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Standardized percentile curves of body mass index of Iranian children compared to the US population reference

M Hosseini[1,2], RG Carpenter[2], K Mohammad[1] and ME Jones[3]*

[1]*Department of Epidemiology and Biostatistics, Tehran University of Medical Sciences, I.R.Iran;* [2]*Medical Statistics Unit, London School of Hygeine and Tropical Medicine; and* [3]*Cancer and Public Health Unit, London School of Hygiene and Tropical Medicine, University of London, Keppel Street, London WC1E 7HT, UK*

OBJECTIVE: To present standardized percentile curves of body mass index (BMI) for Iranian children, and compare these to the US population reference.
SUBJECTS: 1599 boys and 1702 girls aged 2 – 18 y living in urban Tehran as a part of a random cluster sample survey of 1 in 1000 families throughout Iran.
MEASUREMENTS: Heights (cm) and weights (kg) were collected by trained health staff.
RESULTS: Standardized BMI reference curves for Iranian boys and girls were constructed. The curves are shown to fit the data well. The development pattern of BMI for boys and girls are compared.
CONCLUSIONS: The major differences observed between Iranian and the US BMI charts underline the need for population-specific reference data. For children over six years the 5th and 95th percentiles of our data may be used provisionally as cut-off points for defining thinness and obesity for Iranian children and adolescents.

Keywords: body mass index; thinness; obesity; centiles; childhood; adolescence; reference values

Introduction

Poor growth and malnutrition of children is a major problem in developing countries. Such children usually come to attention only when present for acute medical care, at which point they are seriously ill.[1] Obesity is also a health problem, with medical and psychological consequences for children and adolescents which may track into adult life,[2] although childhood obesity is mostly a nutritional problem in the US and Europe.[3] Body composition can be assessed by either elaborate methods such as measurements of body density using underwater weighing, estimation of lean body mass using deuterium distribution, DEXA (dual energy X-ray absortiometry), etc, or anthropometry. The methods generally used for estimating adiposity have high precision, but are expensive,[4] and are inferred from studies largely involving adults. These methods are technically difficult to apply to children and are impractical in most clinical settings.[5] Therefore indirect methods, such as skinfold thickness and weight-for-height indices, are often used as proxy measures of adiposity or as criteria for defining underweight and overweight.[4]

*Correspondence: ME Jones, Cancer and Public Health Unit, London School of Hygiene and Tropical Medicine, University of London, Keppel Street, London WC1E 7HT, UK
E-mail: m.jones@lshtm.ac.uk
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The mody mass index (BMI = weight/height^2) has been recommended to be used routinely to evaluate obesity in children and adolescents.[3,6] BMI reference data have been published only for children in developed countries such as North America,[3,5,7,8] France,[9] Britain,[10] Sweden,[11] Italy,[4] and Germany.[12] However, for any anthropometric indices to be meaningful in the pediatric age group, there must be standards defined by age and sex, based on local data as advocated by Hammer *et al*[5] Currently there are no reference data for assessment of thinness and obesity based on local norms available in Iran.

In this paper percentile curves of BMI for Iranian boys and girls aged 2–18 y are presented based on data on children living in Tehran as a representative norm for the country. The paper compares the results with the recently derived US population reference data,[3] since due to lack of the appropriate local data American references have been used worldwide. Also, we investigate the relationship between the cut-off points for defining thinness and obesity in childhood and adolescence which may be used in Iran.

Methods

Subjects

Weights and heights of 3301 children aged 2–18 years old living in urban Tehran were used to

construct BMI charts. Data were obtained from the National Health Survey 1990–92, a random cluster sample survey of 1 in 1000 families throughout Iran. Extensive data, including heights to nearest centimetre and weights to nearest kilogram of boys and girls between the ages 2–18 y, were collected by trained health staff. Ages were recorded in completed years.[13]

Statistical analysis

BMI charts for boys and girls in urban Tehran were constructed using Healy's method [14] as extended by Pan *et al*,[15] and implemented in GROSTAT II.[16] This method produces smooth centiles which are close to the data, and constrained to accord with neighbouring centiles; observations can be converted to Z-scores. The GROSTAT method and its appropriateness to our data was recently described by Hosseini *et al*.[17]

