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Appropriateness of US and international BMI-for-age reference curves in defining adiposity among Israeli school children

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Abstract

Effective surveillance of trends in paediatric overweight and obesity requires the establishment of valid cutoff values to identify children at risk. In Israel, standard values for childhood BMI-for-age are currently based on growth charts published by the US Centers for Disease Control and Prevention. However, the appropriateness of using US reference values in populations outside the US is questionable, due to inherent differences in ethnicity, culture and socioeconomic status. We recorded data from 9,988 children aged 6-12 selected by random cluster sampling within the framework of school-based health surveys conducted in Israel during the years 1997 and 2000. We constructed population-specific centile BMI-for-age curves valid for Israeli children, and compared these curves to current standard US and international reference values. Curves were constructed using LMS statistical curve smoothing methods. The dataset of Israeli schoolchildren produced reference centiles substantially different than those based on US children. Israeli reference values were closer to centile curves published by the International Obesity Task Force. Local and national health planners should recognize the intrinsic limitations associated with the use of "standard" reference values in defining paediatric overweight and obesity in dissimilar populations. The results of this large population-based study highlight the need for population-specific BMI-for-age reference values in order to accurately describe the prevalence of paediatric overweight and obesity.

Keywords: childhood, obesity, body mass index, growth charts, reference values

Abbreviations: BMI – body mass index; NCHS – US National Center for Health Statistics; IOTF – International Obesity Task Force.

Introduction

Body mass index (BMI) is a widely used measure of adiposity in adults, due to its correlation with adverse health outcomes and the relative ease of its measurement and calculation in clinical and field settings [8,13]. Although BMI has established validity in the definition of adult overweight and obesity, its use in children and adolescents remains controversial [13]. While BMI has been shown to correlate well with adiposity in children [8,13], normal changes in BMI during growth and maturation complicate the use of absolute BMI values in measuring fatness in children [4,14]. An expert committee has recommended guidelines for screening overweight children based on age and sex specific BMI percentiles as an alternative to absolute BMI values. According to this recommendation, children with BMI values above the 85^{th} age and sex specific centile can be considered at risk for overweight in adulthood, while children with BMI values above the 95^{th} centile can be considered obese [1,7,10].

In 2000, the US National Center for Health Statistics (NCHS) published updated BMI-for-age centile charts [11,12,15]. These charts are based on nationally representative US survey data, and are used to determine cut off points to identify the 85^{th} and 95^{th} centile BMI values by age and sex [1]. These growth charts also provide the basis for the childhood overweight and obesity reference values currently in use in Israel, although there is substantial question as to why cutoff values in this country should based on data from the United States [3]. Furthermore, the data sources used for the production of the 2000 NCHS BMI-for-age charts are not recent, and for children aged 6 and over include population data from as early as 1963 and no later than 1980 [11].

The appropriateness of using NCHS reference values in countries outside the US is questionable, due to inherent differences in ethnicity, culture and socioeconomic status. In an effort to establish an international definition of paediatric obesity, the International Obesity Task Force (IOTF) recommended an alternate definition of childhood cutoff points, better designed for international use. The IOTF obtained BMI data from large representative surveys in six countries (Brazil, Great Britain, Hong Kong, Singapore, Netherlands, and the US), extrapolated universal WHO standards for adult obesity at age 18 (overweight: BMI>25 kg/m^2; obesity: BMI>30 kg/m^2) [18], and regressed the appropriate centile cutoff points back through ages 2-18 [3]. Although the resulting IOTF reference values are arguably less arbitrary and more widely applicable than are the US values, wide variation was seen in the individual growth curves of the six participating countries. This finding further strengthens the case for the creation of country-specific reference values, to be used in conjunction with international cutoff values. To the best of our knowledge, no childhood growth charts have been produced to date based on data collected from the Israeli population. We developed sex-specific BMI-for-age reference charts using a datset of Israeli children aged 6 to 12, and compared these cutoff values to those recommended by NCHS and IOTF.

