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Longitudinal BMI percentile curves by maturity status of Japanese children

Tsutomu Mino[1], Robert M. Malina[2] and Koichi Nariyama[1]

[1]Osaka Sangyo University, Japan
[2]University of Texas at Austin, USA

Abstract: The objective of the research was to prepare longitudinal percentile curves for the BMI (kg/m²) relative to time before and after peak height velocity (PHV) in Japanese boys and girls born between 1989 and 1991. Stature and weight were measured in every April from 6.5 to 16.5 years for 283 boys and 480 girls. Age at PHV was estimated by the proportional allotment method. The 50th percentile curves for the BMI of Japanese boys and girls born between 1989 and 1991 were similar to the corresponding curves for Japanese boys and girls born between 1972 and 1974. However, the 97th percentiles of children born between 1989 and 1991 were higher and the corresponding 3rd percentiles were lower compared to children born between 1972 and 1974. The differences can be attributed to the influence of early maturing children born between 1989 and 1991 on the 97th percentiles and of late maturing children born between 1989 and 1991 on the 3rd percentiles. The results highlight the need to consider the timing of maturity, in this case, age at PHV, when interpreting the BMI of adolescents.

Key words: children, adolescents, longitudinal data, maturation, peak height velocity

The Body Mass Index (BMI, kg/m²) is widely used for monitoring overweight and obesity in children, adolescents and adults. BMI cut-offs for underweight (BMI<18.5), normal weight (BMI ≥18.5 and <25.0), overweight (BMI ≥25.0 and <30.0) and obesity (BMI ≥30.0) in adults have been are widely used and have been modified for children and adolescents (Cole et al. 2000; 2007). Although other cut-off values to classify weight status based on the BMI have been developed (National Center for Health Statistics 2002; Vrije Universitetit Brussel, 2004), the criteria described by the International Obesity Task Force (Cole et al. 2000) are perhaps used most widely with children and adolescents.

The number of children classified as overweight and obese has increased globally. Factors related to this trend include changes in diet, lifestyle and physical activity (Campbell et al. 2001). The trend has major implications for health and disease, specifically cardiovascular and metabolic abnormalities (Mei et al. 2002).

BMI cut-off values for the classification of weight status generally use

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cross-sectionally processed percentile curves. These are relevant for group comparisons, but may have limitations for the evaluation of individuals (Tanner et al. 1966; Ellis et al. 1999; Peña Reyes et al. 2002).

The objectives of this study were to describe a longitudinally derived reference of the BMI for Japanese children born between 1989 and 1991 and to compare the longitudinal BMI reference values relative to peak height velocity (PHV) of this sample with corresponding data for Japanese children born between 1972 and 1974.

Materials and methods

Body height and weight were measured every April over a period of 11 years for 283 boys and 480 girls born between 1989 and 1991. The age range spanned aged 6.5 to 16.5 years.

Age at PHV (decimal age) was estimated for each child by the proportional allotment method (Matsumoto et al. 1978). Body mass index (BMI) was calculated as body weight in kg divided by the square of height in meters (BMI, kg/m^2).

In the data analysis a mixed methodological approach was used, cross-sectional and longitudinal. Sex-specific percentiles were estimated cross-sectionally for each chronological age group from 6 to 17 years.

All study children were divided into three maturity groups based on the age at PHV and using the criteria of Mino (1984):

Early maturing subjects included:
- Girls: Age at PHV <10.36 years;
- Boys: Age at PHV <12.28 years;

Average (on time) subjects included:
- Girls: Age at PHV ≥10.36 years and <11.71 years;
- Boys: Age at PHV ≥12.28 years and <13.70 years;

Late maturing subjects included:
- Girls: Age at PHV ≥11.71 years;
- Boys: Age at PHV ≥13.70 years.

BMI percentiles were defined for each group using the longitudinal records of each child.

Sex-specific percentiles were also estimated longitudinally by the proportional allotment method relative to individual ages at PHV.

The percentile curves were smoothed using the PB1 method (Preece and Baines 1978).

Results

Figure 1 shows the cross-sectional BMI percentile curves (3rd, 10th, 25th, 50th, 75th, 90th, and 97th) by chronological age of Japanese boys and girls. Corresponding 10th, 50th and 90th percentiles for American (National Center for Health Statistics 2002) and Belgian (Vrije Universiteit Brussel 2004) children are shown for comparison.

Figure 2 shows the BMI percentiles (3rd, 10th, 25th, 50th, 75th, 90th, and 97th) derived longitudinally relative to age at PHV for Japanese boys and girls in the three maturity groups. Early maturing youth show a larger BMI range up to the 97th percentiles in both sexes.

