

The LMS and Z Scale Growth Reference for Saudi School-age Children and Adolescents

Mohammad I. El Mouzan, Abdullah A. Al Salloum¹, Mansour M. Alqurashi², Abdullah S. Al Herbish³, Ahmad Al Omar⁴,

Department of Pediatrics,
College of Medicine,
King Khalid University Hospital,
King Saud University,
¹Department of Pediatrics,
College of Medicine,
King Khaled University
Hospital, King Saud University,
Riyadh 11461, ²Department of
Pediatrics, Al Yamama Hospital,
Riyadh 11555, ³Department of
Pediatrics, Al Habib Medical
Group, Riyadh, Kingdom of
Saudi Arabia, ⁴The Children
Hospital, King Fahad Medical
City, Riyadh,
Kingdom of Saudi Arabia

Address for correspondence:

Prof. Mohammad I. El Mouzan,
Department of Pediatrics,
College of Medicine,
King Khalid University Hospital,
King Saud University,
P.O. Box 2925, Riyadh 11461,
Kingdom of Saudi Arabia.
E-mail: drmouzan@gmail.com

ABSTRACT

Background/Aim: To establish L, M, and S parameters and z score reference for the assessment of nutrition and growth of Saudi school-age children and adolescents. **Subjects and Methods:** Data from the original cross-sectional study were reanalyzed. The L, M, and S parameters and z scores were calculated for weight, height and body mass index for school-age children and adolescents. **Results:** A total of 19,299 subjects from 5 to 18 years of age were included. All were Saudi nationals and 9,827 (50.9%) were boys. The L M S parameters and z scores for weight for age, height for age, and BMI for age for boys and girls are presented in detailed tables across the age of commonly used z scores (+3, +2, +1, 0, -1, -2, -3). Graphs corresponding to the same parameters (weight, height, and BMI) showing the main z scores across all ages from 5 to 18 years are illustrated. **Conclusion:** This report provides the first reference for nutritional status and growth of Saudi school-age children and adolescents. This tool is essential for more accurate assessment of growth and nutrition in various clinical conditions and research.

Key Words: Growth, nutritional status, Z score reference

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Assessment of nutritional status and growth of children and adolescents using growth charts is an important part of clinical practice. The history of development of growth charts dates back to the end of the 18th century, with continued improvements mainly in terms of statistical methods and chart design.^[1] The National Center for Health Statistics (NCHS) set of growth charts was the first to be endorsed by the World Health Organization (WHO), and was designated as NCHS/WHO growth charts and recommended for international use in 1978.^[2,3] However,

because of the increasing awareness of shortcomings of the existing charts and the secular trends in growth, the Center for Disease Control (CDC) revised and updated NCHS growth charts and published in 2000, the CDC 2000 reference growth charts for the United States of America (USA) children and adolescents.^[4] Similarly, the WHO, recognizing that the CDC 2000 is designed for children in USA, decided to create growth charts for school age children and adolescents that align with the WHO Child Growth Standards for preschool children. The latter was based on a more international multiethnic sample.^[5] After consideration of several growth charts, it was found that the NCHS data aligned best with the WHO preschool standards. Therefore, data from the NCHS were

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reanalyzed using state-of-the-art statistical methods to develop the WHO Growth Reference Charts for School-age Children and Adolescents in 2007.^[6] Although the CDC 2000 and WHO growth reference charts are commonly used worldwide, many countries have created their local national charts.^[7-10] Growth charts have been developed for the Kingdom of Saudi Arabia (KSA), and are recommended for use in hospitals and clinics.^[11] However, the latter did not report z-score values of the main growth indicators. Therefore, the objective of this analysis was to report the L, M, and S parameters and z score tables and graphs of a representative sample of Saudi school-age children and adolescents.

SUBJECTS AND METHODS

The design and methodology of the original study have been published elsewhere.^[11] In summary, random sampling methodology was used to select a representative sample from the 13 regions of the KSA. Only healthy children, as determined clinically by physicians, were eligible for body measurements. Age was converted to Gregorian to conform with the international studies. Weight was measured in kilograms (kg) and height in centimeters (cm). Body mass index (BMI) was calculated using the formula: BMI = Weight (kg)/Height² (cm).

Statistical analysis

In order to determine the standard deviation (-3 to +3) of weight, height, and BMI for boys and girls, school-age children, and adolescents 5 to 18 years of age, the L, M, and S method was used. The LMS parameters are the median (M), the generalized coefficient of variation (S), and the power in the Box-Cox transformation (L). The Box-Cox transformation is used to adjust the distribution of anthropometric data to a normal distribution. The method models the data taking into consideration the degree of skewness (L), central tendency (M), and dispersion (S). The L, M, and S parameters are calculated and smoothed according to the method of maximum penalized likelihood.^[12-14] Z score and percentiles were calculated according to the following formula.^[13]

$$P = M [1 + LSZ]^{1/L}, L \neq 0$$

where L, M, and S are the values from the appropriate table corresponding to the age, in years, of the child. Z is the z-score that corresponds to the percentile.

