THE IMPACT OF THE SEXUAL MATURATION STAGE ON BODY MASS INDEX IN ADOLESCENT GIRLS*

*S. Songül Yalçın MD**, Erol Kınık MD****

SUMMARY: Yalçın SS, Kınık E. (Department of Social Pediatrics, Hacettepe University Institute of Child Health, Ankara, Turkey). The impact of the sexual maturation stage on body mass index in adolescent girls. Turk J Pediatr 1999; 41: 315-321.

Body mass index (BMI) is used in the clinical assessment of adiposity in children and adolescents. Population-based, race-specific and age-specific curves of BMI for children and adolescents exist, but there are noknown sexual maturation-based BMI curves. The aim of this study was to investigate the effects of pubertal development (assessed according to the Tanner breast stage) on BMI in adolescent girls in a cross-sectional study. The study group comprised 167 healthy girls, between the ages of nine and 16 years, attending school near a hospital in Gerede, Bolu. A significant positive correlation was found between the Tanner stage of breast development and BMI ($r = 0.79$, $p < 0.001$). Age also had a significant influence on BMI ($r = 0.69$, $p < 0.001$). After controlling the effects of age, BMI was highly correlated with weight ($r = 0.82$, $p < 0.001$) and the Tanner breast stage ($r = 0.49$, $p < 0.001$), but not with height. The correlation between BMI and the sexual stage was also found to increase with increasing age. But when breast development was taken as a control parameter, BMI was not statistically associated with age or height. As a result, there was a significant variation in BMI with the Tanner breast stage in addition to the well known change with increasing age in adolescent girls. Developmental differences occurring in the same age may require that BMI be evaluated only within the same sexual stages in adolescence. This study indicates that the curves of BMI need to take into account the sexual maturation stage of adolescents.

Key words: body mass index, Tanner breast stage, adolescent girls.

The exact chronologic timing of the initiation, progression and completion of puberty, as well as the degree of linear growth, weight gain and secondary sexual development are variable from individual to individual and between the sexes. Normally, about 50 percent of adult weight and 20-25 percent of final adult height are gained during puberty[1]. So clinical assessment of weight status is difficult in adolescence. Body mass index (BMI) is the most useful criteria for screening adolescent obesity because it correlates significantly with both subcutaneous and total body fat in adolescents, particularly those with the greatest proportion of body fat[2,3]. There are standards of BMI defined by age, sex and race, since adiposity is known to vary with these factors[4-7]. Garn et al.[8] also attributed the relationship of BMI to stature, lean body mass, and body frame or proportion as three limiting factors of BMI. However, there may be other fundamental factors that have not been identified which may limit the

* From the Department of Social Pediatrics, Hacettepe University Institute of Child Health, Ankara.

** Pediatrician, Hacettepe University Institute of Child Health.

*** Professor of Pediatrics, Hacettepe University Faculty of Medicine, Ankara.

accuracy of BMI in adolescence. BMI has a normal low point between four and eight years and then it increases until 19 years of age[4]. Accordingly, the fat component of body weight increases from the childhood baseline of 14.3 percent body fat to 23.7 percent by the end of puberty in girls[9]. This raises the possibility that puberty and the associated changes have been linked to an increase in adiposity during puberty. Thus, one limitation of BMI may be the normal variability of physical growth and development during puberty. Given that adolescence is a time of dynamic biologic change, it would seem useful to incorporate sexual stages into the curves of BMI.

The hypothesis is that pubertal development is a factor for changes in BMI. The goal of this article was to investigate the effects of pubertal development (assessed according to the Tanner breast stage) on BMI in adolescent girls.

Material and Methods

A cross-sectional study of 167 healthy schoolgirls (aged 9-16 years) was carried out in January 1991 to examine the effects of pubertal development on BMI among this group of girls. The study group was chosen from primary and high schools near a hospital in Gerede, Bolu. Students were not included in the study if they had any abnormalities of body proportions or history of chronic illness. Informed conset was obtained from both children and parents.

