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Extended growth charts for Indian children

<https://doi.org/10.1515/jpem-2020-0573>

Received October 4, 2020; accepted November 13, 2020;

published online December 16, 2020

Keywords: children; endocrinologist; growth charts; growth hormone; short stature.

Abstract

Objectives: While growth charts depicting 7 percentile lines for height and weight are useful for healthcare workers and pediatricians, endocrinologists need indication-specific z score cutoffs to plan investigations and treatment. The current Indian charts do not offer lower percentile/z scores (−2.25, −2.5, and −3 z score) lines. Also, increasing prevalence of childhood overweight and obesity necessitates a quick screening of nutritional status without calculations while using the same growth chart. Our objectives were to produce extended and user-friendly growth charts for 0–18-year-old Indian children that depict −2.25, −2.5, and −3 z score height lines in addition to the standard 7 lines and to add a quick BMI assessment tool as an inset.

Methods: LMS values from IAP 2015 growth charts (5–18 years) and WHO 2006 MGRS charts (<5 years) were used to generate −2.25, −2.5, and −3 z score height lines (1.2, 0.6, and 0.1 percentiles, respectively) from 0–18 year for boys and girls. These newly generated lines were added to standard 7 (3, 10, 25, 50, 75, 90, 97) percentile lines for height charts. In addition, modified BMI quick screening tool was incorporated as an inset.

Results: The extended height charts (with 10 lines), standard (7 lines) weight charts, and quick BMI assessment tool are presented in a single unified chart for use by endocrinologists.

Conclusions: These charts will help in defining specific height z score cutoffs as well as screen for overweight and obesity without any calculations in Asian Indian children.

Introduction

Growth charts are invaluable tools in the assessment of anthropometric parameters in a short child. Most growth charts depict the standard 7 percentiles (3rd, 10th, 25th, 50th, 75th, 90th, and 97th) for height and weight as they are primarily aimed at healthcare workers for the assessment of malnutrition [1]. From a healthcare workers' or pediatricians' perspective, charts depicting 7 percentile lines starting at the 3rd and ending with the 97th percentile (−1.88 and +1.88 z scores) for height and weight are adequate. The BMI charts designed to define overweight and obesity for Asian Indians (23 and 27 kg/m² adult equivalent, respectively) are practical.

Short stature is a common referral to an endocrinologist [2]. Unlike for healthcare workers and pediatricians, endocrinologists not only have to confirm short stature but also need to define the degree of shortness and need indication-specific cutoffs so that investigations and treatment may be planned accordingly [3]. Also, z-scores are taken into account for initiating and monitoring of growth hormone therapy, e.g., small for gestational age (SGA) children below −2.5 z score for height and idiopathic short stature below −2.25 z score qualify for growth hormone therapy; a severely short child (below −3 z score) warrants detailed investigations including the Growth hormone-Insulin like Growth Factor (GH-IGF) axis [3].

Further, childhood overweight and obesity are an increasing health problem in Indian children [4]. There are many complications associated with obesity, including metabolic syndrome, increased risk of coronary heart disease, and stroke. Hence, it is necessary to assess over-nutrition in children. A busy practitioner finds it difficult to calculate BMI and plot it due to time constraints [5]. A quick BMI screening tool based on weight for the height that eliminates the need to calculate BMI (for use of children between 8 and 18 years) may help to rapidly decide if a child is overweight, obese, normal, or underweight [6].

Growth monitoring guidelines for Indian children recommend the use of the World Health Organization (WHO) growth charts until 5 years of age and country (India)-specific charts from 5 to 18 years [7]. The recommended growth charts do not have added centiles/z scores

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or tools that may help endocrinologists to rapidly assess for the degree of shortness or classify a child as being underweight, overweight, or obese. Hence, for the ease of use by endocrinologists and pediatric endocrinologists, growth charts need to be modified to include lower height cutoff lines and tools for rapid assessment of overweight/obesity. Our specific objectives were thus: (1) to produce extended growth charts for 0–18-year-old Indian children that depict -2.25 , -2.5 , and -3 z score height lines in addition to the standard 7 percentile height and weight lines; and (2) to add the quick BMI assessment tool to these extended charts as an inset.