A grid test, which compares the observed and expected number of observations between each of the fitted centiles, was used to assess goodness of fit of the smooth centiles to the data.[14] An alternative test is to use the model for the smooth centiles to compute the Normal Z-scores corresponding to each of the original observations. If the curves fit the data, these Z-scores will be Normally distributed.[18]

Results

Measurements on weights and heights for 1599 (48.8%) boys and 1702 (51.6%) girls for children aged 2–18 y living in urban Tehran were used in this analysis. The age-sex distribution of the children is given in Table 1.

Separate BMI charts were constructed for boys and girls. Figure 1 shows the 5th, 15th, 50th, 85th, 95th smooth centiles for boys and girls, and centile values by age and given in Table 1. The grid tests were not significant (boys $\chi^2_5 = 9.91$, $P = 0.08$; girls $\chi^2_5 = 3.69$, $P = 0.59$). The Shapiro-Wilk W-test[19] of Normality of the Z-scores were also not significant (boys $P = 0.30$; girls $P = 0.34$) confirming the goodness of fit of the smooth centiles to the data.

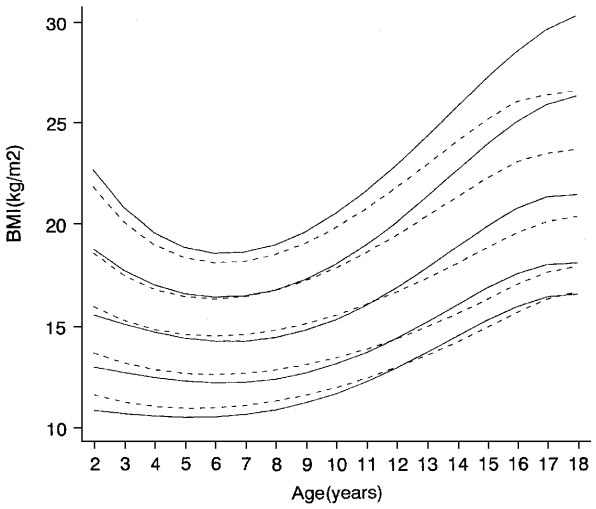

Figure 1 Body mass index (BMI) percentiles curves for Iranian boys (...) and girls (—). Centiles are: 5th, 15th, 50th, 85th, 95th.

For boys, the model for the fitted centiles of log (BMI) is a cubic in age which was splined at the age of 15 with parameter values which are cubic and quadratic polynominals in z. A quartic GROSTAT model covering the entire age range appeared to be the most appropriate one for the girls' log(BMI). The centile curves presented are derived by back transformation. The details of statistical models are available from the first author on request.

In general, the shape of the curves for boys and girls are similar. Figure 1 shows that for boys and girls at age 2 years old, median BMI decrease from 16.0 and 15.6 kg/m^2 until 6–7 when a trough occurs and medians of BMI are about 14.5 and 14.2 kg/m^2 respectively, after which BMI increases again. This

Table 1 Percentile values of body mass index (kg/m^2) by age and sex for Iranian children

