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Percentile Charts for Body Mass Index of Indian Down Syndrome Children

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Abstract

Growth charts are used to detect growth impairment, overweight, and obesity among Down syndrome (DS) children belonging to different population groups. Due to nonavailability of similar information, age, and gender specific body mass index (BMI) charts for DS children of Indian origin, based on serial data, have been developed. A total of 752 boys and 373 girls diagnosed as cases of DS at <1 month to 10 years of age enrolled from the "genetic clinic" were followed up in the "growth clinic/growth laboratory" of the institute, following a mixed-longitudinal growth research design. BMI was calculated from body weight and length/height measured at 6-month-age intervals by using standardized techniques and instruments. Age and sex-specific percentile growth charts for BMI were generated for age range <1 month to 10 years by using the LMS method. DS children remained wasted (BMI <3rd percentile) up to 6 months of age; thereafter, BMI increased to exhibit close similarity with their normal Multicentre Growth Reference Study (World Health Organization 2006) and Indian Academy of Pediatrics (2015) counterparts up to 5 to 10 years, respectively. The percentage of obese DS girls (8.76%) outnumbered boys with DS (4.1%). The use of age and gender specific BMI growth charts may be made for comparative purpose, to assess nutritional status of Indian children with DS, to initiate suitable need-based intervention to improve their overall health and for timely institution of target interventions to prevent growth faltering in this vulnerable population.

Keywords
- body mass index charts
- Down syndrome
- Indian
- obesity

Introduction

Down syndrome (DS) children present with growth impairment, mental retardation as well as a wide spectrum of associated comorbidities. Its occurrence in India is 23,000 to 29,000/year live births.[1] The growth pattern of children with DS showed marked variation from that of their normal counterparts.[2,3] Besides growth restriction, a predisposition to overweight, among adolescents and adults with DS has also been reported,[4–6] mainly due to hypothyroidism, decreased resting metabolic rate, increased energy intake, lack of physical activity, and high fat diet consumption.[7,8] Because of the advancement in medical and surgical care, the survival of patients with DS has improved significantly over a period of time.[9,10] Therefore, persistent and careful monitoring of auxological and nutritional status of these children has become extremely important for early detection and prevention of health problems so as to improve their overall general health and well-being.

Body mass index (BMI) is frequently used as health indicator to assess and classify nutritional status of children and adults. Percentile charts for BMI of DS children have

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mostly emanated from developed world.[3,11–13] However, to date, age and gender specific BMI charts for Indian children with DS who are known to exhibit considerable ethnic and regional diversity do not exist. In view of this, we attempted to establish age and gender specific percentile growth charts for BMI of children with DS inhabiting north-western parts of India.

Materials and Methods

A total of 2,085 observations made on 1,125 (male: 752, female: 373) DS children, karyotypically proven as cases of free trisomy 21, enrolled from the "genetic clinic" of the Department of Pediatrics, Postgraduate Institute of Medical Education & Research, Chandigarh, India comprised the sample for this mixed-longitudinal study. None of the children with mosaicism, as well as translocations, were included in the study.

These children were followed up in the Growth Laboratory/Growth Clinic of the Institute every 3 months for the first 3 years of life (time tolerance limit $\pm$ 15 days) and thereafter every 6 months ($\pm$ 1 month), following a mixed-longitudinal growth research design. A mixed-longitudinal study is defined as a serial study, in which a group of children is followed periodically, at fixed time intervals such that some children leave the study and others, if desired join it at some age points (Tanner).[14] Body weight and length/height were measured at half yearly age intervals by trained anthropometrists, following standardized anthropometric techniques and instruments.[15] BMI (kg/m^2) was calculated by using weight (kg) and length/height (cm) values measured for each child at each age level. In addition, information related to associated comorbidities was also obtained for each child from their clinical health records. No child was excluded from the present study on account of additional comorbidities experienced by them. Information with regard to regional affiliations of subjects enrolled was also recorded.

Informed written consent of parent/guardian of each child was taken prior to his/her enrolment in the study. The study was approved by "institute ethics committee" as well as "department review board."