Material and methods

For this study, we used the LMS [Lambda for the skew, Mu for the median, and Sigma for the generalized coefficient of variation; Cole,

1990] [8] values from the Indian Academy of Paediatrics (IAP) 2015 growth charts (5–18 years) and WHO 2006 MGRS (Multicenter Growth Reference Study) charts (<5 years) to generate -2.25 , -2.5 , and -3 z score height lines (1.2, 0.6, and 0.1 percentiles, respectively) from 0–18 year for boys and girls [7, 9]. The formula used to generate a specific z score value at a specific age was μ multiplied by $(1 + \lambda\sigma Z)$ raised to $(1/\lambda)$ where μ is the mean, λ and σ are the age-specific Lambda and Sigma values, and Z is the required z score [8]. Since there is some discrepancy between WHO and IAP data at the junction of 5 years, a smoothing technique using the cubic-spline method was used to generate continuous smooth curves using G numeric ver 1.2 Software. These newly generated lines were added below the standard seven (3, 10, 25, 50, 75, 90, 97) percentile lines for height charts. Also, the modified BMI quick screening tool was incorporated as an inset. The BMI tool that has been published recently is prepared in such a way that the intersection of height on the x-axis and weight on the y-axis shows the position of the child with reference to four cutoff lines, namely underweight, normal, overweight, and obese [6]. These lines refer to the adult BMI equivalent of 23 adult equivalent (corresponding to z score of 0.54 in boys and 0.67 in girls) and 27 adult equivalent (corresponding to z score of 1.34 in boys and 1.64 in girls) to

Figure 1: Girls height and weight charts 0–18 years.

define underweight, overweight, and obese respectively, and the underweight cutoff corresponds to the 3rd percentile of the Indian BMI. These z scores are lower than +1 and +2, which are normally used to define overweight and obesity because Asian Indians are at higher risk of metabolic syndrome at lower BMI, and hence 23 and 27 adult equivalent lines were fitted as per WHO and IOTF recommendations, to pick up overweight and obesity early in Indian children [7]. The charts were color-coded as per the international convention of blue for boys and pink for girls.

For this study, we utilized published LMS values and no subject/participant data were included; thus, a waiver was obtained from the institutional ethics committee.

Results

Extended (10 z score/percentile lines, i.e., 7 standard and 3 newly designed lower z score/percentiles) height charts

and standard weight charts (7 z score/percentiles) with the BMI screening tool as inset are presented in Figures 1 and 2 for boys and girls, respectively. Table 1 and 2 show the extended height percentiles for boys and girls, respectively. It is observed that the difference between the 3rd percentile (−1.88 z) and 0.1st percentile (−3 z) was 3.2, 4.8, 6.6, 6.5, and 6 cm for girls and 3.2, 4.6, 6.5, 7.8, and 7.3 cm for boys at 2, 5, 10, 15, and 18 years of age, respectively. Tool for mid parental height percentile calculation is illustrated on the right side of the charts.

Discussion

We present here modified growth charts for use by endocrinologists with additional z score/percentile lines for

Figure 2: Boys height and weight charts 0–18 years.

Table 1: Height percentile for boys including 7 standard and 3 extended percentiles.