Materials and methods

Study population. We analyzed data collected in two cross-sectional school-based health surveys conducted by the Barzilai Medical Center in the Ashkelon District of Israel during the years 1997 and 2000 [6,16]. Study schools were selected using a random cluster sample approach. All elementary schools in the district were included in the sampling frame, and were eligible for selection. For age groups under-represented in the original cross-sectional samples, we collected supplementary school medical records using a similar cluster sample approach.

Data collection. Each child was weighed shoeless while wearing shorts and a T-shirt. Scales were calibrated with standard weights prior to use. Barefoot standing height was measured by stadiometer to a precision of ±0.5 cm. Study protocols were approved by the Ministry of Health Helsinki committee and by regional educational authorities.

Definition of obesity. BMI was calculated as weight (kg)/height (m)^2. For IOTF charts, smoothed percentile curves were passed through the adult BMI cutoff points of 25 kg/m^2 (overweight) and 30 kg/m^2 (obesity). Children whose age- and sex-specific BMI values were higher than these corresponding centile curves were accordingly considered overweight or obese. For US NCHS data and for the current study population, cutoff points based on 85th and 95th centiles were used. However, whereas NCHS guidelines use the terms “at risk for overweight” and “overweight” for children who exceed the 85th and 95th centiles, respectively, we used the terms “overweight” and “obese” to represent these cutoff points, in order to remain consistent with the terminology used for adults and that used by the IOTF [10].

Data analysis. The statistical methods for this study were designed to parallel, as closely as possible, those used by NCHS. These methods have been described at length elsewhere [11,12,15]. Briefly, statistical procedures were applied to the study data in two stages, the first intended to generate initial smoothed curves for selected major centiles ("curve smoothing stage"), and the second to generate the parameters that were used to construct the final smoothed curves and additional centiles ("transformation stage"). In the curve smoothing stage, selected empirical centiles were smoothed using polynomial regression procedures. In the transformation stage, the smoothed curves were approximated using a modified LMS estimation procedure to provide the transformation parameters *lambda*, *mu*, and *sigma* (LMS) described below. This resulted in final centile curves that closely matched those smoothed in the first stage, and allowed computation of additional centiles and z-scores. The curve smoothing methods were applied empirically to the 5^{th}, 10^{th}, 25th, 50^{th}, 75^{th}, 90^{th}, and 95^{th} centiles. In addition, the 85th centile was included because this centile of BMI has been recommended as a cutoff to identify children and adolescents at risk for overweight [1,7].

Data transformation. A modified LMS statistical procedure was applied to the smoothed percentile curves in order to estimate additional centiles and allow calculation of standard deviation units and z-scores [2,12]. Since the distribution of BMI is skewed rather than normal, a power transformation can be used to remove the skewness by lengthening one tail of the distribution while shortening the other. A Box-Cox transformation is the most appropriate method, under the assumption that, after the appropriate power transformation, the data are closely approximated by a normal distribution [2]. Under the LMS technique, three parameters are estimated from the smoothed data curves: the median (M), the generalized coefficient of variation (S), and the power of the Box-Cox transformation (L). The M and S curves correspond to the median and coefficient of variation of BMI at each age, whereas the L curve represents the age-dependent skewness of BMI distribution. Parameter estimation was conducted at half-year age intervals, and was done separately for boys and for girls. Once the age-specific values of L, M and S were determined, specific centiles or z-scores were calculated using the following equation [3,15]:

$$X = M\,(1+LSZ)^{1/L}$$

where X represents a given BMI value and Z represents its corresponding *z* score in the normal distribution. The centile corresponding to a given *z* score was obtained from a normal distribution table.

The final result of data transformation was the generation of a series of curves describing the smoothed increase in BMI with age. In order to compare these to other published reference values, additional curves were constructed using LMS and centile data from datasets that accompany the NCHS [12] and IOTF [3] reference charts.