Statistical Analysis

Age and gender specific BMI was calculated from body weight and length/height data recorded at 6-month-age intervals from <1 month to 10 years on DS children representing the present study. Further, Cole's LMS method [16] was employed to construct age and sex-specific growth charts for BMI of DS children. LMS chart maker (Light version 2.54) software[17] based on Cole's LMS approach for constructing normalized growth standards was used to obtain BMI growth charts for male and female children with DS. As the best fit model in LMS requires values of EDF (equivalent degrees of freedom) or the three parameters, L (skewness), M (median), and S (coefficient of variation) were chosen individually for each model so as to minimize the deviance measure. To do so, multiple models with minimum deviance measure were selected by using a loop with range of values for BMI. Out of these selected multiple models, a best fit model was selected by changing the parameter by one unit at a time and then these models were evaluated on the basis of the deviance measure and goodness of fit. Information thus obtained was used to construct percentile charts from LMS values based on best fit model obtained for BMI of male and female DS children aged <1 month to 10 years (►**Figs. 1** and **2**).

Results

Participants: The sample consisted of 1,125 children with DS (67% boys) studied over a period of 24 years (August 1994–November 2018). These children were born to parents residing in north-western parts of India and represented mixed socioeconomic strata. Of these, 34.5% were Punjabis; 26.2% Haryanvis; 14.4% represented the Union Territory of Chandigarh; 14% hailed from Himachal Pradesh; and the rest (7%) represented the states of Uttar Pradesh, Bihar, Jammu, Rajasthan, Uttaranchal, Jharkhand, and Gujarat. Majority (59%) of these children suffered from congenital heart disease (including ASD, VSD, PDA, and AVCD), followed by hypothyroidism (30%), cholestasis (7%), and pneumonia (7.5%). Patients with these comorbidities were treated and extended all possible care.

Percentile BMI charts obtained from body weight and length/height measured amongst children with DS aged <1 month to 10 years, inhabiting north-western region of India and presented in ►**Figs. 1** and **2** were drawn from data presented in ►**Tables 1** and **2**. Average BMI (50th percentile) measuring 12.1 kg/m^2 in boys and 12.6 kg/m^2 in girls with DS at age <1 month grew to a similar value of 16.7 kg/m^2 by 10 years. Mean BMI of our DS children was less than 3rd percentile of WHO growth charts[18] for the first 6 months of life, thus making them wasted; whereafter, it matched well with the 50th percentile of standards given by Multicentre Growth Reference Study (MGRS 2006)[18] and Indian Academy of Pediatrics (IAP 2015)[19] up to 5 and 10 years, respectively. Girls possessed higher BMI than the boys up to around 1 month while; it measured more among boys until 18 months. Both boys and girls with DS were found to have similar BMI between 2 and 4 years afterward; it measured more in girls until 9 years (►**Tables 1** and **2**). Gender differences for BMI depicted statistical significance ($p \leq 0.05$) only at 7 and 8 years. ►**Fig. 3** demonstrates a higher percentage of obesity in DS girls (8.76%) than in boys (4.1%).

Discussion

This is a single center prospective study on the growth pattern of BMI of karyotypically confirmed cases of DS, inhabiting north-western regions of India. Age and gender specific percentile growth charts for BMI presented by us relate to serial observations made on children with DS, aged <1 month to 10 years. Substantially, greater participation of DS boys (67%) over girls (33%) in our study speaks of persistence of gender related preferential treatment still being meted to boys in India due to variety of sociocultural and economic reasons. Pattern-wise curves (50th percentile)