Ages were calculated from each child's date of birth to the date on which the anthropometric measurement was taken during the physical examination. After an overnight fast, body weight was determined to the nearest 0.1 kg using a digital scale, with the subjects wearing light indoor clothing without shoes or coats. Height was measured to the nearest milimeter using a portable, direct reading stadiometer, with subjects standing with shoes removed, with back, buttocks and heels (together) pressed to a wall. In measuring sitting height, girls were asked to sit as far back as possible on the measuring table so that the back of the knee joints were at the front edge of the table. Sexual maturation was assessed according to the Tanner breast stage by examination[10].

Body mass index was calculated as weight per height^2 with weight in kilograms and height in meters. Relative sitting height was calculated as sitting height per height.

Statistical analyses were performed by SPSS (version 6.0 for Windows; SPSS Inc, Chicago, IL). Pearson and Spearman correlation coefficients were used to assess the relationships between BMI and other parameters (Tanner breast stage, age, and measurement of body sizes such as weight, height, and sitting height). After adjusting for age or Tanner breast stage we calculated partial correlations. Changes in BMI by Tanner breast stage or age were assessed by analysis of

variance (one way ANOVA) with pairwise contrasts using the Duncan test. Stepwise multiple linear regression was used to determine which factors among age, Tanner breast stage and sitting height best predicted an individual's BMI. Multiple linear regression included neither weight nor height as a parameter since both were used in calculation of BMI.

Results

The characteristics of the study population are shown in Table I. The mean age for girls was 13.0 (SD, 2.1) years. As shown in Table II, BMIs for girls aged 13-16 years were higher than those of younger girls. The mean BMI varied significantly among girls with different Tanner breast stages ($p < 0.001$, Table II). The percentile values of BMI by Tanner breast stage are presented in Fig. 1, The percentile values of BMI for adolescent girls increased from Tanner stage I to V.

Table I: Clinical Characteristics of Adolescent Girls

Age (yr)	13.0 ± 2.1
Weight (kg)	43.6 ± 11.8
Height (cm)	149.4 ± 12.0
Sitting height (cm)	76.0 ± 5.5
Relative sitting height (%)	50.90 ± 2.1
Body mass index (kg/m^2)	19.2 ± 3.1

Values are mean ± SD.

Table II: Mean Body Mass Index (BMI) of Adolescent Girls by Age and Tanner Stage

	n	BMI
Age range*		
9.0-10.9	25	15.8 ± 1.8^a
11.0-12.9	44	17.3 ± 1.9^a
13.0-14.9	48	20.3 ± 2.7^b
15.0-16.9	50	21.4 ± 2.4^b
Tanner stage**		
I	28	15.7 ± 1.4^a
II	34	17.3 ± 2.0^b
III	37	18.7 ± 1.7^c
IV	42	20.9 ± 2.3^d
V	26	23.0 ± 2.3^e
Total	167	19.2 ± 3.1

Values are mean ± SD, * $F = 47.7$ $p < 0.01$, ** $F = 60.7$ $p < 0.001$.
All comparisons between the groups marked with different lower case letters are statistically significant.