Results

Height and weight measurements were available for 9,988 children. The age and sex distributions of children included in the study studied are presented in Table 1. Group sizes were adequate for analysis, and the smallest study subgroup – girls aged 10 –

numbered 199 children, double the recommended minimum size for LMS calculations at this stage of growth [2].

BMI-for-age curves for Israeli girls and boys are shown in Figure 1. For girls, the tail of a J-shaped growth curve can be seen at the younger ages [3], especially in the upper centile curves. From approximately age 8, most centile curves rise linearly, whereas the 95th centile curves exhibits bimodal behavior as it enters the 12th year of life. For boys, the BMI-for-age curve progresses in a more linear fashion throughout the ages studied, while the uppermost and lowermost centile curves appear to spread slightly from the others towards age 12. Median BMI values, represented by the 50th centile curve, are nearly identical for boys and girls through age 10. However, for all centile curves above the median, BMI values for girls are higher than those for boys at all ages. Overall, girls exhibit a wider range of BMI values than boys at all ages.

Figure 1 also shows a comparison between the 5th, 50th, 85th and 95th centiles of the Israeli and US NCHS reference values. For girls, the 50th centile curve is nearly identical in both populations. However, the BMI values at the 85th and 95th centiles are notably higher in the study population than in the US population. These differences are most pronounced at ages 6-7, remain constant from ages 8-11, and are minimized by age 12. BMI values at the 5th centile are lower among the study population than among the US reference population throughout the entire age span we studied.

Comparisons for boys are similar to those seen in girls. Median BMI values are nearly identical in the study and US populations over the entire range of ages studied. As for girls, BMI values in study population boys are higher than those of their US counterparts at the 85th and 95th centile, although the values of the two populations appear to merge earlier than in girls, between ages 10-11. As in girls, BMI values for boys at the 5th centile are lower among the study population than among the US reference population over the entire range of ages studied.

Figure 2 compares the 85th and 95th centiles of the study population to the corresponding IOTF reference values. As stated above, the IOTF references are age-regressed centile curves corresponding to the adult cutoff points of 25 and 30 kg/m^2, as measured at age 18 in pooled international data [3]. Among girls, the IOTF obesity curve (BMI 30) precisely traces the study population's 95th centile curve from ages 7-11, but shows less agreement above and below this age range. The IOTF overweight curve (BMI 25), while running parallel to the 85th centile throughout over the majority of age ranges, shows consistently lower BMI values than the corresponding study curve. Among boys, the 85th centile curve and the IOTF overweight curve are very similar, and the values of the two overlap after age 10. While the IOTF obesity curve is nearly identical to that of the study population's 95th centile curve through age 9, the former represents increasingly higher BMI values than the latter from ages 9-12.

Discussion

Child obesity has rapidly become an epidemic of global proportions. Paediatric obestity is an especially severe problem, since its onset during childhood increases the overall length of exposure to the detrimental effects of overweight, accelerates the onset of chronic disease, and affects the child's physical, psychological and social development

[9]. While it is of great public health importance to monitor trends in child obesity, international comparisons can prove difficult since a wide variety of definitions of child obesity are in use, and no commonly accepted standard has yet been adopted [3]. Since more sensitive measures of adiposity, such as body fat percentage and skinfold thicknesses, are not practical for use in most clinical settings, BMI has become the most widely used measure of fatness. However, while the cutoff points of 25 and 30 kg/m^2 are recognized internationally as the definitions of adult overweight and obesity, the most appropriate definitions for children are still unclear.

