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Short Communication

The Cubic Functions for Spline Smoothed L, S and M Values for BMI Reference Data of Japanese Children

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Introduction

We have presented BMI reference data for Japanese children using the LSM method (1), where L, S and M values were smoothed by one or two segments of polynomial functions with nonsmooth connection, which was the barrier for adequate evaluation of BMI for children. So, we smoothed L, S and M values by cubic spline with several knots that are presented in this report.

Methods

We used the same datasets as in a previous report, and the same L, S and M values for each age group before smoothing. The smoothing was performed by extended cubic spline function with several knots, which were determined by the inspection of the shape of the curves to be fitted. The cubic functions were determined by the least sum of the squared desiduals.

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Results

The three quantities used in the LMS method were smoothed both for boys and girls from birth to 17.5 yr of age. The functions for smoothed L, S and M for months of age are shown in Tables 1 and 2 along with the ages of the knots. Each quantity fluctuated within almost the same as reported previously (1).

Discussion

We have presented L, S and M values for Japanese reference standards for BMI smoothed by cubic spline. Compared with the previous method (1), we could obtain the median lines that were smoothly connected at around 65 mo of age.

Curves for the centiles are obtained using the formula:

$$M\,(1 + LSZ)^{1/L}, \qquad [1]$$

where Z is the Z-score for the normalized distribution. For example, to calculate the 3rd percentile value, Z was substituted as –1.881.

Also, by rearranging equation [1], Z-scores are given by:

$$[(Q/M)^{L-1}]/LS, \qquad [2]$$

where Q is the observed BMI. The Z-scores obtained using the above equation can be converted to a centile using normal distribution tables.

Table 1 Functions for smoothed L, S and M by age in months (male)

Months of age	Smoothed L	Smoothed S	Smoothed M
0			0.032048517 x^3 + -0.493433273 x^2 + 2.551397766 x + 12.62254537
2.5			0.007972878 x^3 + -0.201998877 x^2 + 1.54342034 x + 13.697217
9.5	1.4345E-06 x^3 + -0.000119864 x^2 + -0.037620259 x + 0.624077322	-7.58553E-08 x^3 + 2.1302E-05 x^2 + -0.001094812 x + 0.090651064	-7.67459E-05 x^3 + 0.007173901 x^2 + -0.251765964 x + 18.77518828
26.75			-3.88384E-06 x^3 + 0.001076046 x^2 + -0.081944537 x + 17.20118685
78	-3.06037E-06 x^3 + 0.001387949 x^2 + -0.190798754 x + 5.531514491		
90		1.99415E-08 x^3 + -1.37006E-05 x^2 + 0.002877807 x + -0.053198893	-3.94748E-06 x^3 + 0.001761925 x^2 + -0.203856428 x + 22.66402577
150	9.04656E-07 x^3 + -0.00066203 x^2 + 0.156555714 x + -13.82908985		
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Table 2 Functions for smoothed L, S and M for age in months (female)

Months of age	Smoothed L	Smoothed S	Smoothed M
0			0.019399718 x^3 + -0.359429206 x^2 + 2.139236779 x + 12.56896799
2.5			0.007312299 x^3 + -0.194108219 x^2 + 1.537772117 x + 13.22824693
9.5	3.47613E-07 x^3 + -2.38575E-05 x^2 + -0.037631412 x + 0.795846301	-1.0218E-07 x^3 + 2.31971E-05 x^2 + -0.000923983 x + 0.08896935	-0.000168505 x^3 + 0.013702125 x^2 + -0.385286062 x + 19.15626964
26.75			-4.80005E-07 x^3 + 0.000350143 x^2 + -0.031651293 x + 16.03450105
69	-5.83768E-06 x^3 + 0.002194825 x^2 + -0.255465003 x + 7.295142629		
90		2.10831E-08 x^3 + -1.43497E-05 x^2 + 0.002839146 x + -0.035441889	-3.03967E-06 x^3 + 0.001541344 x^2 + -0.183867689 x + 21.95124139
150	5.41432E-06 x^3 + -0.002965041 x^2 + 0.532984646 x + -32.85082504		-2.5069E-06 x^3 + 0.000642483 x^2 + 0.049828797 x + 5.323050314
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For using the LMS method, smooth curves for L, M and S can be fitted by a statistical method like cubic spline or polynomial equations or can be drawn by eye (2). The penalized likelihood method has been introduced for smoothing of L, M and S curves, and this method leads to natural cubic spline with knots at the ages of observation (3). Although many recent studies smooth L, M and S by maximum penalized likelihood (4–7), the present study aims to show the mathematical functions for smoothing more simply.

In conclusion, the present study provides the calculations for smoothed L, M and S values for BMI standards from a representative population of Japanese children. The reference data developed here are useful for evaluation of the BMI of the children from birth up to 17.5 yr of age.

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