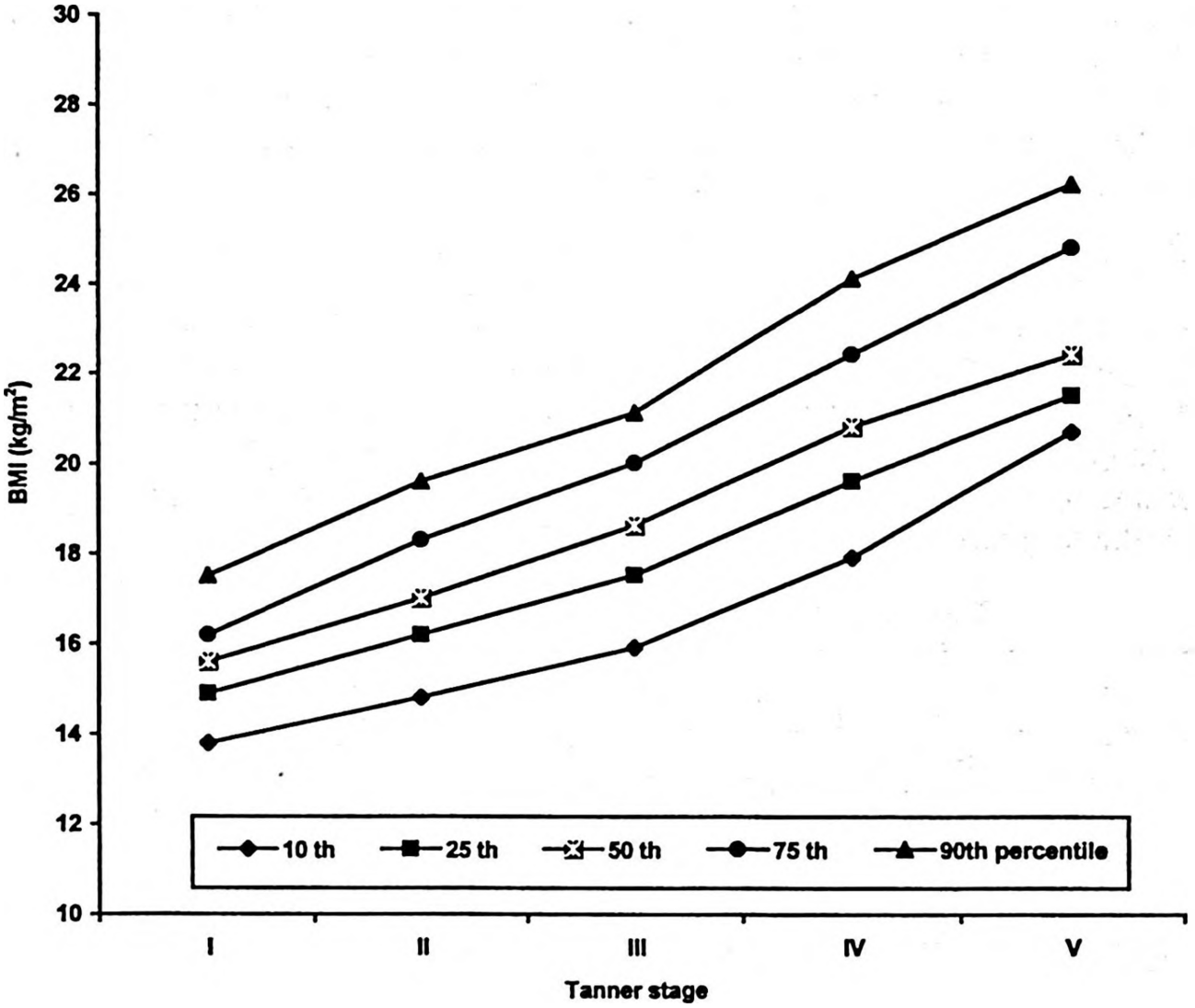

Fig. 1: The percentile values of body mass index (BMI) by Tanner stage.

Body mass index was significantly and positively correlated with Tanner stage ($r = 0.79$ $p < 0.001$), age ($r = 0.68$ $p < 0.001$), weight ($r = 0.90$ $p < 0.001$), height ($r = 0.57$ $p < 0.001$), and sitting height ($r = 0.61$ $p < 0.001$), but not with relative sitting height ($r = -0.08$ $p > 0.05$) (Tabe III). After adjusting for age, BMI was highly correlated with weight ($r = 0.82$ $p < 0.001$), Tanner breast stage ($r = 0.49$ $p < 0.001$) and relative sitting height ($r = 0.20$ $p = 0.011$), but not with height ($r = 0.05$ $p > 0.05$). For girls 9.0-10.9 years of age, there was no significant correlation between Tanner stage and BMI (Table IV). On the other hand, the correlation between BMI and sexual stage was found to increase with age (for girls aged 11.0-12.9, 13.0-14.9 and 15-16.9 years, $r = 0.32$, 0.57 and 0.58 respectively). After adjusting for Tanner breast stage, a significant positive relationship was found between BMI and weight ($r = 0.73$ $p < 0.001$), whereas no statistical correlation was found with age, height or sitting height (Table III). When divided into pubertal stage, there was no correlation between BMI and age in any stages (Table IV).