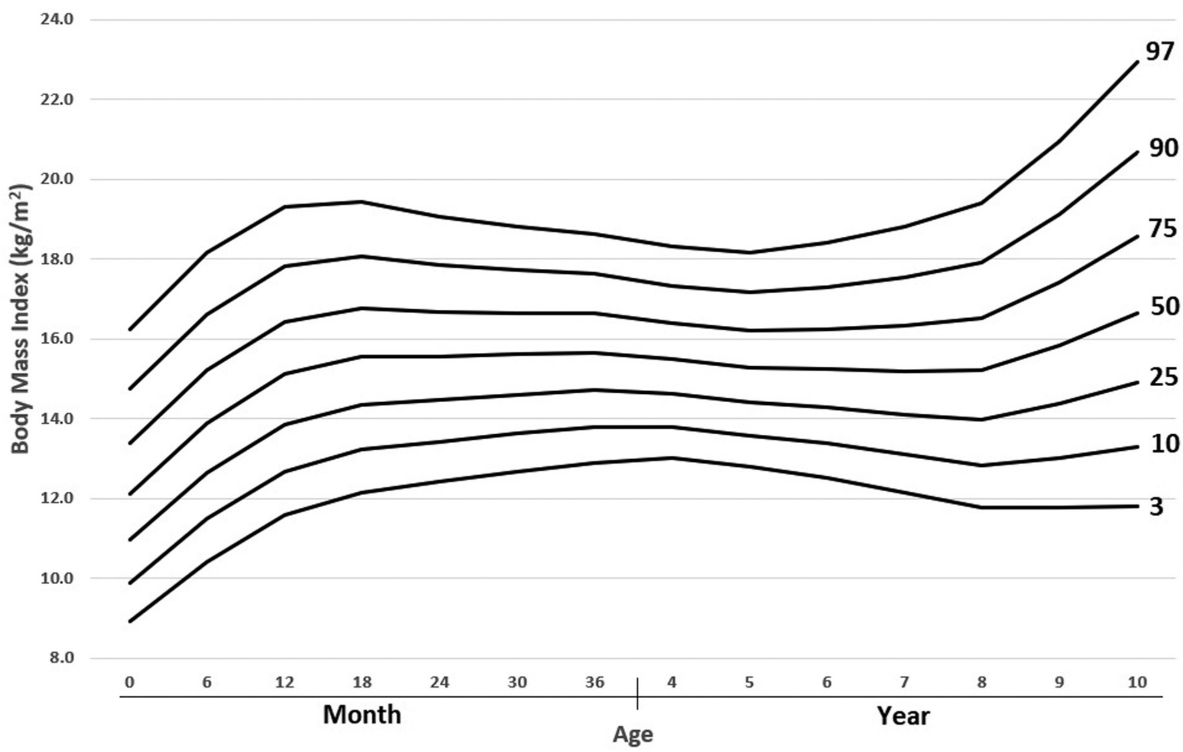

Fig. 1 Body mass index percentiles for Down syndrome boys.