Age	−3 (0.1)	−2.5 (0.6)	−2.25 (1.25)	−1.88 (3)	−1.28 (10)	−0.67 (25)	0 (50)	0.67 (75)	1.28 (90)	1.88 (97)
0	44.4	45.3	45.7	46.4	47.5	48.6	49.9	51.2	52.3	53.5
1	68.9	70.0	70.6	71.4	72.8	74.2	75.7	77.4	78.8	80.3
2	78.4	79.8	80.5	81.6	83.3	85.1	87.1	89.2	91.1	93.1
3	85.6	87.3	88.1	89.4	91.5	93.6	96.1	98.6	101.0	103.3
5	95.5	97.5	98.5	100.1	102.8	105.6	108.9	112.4	115.8	119.4
6	100.4	102.5	103.6	105.3	108.2	111.3	114.8	118.6	122.2	126.0
7	105.2	107.5	108.7	110.5	113.6	116.9	120.7	124.7	128.5	132.5
8	109.8	112.3	113.6	115.5	118.8	122.3	126.4	130.6	134.7	139.0
9	114.2	116.9	118.2	120.3	123.8	127.5	131.8	136.4	140.7	145.2
10	118.5	121.3	122.8	125.0	128.7	132.7	137.2	142.0	146.5	151.2
11	122.9	125.9	127.5	129.8	133.7	137.9	142.7	147.7	152.5	157.4
12	127.6	130.8	132.5	134.9	139.1	143.4	148.4	153.7	158.6	163.7
13	132.7	136.0	137.7	140.3	144.6	149.1	154.3	159.7	164.8	170.0
14	137.8	141.2	143.0	145.6	150.0	154.6	159.9	165.3	170.4	175.7
15	142.5	145.9	147.7	150.3	154.7	159.3	164.5	169.9	175.0	180.1
16	146.5	149.9	151.6	154.2	158.5	163.0	168.1	173.3	178.2	183.1
17	149.9	153.3	155.0	157.5	161.7	166.1	171.0	176.0	180.6	185.3
18	153.3	156.5	158.2	160.6	164.7	168.9	173.6	178.3	182.8	187.2

defining indication-specific cutoff lines and screening for overweight/obesity in Asian Indian children. IAP published contemporary charts for Indian children from 5–18 years, and these together with the WHO MGRS charts are recommended for the monitoring of growth in Indian children [7, 9]. Thus, LMS values from these two data sets were used to generate additional z score/percentile lines for these extended charts in the present paper.

Anthropometry remains the most important and powerful tool in the hands of endocrinologists to screen for and plan further management of growth disorders in children. Many recent guidelines and society recommendations for growth monitoring, treatment, and adequacy of response to treatment are based on anthropometric measurements as defined by z scores [10, 11]. The severity of short stature also depends upon the negativity of the z score.

Table 2: Height percentile for girls including 7 standard and 3 extended percentiles.

Age	−3.00 (0.1)	−2.50 (0.6)	−2.25 (1.25)	−1.88 (3)	−1.28 (10)	−0.67 (25)	0.00 (50)	0.67 (75)	1.28 (90)	1.88 (97)
0	43.8	44.6	45.1	45.7	46.8	47.9	49.1	50.4	51.6	52.7
1	66.8	67.9	68.5	69.4	70.8	72.3	74.0	75.8	77.4	79.1
2	77.4	78.8	79.5	80.6	82.4	84.3	86.4	88.6	90.7	92.8
3	83.9	85.5	86.4	87.6	89.7	91.9	94.4	96.9	99.3	101.8
5	93.3	95.4	96.5	98.1	100.9	104.0	107.5	111.4	115.1	119.1
6	98.3	100.6	101.7	103.5	106.5	109.7	113.5	117.5	121.4	125.5
7	103.3	105.7	107.0	108.8	112.0	115.4	119.4	123.6	127.7	132.0
8	108.3	110.9	112.2	114.2	117.6	121.2	125.4	129.8	134.0	138.4
9	113.4	116.2	117.6	119.7	123.3	127.0	131.4	136.0	140.3	144.8
10	118.7	121.6	123.1	125.3	129.0	132.9	137.4	142.1	146.6	151.2
11	124.0	127.0	128.5	130.8	134.6	138.7	143.3	148.0	152.6	157.2
12	129.0	132.0	133.5	135.8	139.7	143.8	148.4	153.1	157.6	162.2
13	133.0	136.0	137.5	139.8	143.7	147.7	152.2	156.9	161.3	165.8
14	135.9	138.9	140.4	142.6	146.4	150.3	154.7	159.3	163.6	168.0
15	137.9	140.7	142.2	144.4	148.0	151.8	156.1	160.6	164.8	169.0
16	139.1	141.9	143.3	145.5	149.0	152.7	156.9	161.2	165.2	169.3
17	140.2	142.9	144.2	146.3	149.7	153.3	157.4	161.6	165.5	169.5
18	141.1	143.7	145.0	147.1	150.4	153.9	157.8	161.8	165.6	169.5

z scores using LMS tables can be calculated using mathematical formulae or software tools for research purposes. However, implementation of such calculations in everyday clinical practice is cumbersome and hence often omitted. Furthermore, the decision to treat with growth hormone is based on z score analysis especially in conditions such as SGA children and idiopathic short stature (ISS) [3, 10, 11]. We chose to depict -2.25 , -2.5 z score/percentile lines keeping in mind ISS and SGA, respectively. The -3 z score line indicates severe short stature and warrants evaluation of the GH-IGF 1 axis as per recent GHRS [Growth Hormone Research Society] guidelines [3].