Figure 3 shows longitudinal reference values for the maturity groups plotted by chronological age relative to the cross-sectional reference values for Japanese children (Fig. 1). The confounding effect of individual differences in the timing of PHV is apparent in comparing longitudinally derived percentiles for each maturity group to the cross-sectional reference values.

The longitudinal BMI percentile curves by maturity group for children 6 to 16 years of age born between 1989 and 1991 are plotted relative to corresponding values for Japanese children 6 to 17 years of age born between 1972 and 1974 in Figures 4 through 6. The 50th percentile curve for average maturing children (Fig. 4) shows similar variation in children born between 1972 and 1974, and between 1989 and 1991. The 25th percentile curve is lower for children born between 1989 and 1991, while the 75th percentile curve is higher for children born between 1989 and 1991 compared to those born between 1972 and 1974.

The 50th percentile curve for early maturing boys (Fig. 5) also shows similar variation in youth born between 1972 and 1974, and between 1989 and 1991. The 25th percentile curve is lower for those born between 1989 and 1991 while the 75th percentile curve is higher for those born between 1989 and 1991 compared to those born between 1972 and 1974. For girls, on the other hand, the 25th, 50th and 75th percentile curves are higher for those born between 1989 and 1991 compared to those born between 1972 and 1974.

For the late maturing youth (Fig. 6), the 25th, 50th and 75th percentile curves are lower for both boys and girls born between 1989 and 1991 compared to those born between 1972 and 1974.

Discussion

Growth status is commonly evaluated on a group basis for individuals of the same age. However, given individual differences in the timing of the adolescent growth spurt, evaluation of growth status is more complicated among pubescent children.

Tanner et al. (1966) studied height growth and height velocity from birth

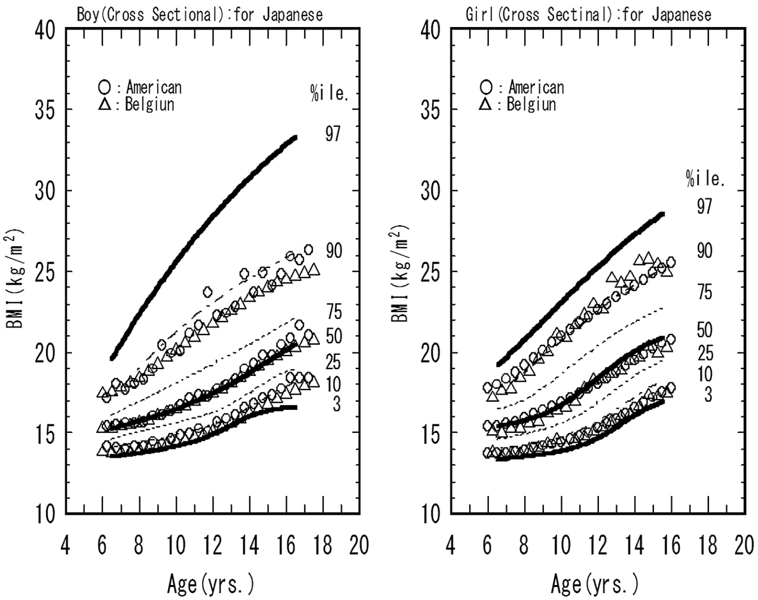

Fig. 1. Cross sectional BMI reference values for Japanese boys and girls. 10th, 50th and 90th percentile curves for American and Belgian boys and girls are included for comparison. Left – boys, right – girls

to adulthood in children differing in the timing of adolescent maturation. Focusing on peak height velocity, a standard chart for the longitudinal height velocity curve and current weight-for-height was presented. This permitted evaluation of growth status by degree of maturity based on age at PHV. The present study applied this rational to the evaluation of growth of the BMI relative to age at PHV in Japanese children.