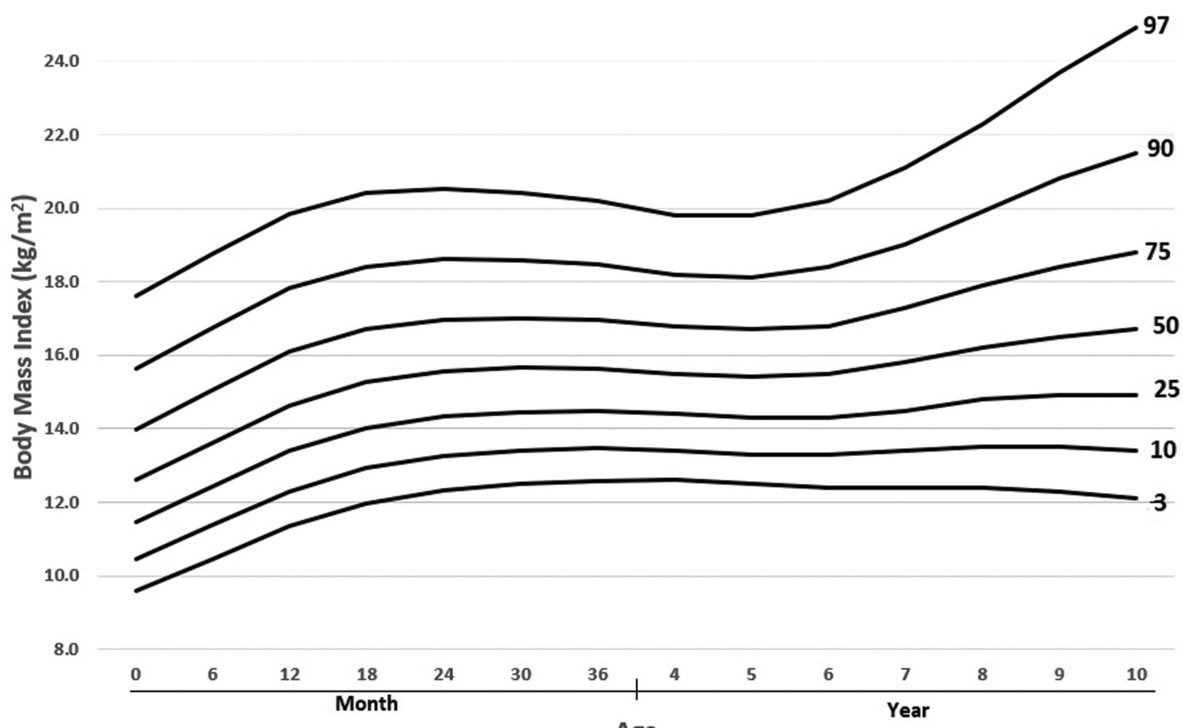

Fig. 2 Body mass index percentiles for Down syndrome girls.

Table 1 Percentiles for body mass index of Down syndrome boys

Age	*n* (no. of observations)	L	M	S	3rd	10th	25th	50th	75th	90th	97th
<1 mo	21	0.159	12.117	0.149	8.9	9.9	11.0	12.1	13.4	14.7	16.2
3 mo	51	0.201	12.977	0.144	9.6	10.7	11.8	13.0	14.3	15.7	17.2
6 mo	75	0.247	13.872	0.138	10.4	11.5	12.6	13.9	15.2	16.6	18.1
9 mo	66	0.292	14.603	0.133	11.1	12.2	13.3	14.6	15.9	17.4	18.9
12 mo	90	0.336	15.109	0.127	11.6	12.7	13.9	15.1	16.4	17.8	19.3
15 mo	43	0.380	15.410	0.122	11.9	13.0	14.2	15.4	16.7	18.0	19.5
18 mo	80	0.424	15.542	0.116	12.2	13.2	14.4	15.5	16.8	18.1	19.4
21 mo	36	0.465	15.562	0.111	12.3	13.3	14.4	15.6	16.7	18.0	19.2
24 mo	65	0.504	15.558	0.106	12.4	13.4	14.5	15.6	16.7	17.9	19.1
27 mo	28	0.540	15.572	0.102	12.5	13.5	14.5	15.6	16.7	17.8	18.9
30 mo	64	0.574	15.608	0.098	12.7	13.6	14.6	15.6	16.6	17.7	18.8
33 mo	34	0.606	15.634	0.094	12.8	13.7	14.7	15.6	16.6	17.7	18.7
36 mo	146	0.634	15.660	0.091	12.9	13.8	14.7	15.7	16.6	17.6	18.6
4 y	164	0.211	15.480	0.085	13.0	13.8	14.6	15.5	16.4	17.3	18.3
5 y	128	0.211	15.287	0.087	12.8	13.6	14.4	15.3	16.2	17.2	18.2
6 y	91	0.211	15.238	0.096	12.5	13.4	14.3	15.2	16.2	17.3	18.4
7 y	67	0.211	15.184	0.109	12.1	13.1	14.1	15.2	16.3	17.5	18.8
8 y	72	0.211	15.203	0.124	11.8	12.8	14.0	15.2	16.5	17.9	19.4
9 y	56	0.211	15.838	0.143	11.8	13.0	14.4	15.8	17.4	19.1	20.9
10 y	51	0.211	16.655	0.165	11.8	13.3	14.9	16.7	18.6	20.7	22.9

Abbreviations: L, skewness; M, median; S, coefficient of variation.