In the US, overweight and obesity cutoff points are marked at the 85th and 95th sex- and age-specific BMI values, respectively. These definitions, however, present a major problem in tracking trends over time. Since the prevalence of paediatric overweight is on the rise, the absolute BMI value at these percentiles tends to increase over time, and a BMI considered overweight or obese in the past may fall below the 85th or 95th centile today, and might thus be considered normal. In an effort to minimize the effects of trends in weight over time, the NCHS BMI-for-age reference values, published in 2000, did not include any recent data collected from children over the age of 6, in order to leave today's fatter children out of the reference value calculations. Specifically, all data collected from children aged 6 and above in the US NHANES III study (1988-1994) were excluded from the latest BMI calculations, such that the "current" 2000 US reference values for children aged 6-18 are based on data collected between the years 1963 and 1980 [11].

The appropriateness of the the NCHS reference values in countries outside the US is unclear, due to obvious differences from country to country in population ethnicity, culture and socioeconomic status. Accordingly, the IOTF recommended an alternative definition of childhood overweight and obesity cutoff points, based on BMI data from large representative surveys in several countries. The IOTF system pools international data, and bases childhood cutoff points on centile values associated with BMI 25 and 30 at age 18 [3,18]. Although these reference values are less arbitrary than the US values, substantial variation was seen between the curves of the participating countries, strengthening the case for the creation of country-specific reference values.

To the best of our knowledge, no national childhood growth charts have been produced to date based on data collected from the Israeli population. Instead, Israel currently employs the 2000 NCHS curves as reference values for the routine evaluation of paediatric growth and development. The use a local reference such as ours would have several pronounced benefits over the continued use of US standards. First, our data was collected in a narrower and more recent cross-section. Our data was collected between the years 1997-2000, while the corresponding NCHS data was collected as long ago as 1963, but no more recently than 1980. Thus, Israeli data such as ours reflect a more accurate indication of today’s children. Second, the NCHS charts are intended for use only in the US, as they are based on a sample specifically weighted to reflect the US population [11]. Children in Israel, however, most likely differ substantially from US children with respect to origin, culture, environment, nutrition and genetics, and the external validity of the NCHS reference values is in question. Finally, the massive demographic changes experienced in Israel over the last decade, especially the large scale immigration seen from countries of the former Soviet Union, require close monitoring of local trends and references. Furthermore, if a foreign reference is chosen for purposes of standardization and international comparison, it appears from this study that the IOTF reference values provide a closer representaion of true Israeli values than do the NCHS growth charts.

Our data were collected in the Ashkelon District of Israel. One potential limitation of this study may be the appropriateness of generalizing its findings to the rest of the Israeli population, and especially to Bedouin and Arab children, due to their lack of representation in the study sample. A previous study [17], however, demonstrated no significant difference in the prevalence of obesity between Jewish and Bedouin children, so that the present results may accurately reflect the distribution of BMI among non-Jewish children in Israel as well. Additionally, our study sample was limited to children aged 6-12. While this age range is appropriate for children of elementary school age, additional Israeli datasets should be studied and analyzed in order to widen the range of local growth charts, ideally to span all ages from birth to 18 years.

The differences observed between the various reference curves may reflect, to a limited extent, differences in the smoothing methods or the statistical approaches chosen. However, they likely indicate true differences in the population data values as well. As has been shown before, although the results of the NCHS and IOTF methods are similar in many cases, there may be large differences between them in the prevalence estimates of overweight and obesity, especially for young girls [5].

The results of our study demonstrate several apparent disagreements between NCHS, IOTF and Israeli reference curves in defining overweight and obesity among Israeli school children. Since effective primary and secondary prevention of the ongoing epidemic of paediatric overweight are dependent on surveillance of BMI in children, our findings underscore the need for the development of valid population-specific BMI-for-age reference values in this country and elsewhere.