As shown in Figure 1, the cross-sectional BMI percentile curves (10th, 50th, and 90th percentiles) agree with the

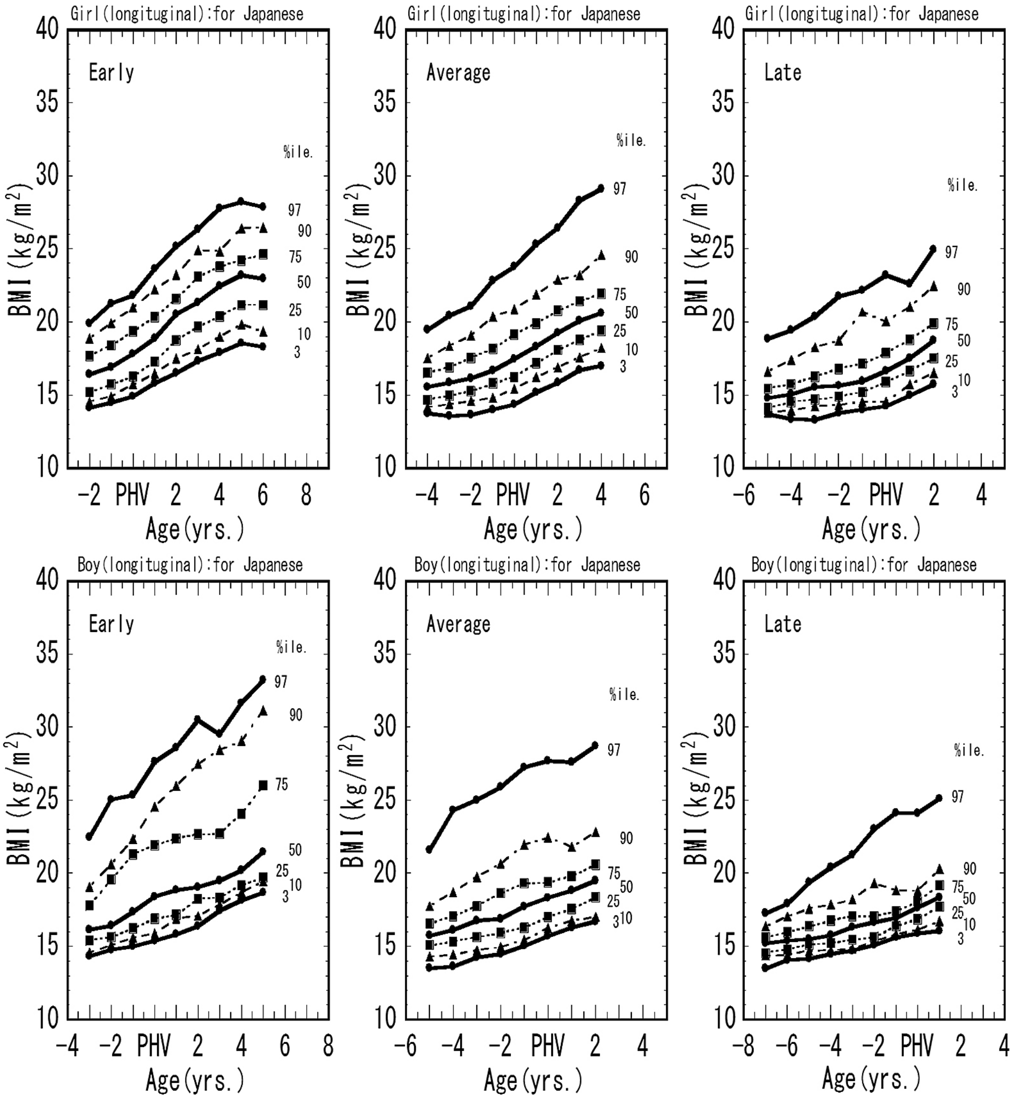

Fig. 2. Variation of the 3rd, 10th, 25th, 50th, 75th, 90th and 97th percentiles statistically processed by maturity status based on age at PHV. Upper – girls, lower – boys. Left – early maturers; center, average (on time) maturers; right – late maturers

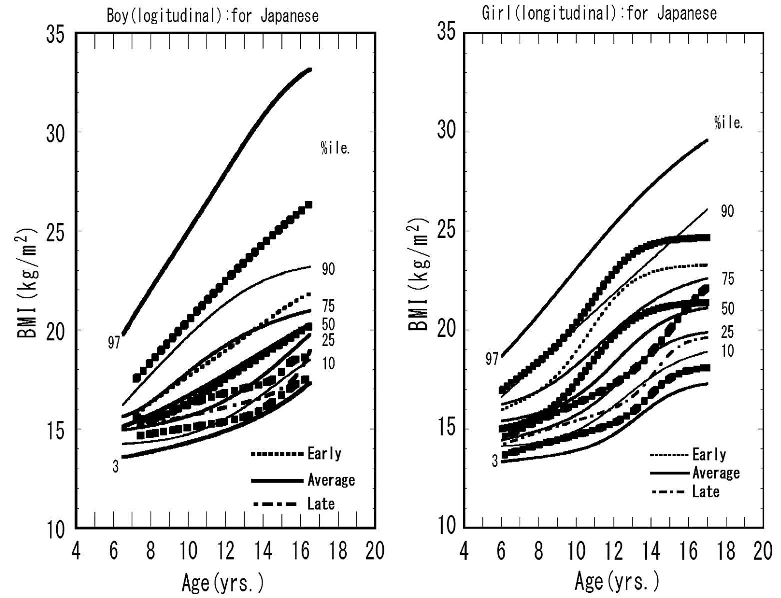

Fig. 3. Reference values for longitudinal BMI percentile curves presented by chronological age. Left – boys, right – girls