Table 2 Percentiles for body mass index of down syndrome girls

Age	*n* (no. of observations)	L	M	S	3rd	10th	25th	50th	75th	90th	97th
<1 mo	10	−0.656	12.616	0.149	9.6	10.5	11.5	12.6	14.0	15.6	17.6
3 mo	21	−0.656	13.044	0.147	10.0	10.8	11.9	13.0	14.4	16.1	18.1
6 mo	41	−0.656	13.630	0.144	10.5	11.4	12.4	13.6	15.1	16.7	18.8
9 mo	33	−0.656	14.173	0.141	10.9	11.9	12.9	14.2	15.6	17.3	19.4
12 mo	53	−0.656	14.639	0.138	11.4	12.3	13.4	14.6	16.1	17.8	19.9
15 mo	30	−0.656	15.006	0.134	11.7	12.7	13.8	15.0	16.5	18.2	20.2
18 mo	39	−0.656	15.273	0.132	12.0	12.9	14.0	15.3	16.7	18.4	20.4
21 mo	25	−0.656	15.451	0.129	12.2	13.1	14.2	15.5	16.9	18.6	20.5
24 mo	40	−0.656	15.562	0.126	12.3	13.3	14.3	15.6	17.0	18.6	20.5
27 mo	18	−0.656	15.625	0.124	12.4	13.4	14.4	15.6	17.0	18.6	20.5
30 mo	32	−0.656	15.652	0.121	12.5	13.4	14.5	15.7	17.0	18.6	20.4
33 mo	14	−0.656	15.656	0.119	12.5	13.5	14.5	15.7	17.0	18.5	20.3
36 mo	61	−0.656	15.643	0.117	12.6	13.5	14.5	15.6	17.0	18.5	20.2
4 y	70	−0.656	15.519	0.113	12.6	13.4	14.4	15.5	16.8	18.2	19.8
5 y	41	−0.656	15.442	0.114	12.5	13.3	14.3	15.4	16.7	18.1	19.8
6 y	46	−0.656	15.502	0.120	12.4	13.3	14.3	15.5	16.8	18.4	20.2
7 y	30	−0.656	15.818	0.131	12.4	13.4	14.5	15.8	17.3	19.0	21.1
8 y	20	−0.656	16.200	0.144	12.4	13.5	14.8	16.2	17.9	19.9	22.3
9 y	19	−0.656	16.508	0.160	12.3	13.5	14.9	16.5	18.4	20.8	23.7
10 y	18	−0.656	16.671	0.176	12.1	13.4	14.9	16.7	18.8	21.5	24.9

Abbreviations: L, skewness; M, median; S, coefficient of variation.

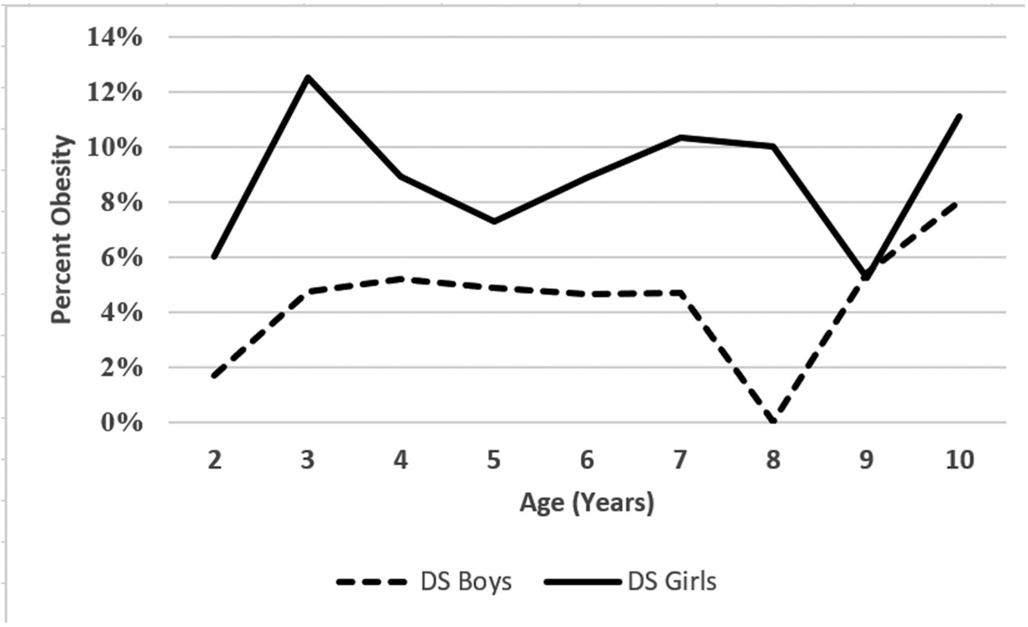

Fig. 3 Percentage of obese Down syndrome children.

plotted for BMI of DS children showed a regular but slow increase up to around 18 months in boys and 30 months in girls. Whereafter, flattening of BMI curves occurred until 8 years and 6 years in boys and girls, respectively. A more rapid increase in BMI was observed thereafter in boys as compared with girls (►**Figs. 1** and **2**). This may be a disease severity related phenomenon affecting progression of growth variably among DS children of two sexes. As is evident from our results, which revealed that 59% of our DS children suffered from congenital heart disease and 30% with hypothyroidism. Similar observations have also been reported by Pierce et al[20] who also noticed comorbidities among 50% of the DS population.