Table III: Correlations between Body mass Index (BMI) and Age, Weight, Height, Sitting Height, Relative Sitting Height, and Tanner Breast Stage in Adolescent Girls

	BMI	Partial Correlations Adjusting for Age	Partial Correlations Adjusting for Tanner Stage
Age	0.68**	–	0.09
Weight	0.90**	0.82**	0.73**
Height	0.57**	0.05	-0.07
Sitting height	0.61**	0.18*	0.07
Relative sitting height	-0.08	0.20*	0.16*
Tanner stage	0.79**	0.49**	–

* $p < 0.05$, ** $p < 0.001$.

Table IV: Correlations Between Age and Body Mass Index (BMI) by Tanner Stage and Between Tanner Stage and BMI by Age in Adolescent Girls

	Correlation Between Age and BMI by Tanner Stage			Correlation Between Tanner Stage and BMI by Age			
Stage	n	r	p	Age	n	r	p
I	28	0.23	> 0.05	9.0-10.9	25	0.30	> 0.05
II	34	0.18	> 0.05	11.0-12.9	44	0.32	0.03
III	37	0.26	> 0.05	13.0-14.9	48	0.57	< 0.001
IV	42	0.08	> 0.05	15.0-16.9	50	0.58	< 0.001
V	26	-0.18	> 0.05				

To explore possible causal relationships between BMI and other parameters, stepwise multiple linear regression was performed using BMI as the independent variable, and age, Tanner breast stage and sitting height as the dependent variables. Tanner breast stage, but neither age nor sitting height, was found to be a significant predictor of BMI (adjusted $r^2 = 0.59$, $p < 0.001$).

Discussion

Body mass index has been proposed as a practical measure of weight status although it has some well-known limitations in adolescents. To some extent BMI is influenced by age, sex, race, genetic and socioeconomic status[4-7,11-14]. It is known that BMI increases concomitantly with increasing age. Interestingly, we found a significant variation in BMI with Tanner breast stage in both univariate and multivariate analyses. There was a positive significant correlation between BMI and sexual maturation after controlling for age. Differences in development between children of the same age suggest that age- and sex-specific curves of BMI will be misleading for at least some children. Developmental differences

occurring in the same age may require that BMI be evaluated only within the same sexual stages in adolescents. Furthermore, the correlation between Tanner breast stage and BMI in the older adolescent girls was more noticeable than that in the younger ones. The absence of a correlation between age and BMI within the same Tanner breast stage supports our hypothesis. There are sex- and age-specific, population-based curves of BMI for children and adolescents[4-7]. Currently there is no known sexual maturation-specific BMI curves for adolescents. It has been reported that the mean levels of BMI in Mexican-American children were higher than those of white children and black children[7,13]. Roche et al.[7] suggested that differences in growth between Mexican-American and white children could have been due, in part, to differences between these groups in the rates of sexual maturation. Our results confirm this hypothesis.

Recently, the World Health Organization Expert Committee recommended that maturational status be taken into account for interpreting anthropometric data based on chronological age. The Committee reported that age-specific means or medians for anthropometry might be adjusted for rates of maturation of a population that differ from the reference data[2]. Furthermore, the age of sexual maturation of a population should be known for use of this age-specific data. In our study, the significant relationship between BMI and Tanner breast stage which was independent of age implies that care must be taken when assessing different sexual stages using existing BMI curves. Alternatively, BMI reference data from different sexual stages is needed to appropriately evaluate weight status using BMI. If sexual maturation-based curves of BMI are created, adolescent girls can be compared with reference data for that sexual stage without any need of adjustment. Thus, we suggest that BMI data classified according to the pubertal stage could be more applicable to most population groups.