References

1. Barlow SE, Dietz WH (1998) 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 102: E29

2. Cole TJ (1990) The LMS method for constructing normalized growth standards. Eur J Clin Nutrition 44: 45-60

3. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH (2000) Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ 320: 1–6

4. Daniels SR, Khoury PR, Morrison JA (1997) The utility of body mass index as a measure of body fatness in children and adolescents: differences by race and gender. Pediatrics 99: 507-526

5. Flegal KM, Ogden CL, Wei R, Kuczmarski RL, Johnson CL (2001) Prevalence of overweight in US children: comparison of US growth charts from the Centers for Disease Control and Prevention with other reference values for body mass index. Am J Clin Nutr 73: 1086–93

6. Goren A, Bibi H, Goldsmith JR (1991-92) Prospective lung-health monitoring in relation to a new power plant. Public Health Rev 19: 103-108

7. Himes JH, Dietz WH (1994) Guidelines for overweight and adolescent preventive services: recommendations from an expert committee. Am J Clin Nutr 59: 307-316

8. Horlick M (2001) Body mass index in childhood - measuring a moving target.

J Clin Endocrinol Metab 86: 4059-60

9. Huerta M, Bibi H, Haviv J, Scharf S, Gdalevich M (2006) Parental smoking and education as determinants of overweight and obesity in Israeli schoolchildren. Prev Chronic Dis 3: A48

10. Janssen I, Katzmarzyk PT, Srinivasan SR, Chen W, Malina RM, Bouchard C, Berenson GS (2005) Utility of childhood BMI in the prediction of adulthood disease: comparison of national and international references. Obes Research 13: 1106-15.

11. Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, Flegal KM, Guo SS, Wei R, Mei Z, Curtin LR, Roche AF, Johnson CL (2000) CDC growth charts: United States. Advance Data 314: 1-27

12. Kuczmarski RJ, Ogden CL, Guo SS, Grummer-Strawn LM, Flegal KM, Mei Z, Wei R, Curtin LR, Roche AF, Johnson CL (2002) 2000 CDC Growth Charts for the United States: methods and development. Vital Health Stat 11: 1-190

13. Lindsay RS, Hanson RL, Roumain J, Ravussin E, Knowler WC, Tataranni PA (2001) Body mass index as a measure of adiposity in children and adolescents: relationship to adiposity by dual energy X-ray absorptiometry and to cardiovascular risk factors. J Clin Endocrin Metabol 86: 4061-7.

14. Maynard LM, Wisemandle W, Roche AF, Chumlea WC, Guo SS, Siervogel RM (2001) Childhood body composition in relation to body mass index. Pediatrics 107: 344-350

15. Ogden CL, Kuczmarski RJ, Flegal KM, Mei Z, Guo S, Wei R, Grummer-

Strawn LM, Curtin LR, Roche AF, Johnson CL (2002) Centers for Disease Control and Prevention 2000 growth charts for the United States: improvements to the 1977 National Center for Health Statistics version. Pediatrics 109: 45-60

16. Peled R, Bibi H, Pope CA III, Nir P, Shiachi R, Scharff S (2001) Differences in lung function among school children in communities in Israel. Arch Environ Health 56: 89-95

17. Pilpel D, Leer A, Phillip M (1995) Obesity among Jewish and Bedouin secondary school students in the Negev, Israel. Public Health Rev 23: 253-62

18. World Health Organization (1998) *Obesity: Preventing and Managing the Global Epidemic*. Geneva, Switzerland: World Health Organization

Table 1: Age and sex distribution of children included in study

Age (years)	Boys (n)	Girls (n)
6	235	272
7	319	261
8	1,438	1,888
9	702	659
10	220	199
11	1,441	1,539
12	455	360
Total	4,810	5,178

