicted values for diagnosis of obesity in Thai male adolescents age 11-16 years without growth curve.

The best p in adult is about 2, so body mass index [weight / $(height)^2$] is the best weight-to-height index in adult. In children, the best p varies with age: about 2 at age 1-5 years, increases to about 3.5 at age 9-11 years and then decreases to about 2 again at age 18-20 years.[11,12] Since body mass index (p=2) is rather much apart from the best p in children age 8-16 years, Franklin cautioned the use of body mass index to assess obesity in this population.[11]

The best p in this study population (Thai male adolescents, age 11-16 years) is 2.842, consistent with the previous studies in which the best p in males age 11-16 years is about 2.8 to 3.5. [11, 12] Obviously, the best weight-to-height index, weight / $(height)^{2.842}$, is difficult to remember and calculate. Ponderal index (p=3), which is most approximate the best p, would be better than body mass index (p=2) and weight-to-height ratio (p=1) in the diagnosis of obesity among Thai male adolescents. High correlation of ponderal index to percent weight-for-height and high accuracy of ponderal index in diagnosis of childhood obesity as shown in this study would support but cannot confirm this hypothesis, since one may question the validity of percent weight-for-height used as a gold standard in this study. However, negligible correlation with height confirms that ponderal index is a good, if not the best, weight-to-height index.

Whether ponderal index or body mass index or any other weight-to-height index is the best index for assessment of obesity in Thai children remains to

be carefully evaluated and determined. Further studies about this issue are certainly needed. This study provides an evidence that ponderal index is superior to body mass index as a tool for assessment of obesity, at least among Thai male adolescents age 11-16 years.

However, the body mass index and ponderal index cut-off points proposed in this study should be used with caution. Since they are based on percent weight-for-height, the validity of these cut-off points are at best as good as percent weight-for-height. Using these cut-off points has advantages in correctly identifying children who have percent weight-for-height higher than 120 without the standard growth curve.

In conclusion, ponderal index and body mass index are highly correlated with percent weight-for-height (correlation coefficient > 0.95). Specific cut-off points of these indices (ponderal index >14, body mass index >23) can be used for the diagnosis of obesity among Thai male adolescents with reasonable accuracy. Ponderal index may be more appropriate than body mass index as an index of obesity in children.

References

1. Styne DM. Childhood and adolescent obesity: Prevalence and significance. Pediatr Clin North Am 2001 Aug; 48(4): 823 - 54
2. Freedman DS, Dietz WH, Srinivasan SR, Berenson GS. The relation of overweight to cardiovascular risk factors among children and adolescents : the Bogalusa Heart Study. Pediatrics 1999 Jun; 103(6 Pt 1):1175 - 82
3. Must A, Jacques PF, Dallal GE, Bajema CJ, Dietz WH. Long-term morbidity and mortality of overweight adolescents. A follow-up of the Harvard Growth Study of 1922 to 1935. N Engl J Med 1992 Nov 5; 327(19):1350 - 5
4. Barlow SE,Dietz WH. Obesity evaluation and treatment: Expert Committee recommendations. The Maternal and Child Health Bureau, Health Resources and Services Administration and the Department of Health and Human Services. Pediatrics [online]. 1998 Sep [cited 2004 Mar 3];102(3):E29.
5. Dietz WH, Robinson TN. Use of the body mass index (BMI) as a measure of overweight in children and adolescents. J Pediatr 1998 Feb; 132(2): 191 - 3
6. Guillaume M. Defining obesity in childhood: current practice. Am J Clin Nutr 1999 Jul; 70 (1): 126s - 30s
7. Bellizzi MC, Dietz WH. Workshop on childhood obesity: summary of the discussion. Am J Clin Nutr 1999 Jul; 70(1): 173s-5s
8. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey BMJ 2000 May 6; 320(7244): 1240 - 3
9. Pruksananonda C. Adolescent obesity in adolescent clinic, Chulalongkorn University. Chula Med J 2541 Feb; 42(2): 91 - 104
10. Mo-Suwan L, Geater AF. Risk factors for childhood obesity in a transitional society in Thailand. Int J Obes Relat Metab Disord 1996 Aug; 20(8): 697 - 703
11. Franklin MF. Comparison of weight and height relations in boy from 4 countries. Am J Clin Nutr 1999 Jul; 70(1): 157s - 62s

12. Frontini MG, Bao W, Elkasabany A, Srinivasan SR, Berenson G. Comparison of weight-for-height indices as a measure of adiposity and cardiovascular risk from childhood to young adulthood: the Bogalusa heart study. J Clin Epidemiol 2001 Aug; 54(8): 817 - 22