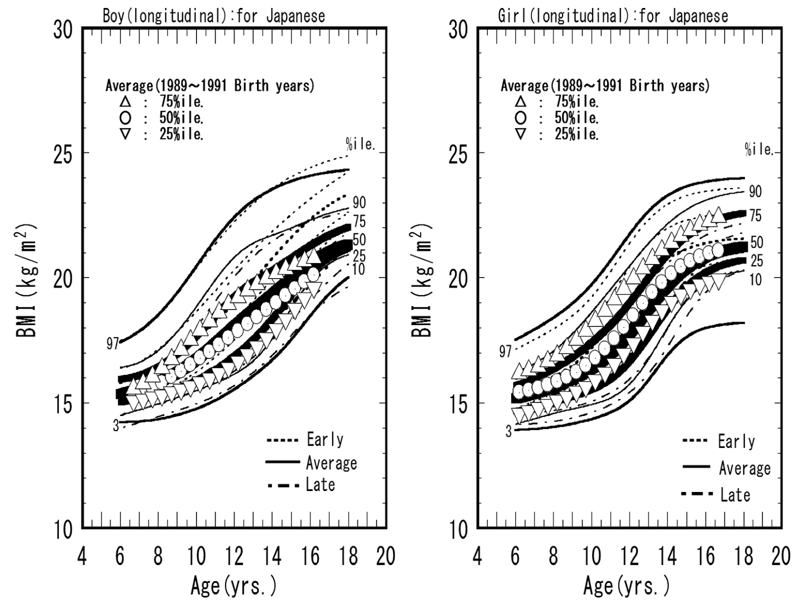

Fig. 4. Comparison of longitudinal reference values for children born between 1972 and 1974 inclusive, and 25th, 50th and 75th percentile curves for children of average (on time) maturity status born between 1989 and 1991 inclusive. Left, boys; right, girls. Inverse triangular marks 25th percentile curve; circular marks 50th percentile curve; triangular marks 75th percentile curve

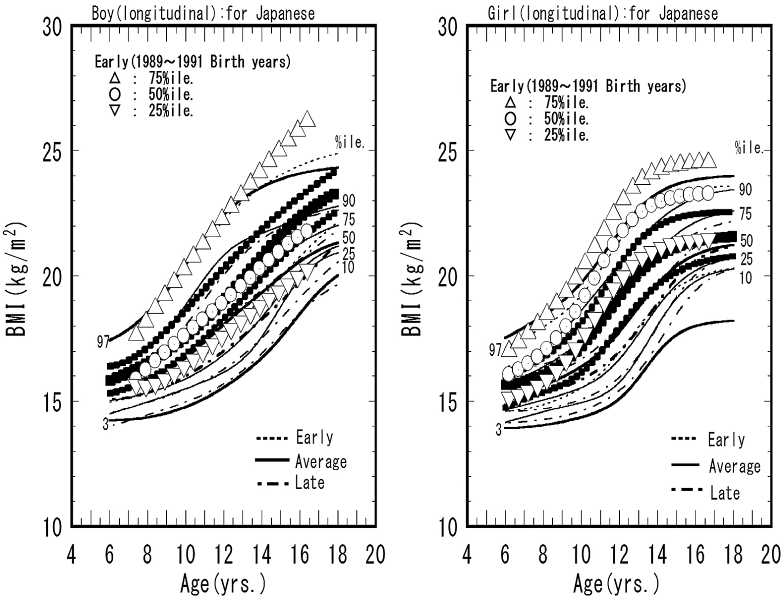

Fig. 5. Comparison of longitudinal reference values for children born between 1972 and 1974 inclusive, and 25th, 50th and 75th percentile curves for children of early maturity status born between 1989 and 1991 inclusive. Left – boys, right – girls. Inverse triangular marks 25th percentile curve; circular marks 50th percentile curve; triangular marks 75th percentile curve