Figure legends

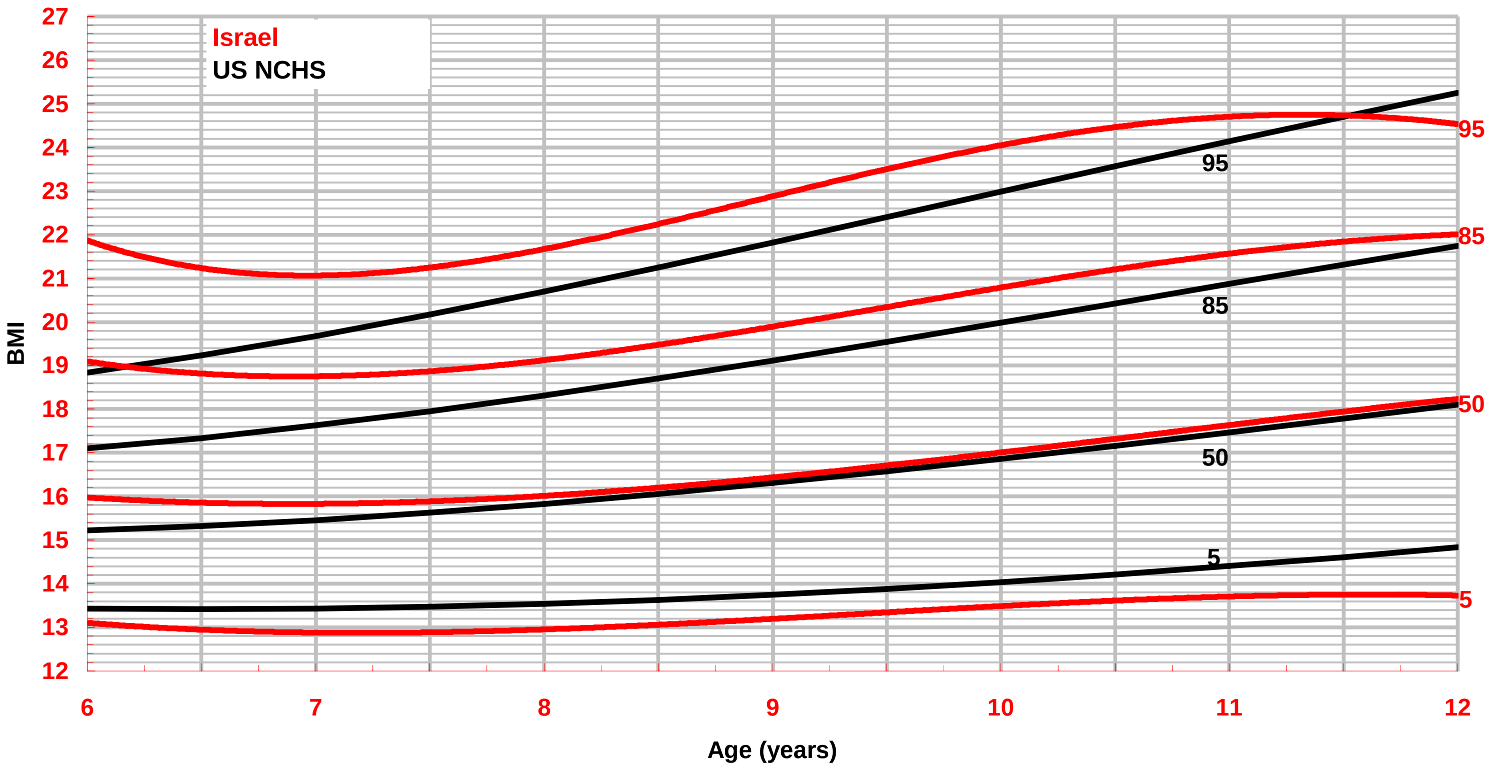
Legend for Figure 1:

Comparison of BMI-for-age reference centile curves for children aged 6-12 years, based on Israeli (Ashkelon District, 1997-2000) and US (National Center for Health Statistics [NCHS] 2000) data sets. Curves for girls are shown in upper panel, for boys in lower panel.

Legend for Figure 2:

Comparison of BMI-for-age reference centile curves for children aged 6-12 years, based on Israeli (Ashkelon District, 1997-2000) and International Obesity Task Force (IOTF) data sets. Curves for girls are shown in upper panel, for boys in lower panel.