For the present analysis, we have calculated the z-score values of -3, -2, -1, 0, +1, +2, +3 for weight, height, and BMI for age. Data processing was performed using the LMS Chart Maker Light 2.1 (Medical Research Council, London, UK). The goodness of fit of all L, M, and S models was assessed using Q-test.^[15]

Ethics

This study is a part of the national health profile of Saudi children and adolescents approved by the King Abdul Aziz City for Science and Technology, Riyadh, Kingdom of Saudi Arabia.

RESULTS

In this study, there were 19,299 Saudi children and adolescents aged 5 to 18 years, with 9,827 (50.9%) boys. Table 1 shows the L, M, and S parameters and z scores for weight for age for boys aged 5 to 13 years. Table 2 illustrates the same parameters for height for age for boys aged 5 to 18 years, and Table 3 shows the same parameters for BMI for age for boys aged 5 to 18 years. Similarly, Table 4 shows the L, M, and S parameters and z scores for weight for age for girls aged 5 to 13 years. Table 5 illustrates the same parameters for height for age for girls aged 5 to 18 years, and Table 6 shows the same parameters for BMI for age for girls aged 5 to 18 years.

Figure 1 displays z scores for weight for age for boys aged 5 to 13 years. Figure 2 shows the same parameters for height for age for boys aged 5 to 18 years, and Figure 3 depicts the same parameters for BMI for age for boys aged 5 to 18 years. Similarly, Figure 4 shows z scores for weight for age for girls aged 5 to 13 years. Figure 5 illustrates the same parameters for height for age for girls aged 5 to 18 years, and Figure 6 shows the same parameters for BMI for age for girls aged 5 to 18 years.

Age (years)	L	M	S	-3	-2	-1	0	+1	+2	+3
5	-1.046774	16.65079	0.1550993	11.54415	12.7352	14.43236	16.65079	19.70112	24.20275	30.38897
6	-1.032594	18.64088	0.1685233	12.58045	13.96723	15.97119	18.64088	22.40697	28.17471	36.53489
7	-1.015487	20.66037	0.1819188	13.57652	15.16817	17.49883	20.66037	25.23193	32.49395	43.61045
8	-0.991157	23.2016	0.1951612	14.84524	16.69153	19.42797	23.2016	28.78258	37.95114	52.72433
9	-0.9524795	26.06358	0.2080576	16.22759	18.3699	21.57825	26.06358	32.8181	44.20689	63.27654
10	-0.8979311	29.04166	0.2201021	17.58791	20.05554	23.7813	29.04166	37.05619	50.76506	74.11462
11	-0.8295125	32.4206	0.2305578	19.10816	21.95729	26.28229	32.4206	41.80883	57.87197	84.9978
12	-0.7531365	36.42373	0.2388563	20.93089	24.23916	29.27395	36.42373	47.31989	65.73447	95.92641
13	-0.678714	40.85276	0.2446715	22.97458	26.79711	32.61524	40.85276	53.29852	73.92265	106.4492

Table 2: L, M, and S parameters and Z scores for height for age: Boys 5 to 18 years

Age (years)	L	M	S	-3	-2	-1	0	1	2	3
5	1.245451	108.0048	0.05210	91.48145	96.62201	102.3707	108.0048	113.5676	119.0998	123.9271
6	1.066822	113.6056	0.05180	96.59428	101.8317	107.7485	113.6056	119.4426	125.2984	130.4477
7	0.9035738	119.1066	0.05140	101.6104	106.948	113.0313	119.1066	125.212	131.3863	136.8551
8	0.76963	124.3874	0.05120	106.3878	111.8392	118.0953	124.3874	130.7537	137.2345	143.0094
9	0.6647016	129.3106	0.05100	110.79	116.3681	122.8032	129.3106	135.9298	142.703	148.7676
10	0.5849866	133.9453	0.05100	114.8844	120.6014	127.2224	133.9453	140.8113	147.8653	154.2048
11	0.5631689	138.8036	0.05100	119.0943	124.9991	131.8448	138.8036	145.9182	153.2355	159.8185
12	0.6621022	144.1869	0.05080	123.6255	129.818	136.9621	144.1869	151.5362	159.057	165.7914
13	0.9035376	149.9352	0.05040	128.3408	134.9294	142.4376	149.9352	157.4692	165.0875	171.8348
14	1.274853	155.9127	0.04960	133.1678	140.2503	148.1638	155.9127	163.557	171.1532	177.7765
15	1.751719	161.2155	0.04850	137.3891	145.0087	153.2995	161.2155	168.8495	176.2796	182.6424
16	2.291483	164.9734	0.0470	140.3228	148.4497	157.0192	164.9734	172.4606	179.595	185.5964
17	2.858366	167.3224	0.04530	142.1275	150.703	159.4421	167.3224	174.5674	181.3352	186.937
18	3.434741	168.7339	0.04360	143.2117	152.181	161.0019	168.7339	175.6882	182.0697	187.278