Age group	Boys percentiles						Girls percentiles					
	n	5th	15th	50th	85th	95th	*n*	5th	15th	50th	85th	95th
2–	87	11.6	13.7	16.0	18.6	21.8	82	10.8	13.0	15.6	18.8	22.7
3–	109	11.2	13.2	15.3	17.5	20.1	111	10.7	12.7	15.1	17.7	20.8
4–	117	11.0	12.8	14.8	16.8	19.0	139	10.5	12.5	14.7	17.0	19.6
5–	121	10.9	12.6	14.6	16.4	18.3	128	10.5	12.3	14.4	16.5	18.8
6–	136	10.9	12.5	14.5	16.3	18.0	128	10.4	12.1	14.2	16.3	18.5
7–	129	11.0	12.6	14.5	16.4	18.1	121	10.5	12.1	14.2	16.4	18.5
8–	121	11.2	12.7	14.7	16.6	18.4	129	10.8	12.3	14.3	16.7	18.9
9–	98	11.5	13.0	15.0	17.1	18.9	123	11.1	12.6	14.7	17.2	19.5
10–	118	11.8	13.3	15.4	17.7	19.6	113	11.5	13.0	15.2	17.9	20.3
11–	101	12.3	13.7	15.9	18.4	20.5	98	12.1	13.5	15.8	18.8	21.4
12–	88	12.8	14.2	16.5	19.2	21.5	105	12.7	14.2	16.7	19.8	22.6
13–	79	13.4	14.8	17.1	20.1	22.6	82	13.5	15.0	17.6	21.1	24.0
14–	86	14.0	15.4	17.8	21.1	23.8	70	14.3	15.8	18.6	22.4	25.5
15–	61	14.7	16.1	18.6	22.0	24.9	89	15.1	16.7	19.6	23.6	26.9
16–	58	15.5	16.8	19.3	22.8	25.8	56	15.7	17.4	20.5	24.8	28.2
17–	43	16.1	17.4	19.9	23.2	26.1	74	16.2	17.8	21.1	25.6	29.3
18–19	47	16.4	17.7	20.1	23.4	26.3	54	16.3	17.9	21.2	26.1	30.0

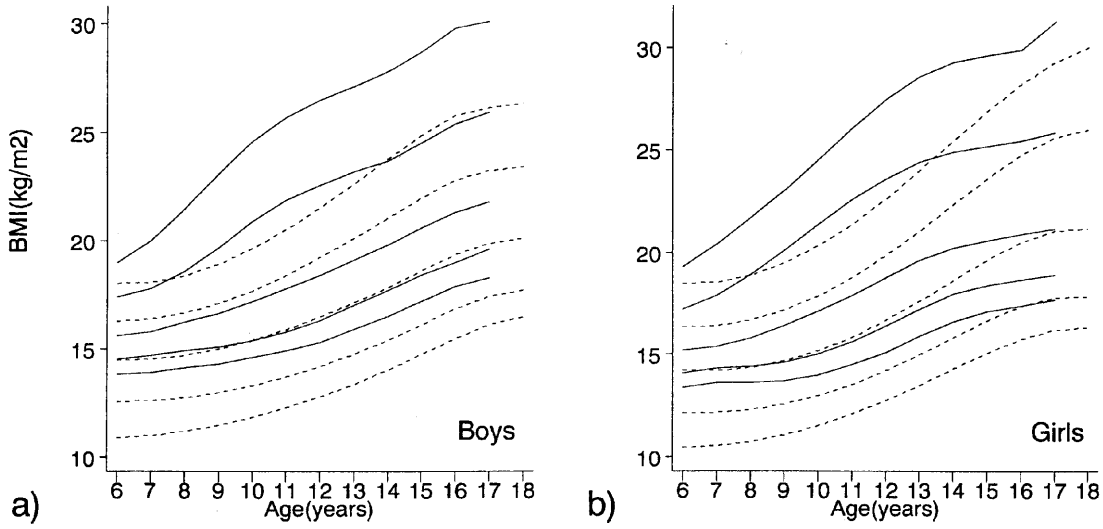

Figure 2 Comparisons of BMI percentile curves for Iranian children (...) with the U.S.(—) reference data. Centiles are: 5th, 15th, 50th, 85th, 95th.

dip in the BMI is called the adiposity rebound.[20,21] The age at adiposity rebound appears to occur slightly earlier on the lower than higher centiles, by one year for both boys and girls (Figure 1 and Table 1). After the rebound median BMI increases more rapidly in girls than in boys and the curves cross at about 12 y. From the age of 13 y all the centile curves especially the fifth and upper percentiles for girls are higher than boys. The female-male difference at upper centiles (85th to 95th) increase from about 0.5 kg/m^2 at 11 y to 2.7 kg/m^2 and 3.7 kg/m^2 at the age of 18 y respectively.