Our children with DS were found to be wasted (BMI $<$3rd percentile) from less than 1 to 6 months of age as compared with normal MGRS children. This may be attributed to early feeding difficulties experienced by mothers due to hypotonia and chronically open mouth. Thereafter, BMI among our DS children increased uninterruptedly to show close similarity with their normal MGRS[18] and IAP[19] counterparts up to 5 and 10 years, respectively. The percentage of underweight (BMI $\leq$5th percentile of CDC 2000)[21] DS boys (16.7%) was more than the girls (14.6%) representing this study. BMI (50th percentile) of our study children corresponded with the 25th percentile of their Swedish[3] and Brazilian[12] counterparts with DS. On the contrary, having a mean BMI corresponding to 25th percentile of American[22] children with DS at 2 years of age, BMI of both American, and our DS children became similar between 5 and 10 years. This suggests that despite affiliation to different ethnicities pattern-wise, Indian children with DS exhibit close auxological similarity to their U.S. counterparts after age 5 years in terms of BMI.

According to CDC (2000)[21] reference, the percentage of overweight (7.28%) and obese (4.1%) DS boys—representing this study—was lesser than the DS girls (overweight: 8.0%, obese: 8.76%). These observations match with findings of Pierce et al,[23] who too reported, that DS girls were almost twice as likely to be obese as boys from Oregon (United States). It also conforms to the findings of Hatch-Stein et al,[13] who noted higher rates of obesity in girls with DS compared with age-matched boys with DS and age-matched girls without DS. On the contrary, findings of Selvi et al[24] remain at variance with these observations who did not report obesity up to the age of 18 years in DS children in their study from Tamil Nadu (India).

It was interesting to note, that in the present study, after attaining peak prevalence rate at 3 years, obesity among our DS children declined inconsistently to a minimum by 9 years in boys and 8 years in girls; thereafter, obesity among DS children increased sharply (►**Fig. 3**). As compared with increase in obesity noticed among Oregon DS[23] children between 2 and 6 years, our DS children experienced similar increase up to 3 years. Similarly, 47.8% American DS children with DS in the age range 2 to 18 years were found to be obese.[24] While, one-third of the Swedish children with DS were found to be overweight (BMI $>25\,kg/m^2$) as defined by the National Institute of Health.[3] This shows that a reasonable number of DS children start becoming obese during their initial years and thus may be at risk of obesity related complications. In view of this, the initiation of physical activity based interventions under supervision at younger ages among DS children becomes imperative for preventing overweight/obesity and development of various other associated diseases,[24,25] and the need for instituting the same is advocated. Inappropriate eating habits with high fat diets, which lack proteins and other quality nutrition, may also result in obesity of DS.[26] Artioli[27] recommended that with proper exercise and nutrition-based interventions DS children may have a greater chance to live a better and healthier life.

Conclusion

DS children representing different parts of the globe exhibit variable growth pattern. Hence, the need to use references or percentile distributions constructed specifically for each population group for assessing the nutritional status of children with DS becomes essential. The use of BMI for age growth charts presented for Indian children is recommended to understand the growth and nutritional dynamics of Indian DS children and would aid in identification of the weight alteration, primarily overweight, which is often associated with these children.

Conflict of Interest
None declared.