Previous studies reported that BMI is positively correlated with height in adolescents[8]. This was also observed in the present study. On the other hand, after controlling for Tanner breast stage, the effect of height on BMI disappeared. Thus, height would not affect the evaluation of adolescent girls by sex-specific BMI curves.

In conclusion, there was a significant variation in BMI with Tanner breast stage in addition to the well-known change with increasing age in adolescent girls. These factors may be responsible for the instability of BMI to indicate weight status with greater accuracy in adolescents. In general, our data suggest that the existing BMI curves will be of limited value in the evaluation of weight status among adolescents. This study indicates that the BMI curves need to be created considering the sexual maturation stage of adolescents. Other studies are required to detect the presence of a relationship between BMI and the sexual stage in adolescent boys. Additional studies are also necessary to deal with

the important issue of appropriate reference data for defining weight status of adolescents, taking into account that cut-off limits probably differ depending on age, sex, race and also sexual maturation stage.

REFERENCES

1. Barnes HV. Physical growth and development during puberty. Med Clin North Am 1975; 1305-1317.
2. De Onis M, Habicht JP. Anthropometric reference data for international use: recommendations from a World Health Organization Expert Committee. Am J Clin Nutr 1996; 64: 650-658.
3. Lazaruz R, Baur L, Webb K, Blyth F. Body mass index in screening for adiposity in children and adolescents: systematic evaluatilon using receiver operating characteristic curves. Am J Clin Nutr 1996; 63: 500-506.
4. Hammer LD, Kraemer HC, Wilson DM, Ritter PL, Dornbusch SM. Standardized percentile curves of body-mass index for children and adolescents. Am J Dis Child 1991; 145: 259-263.
5. Jackson MY. Height, weight, and body mass index of American Indian schoolchildren, 1990-1991. J Am Diet Assoc 1993; 93: 1136-1140.
6. Lindgren G, Strandell A, Cole T, Healy M, Tanner J. Swedish population reference standards for height, weight and body mass index attained at 6 to 16 years (girls) or 19 years (boys). Acta Pediatr 1995; 84: 1019-1028.
7. Roche AF, Guo S, Baumgartner RN, Chumlea WC, Ryan AS, Kuczmarski RJ. Reference data for weight, stature, and weight/stature^2 in Mexican Americans from the Hispanic Health and Nutrition Examination Survey (HHANES 1982-1984). Am J Clin Nutr 1990; 51: 917S-924S.
8. Garn SM, Leonard WR, Hawthorne WM. Three limitations of the body mass index. Am J Clin Nutr 1986; 44: 996-997.
9. Poskitt EM. The fat child. In: Brook CG (ed). Clinical Paediatric Endocrinology. Oxford: Blackwell Scientific Pub; 1989: 143-165.
10. Marshall WA, Tanner JM. Variations in pattern of pubertal changes in girls. Arch Dis Child 1969; 44: 291-303.
11. Martorell R, Mendoza FS, Castillo RO. Genetic and environmental determinants of growth in Mexican-Americans. Pediatrics 1989; 84: 864-871.
12. Moll PP, Burns TL, Lauer RM. The genetic and environmental sources of body mass index variability: the Muscatine Ponderosity Family Study. Am J Hum Genet 1991; 49: 1243-1255.
13. Ryan AS, Martinez GA, Roche AF. An evaluation of the associations between socioeconomic status and the growth of the Mexican-American children: data from the Hispanic Health and Nutrition Examination Survey (HHANES 1982-1984). Am J Clin Nutr 1990; 51: 944S-952S.
14. Wang J, Thornton JC, Russell M, Burastero S, Hymsfield S, Pierson RN Jr. Asians have lower body mass index (BMI) but higher percent body fat than do whites: comparisons of anthropometric measurements. Am J Clin Nutr 1994; 60: 23-28.