Figure 1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Age (years)
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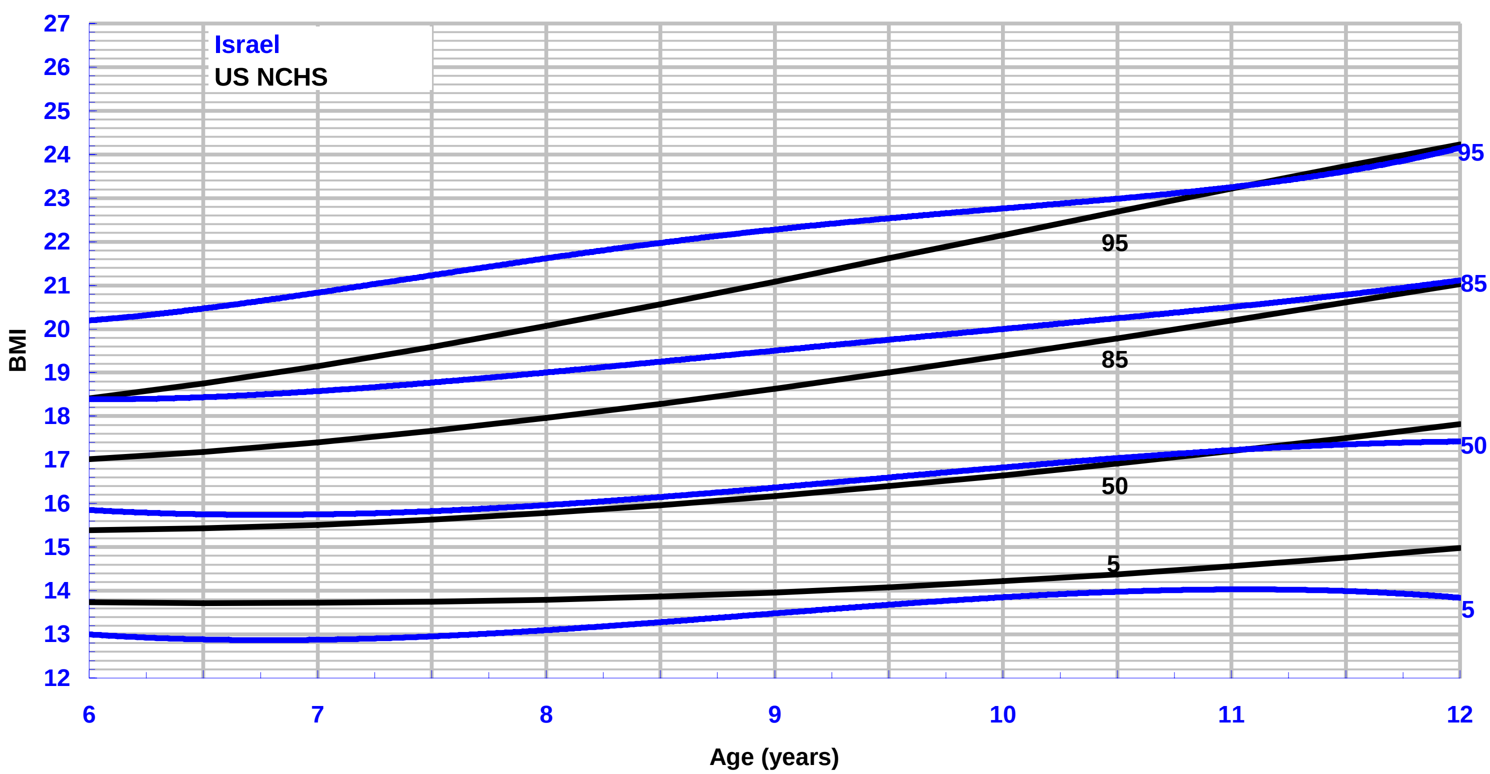