Discussion

BMI is a useful index of weight relative to stature.[22] The standardized curves of BMI offer an opportunity to monitor an individual's degree of underweight and overweight from childhood through adolescence. The population of Iran is extremely young with over 52% below 18 years of age.[23] We have shown elsewhere that data on weight and height of children living in urban Tehran are representative of urban children in Iran.[13] Similarly, further analysis revealed that BMI data for Tehrani children may be used for all children in Iran. Because of the absence of local data, the WHO-standards based on American children have often been used worldwide and in most developing countries, as in Iran. However, due to differences in genetic and environmental factors, in different parts of the world children grow differently. So the application of the US norms can be misleading.

Figures 2a-b compare the BMI charts for Tehrani children, which are proposed as appropriate for Iran, with the US reference data presented by Rosner *et al*.[3] To compare our data with the US population reference, comparison was confirmed to the age range 6–18 years old. There are striking differences in the lower as well as the upper centiles. Up to the age of 15, the 25th centiles (centile not shown) of BMI for Iranian children is about the 5th centile of the US reference data, after the age of 16 there is a catch up in BMI for boys and girls, although BMI is higher for girls. The median BMI values for boys are lower than their US counterparts, though from the age of 16 the median BMI for Iranian girls is similar to the BMI for girls in the US.

At first sight these comparisons may imply that children in Iran are generally seriously malnourished, however, Figures 2a-b show a general shift downward for Iranian BMI centiles but little change in spread of the centiles in each age group. If serious malnutrition were present in a proportion of the population the upper centiles may follow the pattern of US data and the lower centiles would be relatively much lower than expected. The general shift of our centiles suggest that either the usual diet of Iranian children does not promote growth as much as the usual diet of US children or that there are genetic differences between populations.

The 85th and 95th percentiles of BMI (often used operationally to define obesity and superobesity, respectively) [7,8,24] for US children are substantially higher than for Iranian boys and girls over the age range of 6–18 y, though the 85th centile of Iranian girls catches up with the US value after the age of 16 y. These findings show that the US reference data are too high for identification of the nutritional status of an Iranian child relative to its compatriots.

The timing of the age of adiposity rebound is diagnostic of later fatness–the earlier the adiposity rebound the greater the risk of adult obesity.[10] Although the current BMI centiles are based on cross sectional rather than longitudinal data, it is striking that the lower centiles have their rebound by one year earlier than the higher centiles. In contrast, Hammer *et al*,[5] and Cole *et al*,[10] observed that

the lower centiles have their rebound later, by three years or more, than the higher centiles.

The NIH Consensus Development Conference on Obesity has recommended use of the 85th percentiles (weight-for-height) as a cut-off point for obesity in adults, with its 95th percentile frequency being used to define superobesity.[7,8,24] For clinical purposes, Hammer *et al*,[5] found the 95th percentile BMI to be a conservative cut-off for defining obesity in childhood. Following the BMI pattern provides more useful clinical information, however, than any single measurement of BMI. Comparisons of our data with the U.S. reference (figure 2) suggest that for children over six years the 5th and 95th percentiles of our data may be used provisionally as cut-off points for defining thinness and obesity for Iranian children and adolescents. However, further studies are needed in Iran to define more accurate criteria for defining grades of underweight and overweight using BMI in childhood and adolescents. These studies should consider the morbidity associated with abnormally low or high percentile levels of BMI, including increased risk for long-term poor growth and obesity.[5]

Conclusion

Standardized curves of BMI presented here may be used to monitor the development of obesity as well as changes in BMI associated with malnutrition in childhood and adolescence in Iran over the age of six. We have shown (M Hosseini, RG Carpenter, K Mohammad, unpublished data) that under the age of six, BMI curves do not provide a satisfactory normal range of weight-for-height, especially for some of the very short children in Iran for whom a special table of normal ranges have been constructed. Generally, low and high values of BMI are predictors of long-term underweight and obesity in childhood, and increased morbidity and mortality in adulthood. Assuming these predictions are applicable in Iran, we recommend that Primary Health Care (PHC) in Iran should include routine monitoring of height and weight and BMI of children.

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