References

1 Down Syndrome Federation of India. Accessed 2020 at: https://www.downsyndrome.in/
2 Farkas LG, Katic MJ, Forrest CR. Age-related changes in anthropometric measurements in the craniofacial regions and in height in Down's syndrome. J Craniofac Surg 2002;13(05):614–622
3 Myrelid A, Gustafsson J, Ollars B, Annerén G. Growth charts for Down's syndrome from birth to 18 years of age. Arch Dis Child 2002;87(02):97–103
4 Chumlea WC, Cronk CE. Overweight among children with trisomy. J Ment Defic Res 1981;25(Pt 4):275–280
5 Luke A, Sutton M, Schoeller DA, Roizen NJ. Nutrient intake and obesity in prepubescent children with Down syndrome. J Am Diet Assoc 1996;96(12):1262–1267
6 Melville CA, Cooper SA, McGrother CW, Thorp CF, Collacott R. Obesity in adults with Down syndrome: a case-control study. J Intellect Disabil Res 2005;49(Pt 2):125–133
7 Wong C, Dwyer J, Holland M. Overcoming weight problems in adults with Down syndrome. Nutr Today 2014;49(03):109–119
8 Rimmer JH, Yamaki K, Lowry BM, Wang E, Vogel LC. Obesity and obesity-related secondary conditions in adolescents with intellectual/developmental disabilities. J Intellect Disabil Res 2010;54(09):787–794
9 Bittles AH, Bower C, Hussain R, Glasson EJ. The four ages of Down syndrome. Eur J Public Health 2007;17(02):221–225
10 Weijerman ME, van Furth AM, Vonk Noordegraaf A, van Wouwe JP, Broers CJ, Gemke RJ. Prevalence, neonatal characteristics, and first-year mortality of Down syndrome: a national study. J Pediatr 2008;152(01):15–19
11 Su X, Lau JT, Yu CM, et al. Growth charts for Chinese Down syndrome children from birth to 14 years. Arch Dis Child 2014;99(09):824–829
12 Bertapelli F, Martin JE, Gonçalves EM, de Oliveira Barbeta VJ, Guerra-Júnior G. Growth curves in Down syndrome: implications for clinical practice. Am J Med Genet A 2014;164A(03):844–847
13 Hatch-Stein JA, Zemel BS, Prasad D, et al. Body composition and BMI growth charts in children with Down syndrome. Pediatrics 2016;138(04):e20160541
14 Tanner JM. The human growth curve. In: Harrison GA, Weiner JS, Tanner JM, Barnicot NA, Reynolds V, eds. Human Biology. London: Oxford University Press; 1977:301–319
15 Weiner JS, Lourie JA. Human Biology: A Guide to Field Methods. Oxford: Blackwell International; 1969
16 Cole TJ. The LMS method for constructing normalized growth standards. Eur J Clin Nutr 1990;44(01):45–60
17 Pan H, Cole TLMS chart maker Light version 2.54. A program for calculating age-related reference centiles using the LMS method. Accessed 2011 at: https://www.nature.com/articles/pr2015160
18 WHO Multicentre Growth Reference Study Group. WHO child growth Standards based on length/height, weight and age. Acta Paediatr Suppl 2006;450:76–85
19 Khadilkar V, Yadav S, Agrawal KK, et al; Indian Academy of Pediatrics Growth Charts Committee. Revised IAP growth charts for height, weight and body mass index for 5- to 18-year-old Indian children. Indian Pediatr 2015;52(01):47–55
20 Pierce MJ, LaFranchi SH, Pinter JD. Characterization of thyroid abnormalities in a large cohort of children with Down syndrome. Horm Res Paediatr 2017;87(03):170–178
21 Ogden CL, Kuczmarski RJ, Flegal KM, et al. Centers for Disease Control and Prevention 2000 growth charts for the United States: improvements to the 1977 National Center for Health Statistics version. Pediatrics 2002;109(01):45–60
22 Zemel BS, Pipan M, Stallings VA, et al. Growth charts for children with Down Syndrome in the United States. Pediatrics 2015;136(05):e1204–e1211
23 Pierce M, Ramsey KJoseph Pinter JTrends in obesity and overweight in oregon children with Down syndrome. Glob Pediatr Health 2019;6:2333794 × 19835640
24 Selvi GP, Srinivasan KR, Koteeswary P, Shastri D, Babu SK. Prevalence of overweight and obesity in Down syndrome. Int J Health Sci Res 2017;7(07):75–79
25 Basil JS, Santoro SL, Martin LJ, Healy KW, Chini BA, Saal HM. Retrospective study of obesity in children with Down syndrome. J Pediatr 2016;173:143–148
26 Kusters MA, Verstegen RHJ, Gemen EFA, de Vries E. Intrinsic defect of the immune system in children with Down syndrome: a review. Clin Exp Immunol 2009;156(02):189–193
27 Artioli T. Understanding obesity in Down's syndrome children. J Obes Metab 2017;1:1