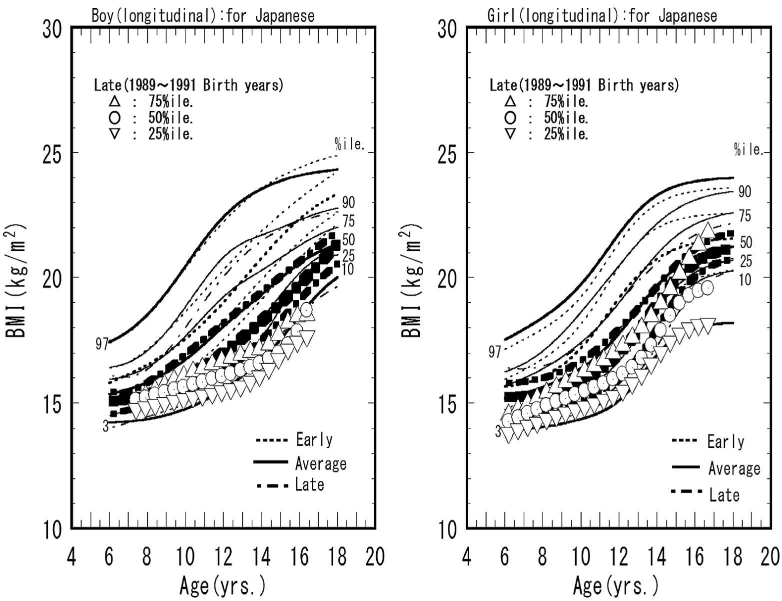

Fig. 6. Comparison of longitudinal reference values for children born between 1972 and 1974 inclusive, and 25th, 50th and 75th percentile curved for children of late maturity status born between 1989 and 1991 inclusive. Left – boys, right – girls. Inverse triangular marks 25th percentile curve; circular marks 50th percentile curve; triangular marks 75th percentile curve

10th, 50th and 90th percentile curves for American and Belgian children. It can be inferred, therefore, that there is a similar tendency for Japanese children to be obese as observed in America and Belgium children. The comparison also suggests that the distribution of the BMI for Japanese children is similar to that of American and Belgian children.

The BMIs of boys and girls born between 1989 and 1991 were evaluated relative to longitudinally derived curves for children of in three different maturity groups. Compared to Japanese boys and girls born between 1972 and 1974 (Mino 2004), there was a significant change in BMI of children over a span of approximately 20 years (Figs. 4–6).

The cross-sectional BMI values of the 3rd percentile for children born between 1989 and 1991 were lower than those for children born between 1972 and 1974, while the corresponding 97th percentiles were significantly larger than those for children born between 1972 and 1974. When considered by maturity status, the BMI value of the 50th percentile for children of average maturity status born between 1989 and 1991 was the same as that of children born between 1972 and 1974, but the range of BMI values of the 25th–75th percentiles was larger compared to children born between 1972 and 1974. The range of BMI values of the 25th–75th percentiles for early maturing children born between 1989 and 1991 was larger than that of children born between 1972 and 1974; the BMI value of each percentile was also higher. The range of the 25th–75th percentile curves for late maturing children was also larger than that of children born between 1972 and 1974, but the BMI value of each percentile was lower.

The subjects of the present study were born between 1989 and 1991. Compared with those born between 1972 and 1974, the distribution of BMI values for the 3rd and 97th percentiles was more spread out from the 50th percentile. BMIs of the 97th percentiles were especially larger. The reason for higher BMI values of the 97th percentile reflected primarily the increase in the 25th, 50th and 75th percentiles of the early maturing group. On the other hand, the cross-sectional BMI values of the 3rd percentiles were smaller than those of children born between 1972 and 1974 due to the observation that the 25th, 50th and 75th percentiles of the late maturing group were smaller.

Conclusion

In summary, 50th percentile curves for the BMI of Japanese children born between 1972 and 1974, and between 1989 and 1991 were approximately similar. However, the 97th percentiles of children born between 1989 and 1991 became larger and the corresponding 3rd percentiles became smaller compared to children born between 1972 and 1974. The differences can be attributed to the influence of early maturing children born between 1989 and 1991 on the 97th percentiles and of late maturing children born between 1989 and 1991 on the 3rd percentiles.

The results highlight the need to consider the timing of maturity, in this case, age at PHV when interpreting the BMI of adolescents.

Conflicting interests

The authors declare that they have no conflicts of interest in the research.

Corresponding author

Koichi Nariyama, Department of Sport and Health Science, Faculty of Human Environment, Osaka Sangyo University, 3-1-1 Nakagaito, Daito: 574-8530 Osaka, Japan; e-mail address: koichi.nariyama@gmail.com

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