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Age (years)
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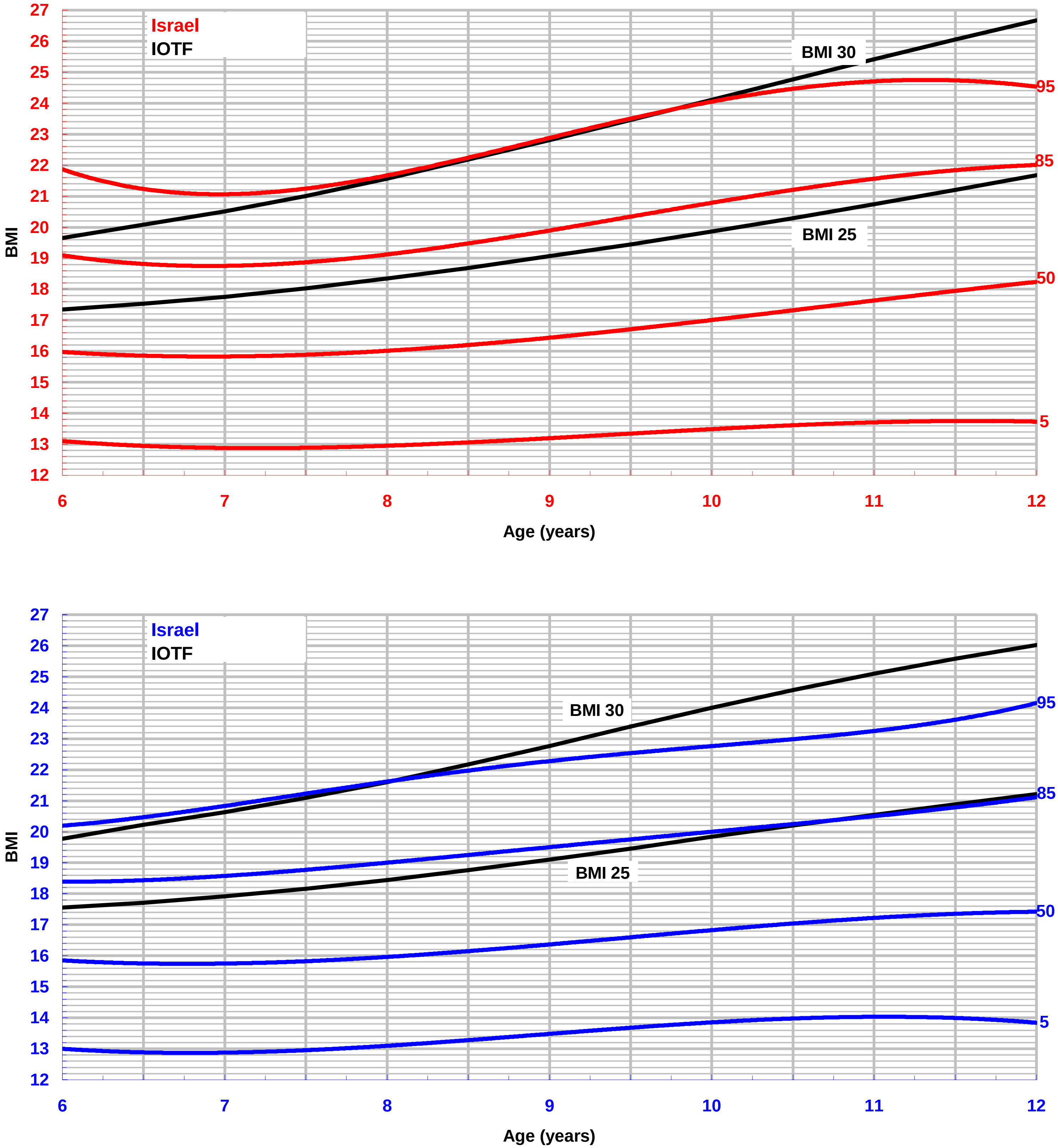
Figure 2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