An important reason for the popularity of WHO under-5 growth charts [12] is that they provide -2 , -3 , and even -4 z score lines for length/height, weight, and weight-for-height parameters. It gives the healthcare worker a quick assessment of the degree of stunting, underweight, and wasting. Similarly, the United Kingdom Royal College of Paediatrics and Child Health (UK RCPCH) growth charts depict 0.4th and 2nd percentile lines in addition to the standard 7 percentiles [13]. Many variations of growth charts exist in the world that depict lines lower than -1.88 z (3rd centile); for example, in Flemish height charts, the zone between -2 and -2.5 z score lines is colored gray and the instruction is to refer any child below the gray zone for investigations [14]. Lifshitz et al. have modified the Center for Disease Control (CDC) height charts with lines going down to -5 z scores for easy assessment of the degree of short stature and response to treatment [15]. No such attempt has been made for growth charts of Asian Indian children so far, chiefly because healthcare workers and pediatricians do not need to use these lower percentiles on a day-to-day basis. However, for the endocrine community dealing with short stature due to various etiologies, it is an everyday requirement.

The BMI tool added as an inset eliminates the need for BMI calculation and is designed for use in children between the ages of 8 and 18 years. This is the age at which overweight/obesity becomes more common and screening for metabolic syndrome needs to be performed [16]. The tool has three lines that depict obese (OB), overweight (OV), and underweight (UW). Based on where the weight lies on the y-axis for the height on the x-axis, the child can be classified as having BMI within the reference range (between UW and OV lines), overweight (between OV and OB lines), obese (above the OB line), or underweight (under the UW line) (Figures 1 and 2). The tool had sensitivity of 95.7% and specificity of 85.7% for boys, and 95.7 and 89.7% for girls, respectively. For underweight, sensitivity of 100% for boys and girls and specificity of 88.9% for boys and 82.4% for girls were observed [6]. In the UK RCPCH charts, a

similar key based on the z score for height and weight has been included [13]. As charts with extended z score/percentile lines are not at presently available for Asian Indian children, endocrinologists either use British/CDC/WHO charts that are inappropriate for use in Indian children beyond 5 years of age or go by their “gut feeling.” If CDC or WHO charts for 5–19 year olds are used to define these cutoffs, a large proportion of normal Indian children may be labeled as short and unnecessarily be treated as abnormal, this would also result in anxiety in parents [17, 18]. To avoid this, additional z score/percentile lines are needed in the charts currently recommended for Indian children from 0 to 18 years. We believe that the addition of these cutoff lines will help the endocrinologist to assess the degree of short stature and have ready-to-use indication-specific height cutoffs. The quick BMI lookup tool will be handy for rapid nutritional status assessment.

The limitations of our study include that the centile curves for height are placed too close together at younger ages, making it difficult to plot, further, despite using statistical smoothing, a small blip is evident at the junction of 5 years (where WHO and IAP charts meet). Dotted lines to show pubertal age limits are desirable, but recent data on age at sexual maturity in Indian children were not available and hence could not be added to the charts.

Conclusion

Extended (with 10 percentile lines) height charts, standard 7 lines weight charts, and quick BMI assessment tool are presented in a single unified chart for everyday use by endocrinologists. These charts will help in the rapid assessment of degree of growth failure as well as screen for overweight and obesity in Asian Indian children.

Acknowledgments: The data used originally was published in the Indian Pediatrics, and the authors thank the Indian Pediatrics for giving permission to use this material.

Research funding: Not Applicable.

Author contributions: All the authors have accepted responsibility for the entire content of this submitted article and approved submission.

Competing interests: Nil.

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