Table 3: L, M, and S parameters and z scores for body mass index for age: Boys 5-18 years

Age (years)	L	M	S	-3	-2	-1	0	+1	+2	+3
5	-1.31529	14.37962	0.1250908	10.70884	11.58793	12.81482	14.37962	16.47186	19.46013	23.4204
6	-1.275914	14.53639	0.1334316	10.63462	11.55877	12.85933	14.53639	16.81101	20.12519	24.64046
7	-1.236501	14.75179	0.1417807	10.60142	11.5741	12.95389	14.75179	17.22387	20.89531	26.03322
8	-1.19709	15.11439	0.1501298	10.66941	11.70061	13.17456	15.11439	17.8165	21.90345	27.7718
9	-1.157679	15.6261	0.1584788	10.83411	11.93504	13.52013	15.6261	18.59606	23.1664	29.89087
10	-1.118279	16.23582	0.1668279	11.05496	12.23416	13.94378	16.23582	19.50611	24.62103	32.32071
11	-1.078889	16.89858	0.1751773	11.29813	12.56144	14.40528	16.89858	20.49538	26.20684	34.98787
12	-1.0395	17.58401	0.1835265	11.54159	12.89289	14.87786	17.58401	21.52832	27.87987	37.83368
13	-1.000108	18.26542	0.1918757	11.76717	13.20843	15.33864	18.26542	22.57259	29.59766	40.79568
14	-0.9607132	18.94915	0.200225	11.97883	13.51254	15.79292	18.94915	23.63574	31.36824	43.87638
15	-0.92132	19.6475	0.2085749	12.18388	13.81363	16.25075	19.6475	24.73305	33.21011	47.09212
16	-0.8819306	20.34302	0.2169252	12.37094	14.09898	16.69744	20.34302	25.84257	35.09175	50.38718
17	-0.8425444	21.01484	0.2252758	12.52739	14.35419	17.11596	21.01484	26.93708	36.97277	53.6895
18	-0.803159	21.65896	0.2336265	12.65141	14.57705	17.50342	21.65896	28.01018	38.83982	56.96384

Table 4: L, M, and S parameters and z scores for weight for age: Girls 5-13 years

Age (years)	L	M	S	-3	-2	-1	0	+1	+2	+3
5	-0.9263435	16.38057	0.168596	10.97211	12.22216	14.01665	16.38057	19.65447	24.51356	31.20252
6	-0.9001132	18.40183	0.1787036	12.05846	13.50684	15.60507	18.40183	22.33381	28.28946	36.7129
7	-0.8715369	20.68229	0.1897232	13.23186	14.91125	17.36754	20.68229	25.41663	32.74276	43.40592
8	-0.8425242	23.23136	0.2004226	14.5178	16.45848	19.32232	23.23136	28.89579	37.83365	51.18528
9	-0.8136664	26.21636	0.2101859	16.02982	18.27513	21.61415	26.21636	32.96652	43.78944	60.29851
10	-0.7861002	29.77336	0.2182795	17.86845	20.47168	24.36615	29.77336	37.77409	50.74456	70.79939
11	-0.7621664	33.86588	0.2240021	20.045	23.05212	27.56804	33.86588	43.23001	58.49327	82.22218
12	-0.748107	38.24305	0.2270645	22.46354	25.88831	31.04134	38.24305	48.97466	66.50443	93.80071
13	-0.7468908	42.49973	0.227857	24.92189	28.73346	34.47232	42.49973	54.47532	74.06789	104.6428

DISCUSSION

In a recent systematic review, worldwide variations of human growth was demonstrated, indicating the risks of using a single reference growth chart in all countries.^[16] In fact, the same remarks have been reported in previous studies

from the KSA indicating the difference in growth between children in the USA and KSA.^[17-19] This was confirmed in two recent reports regarding the implications of using the CDC or WHO growth charts for the assessment of nutrition and growth of Saudi children, potentially exaggerating the prevalence of short stature and malnutrition.^[20,21]

Table 5: L, M, and S parameters and Z scores for height for age: Girls 5 to 18 years

Age (years)	L	M	S	-3	-2	-1	0	1	2	3
5	0.9656725	107.7197	0.0540	91.03188	96.13991	101.943	107.7197	113.5072	119.3425	124.4972
6	0.9925366	113.0395	0.0528	95.84769	101.1184	107.097	113.0395	118.9843	124.9701	130.251
7	1.012246	118.5896	0.0517	100.9319	106.3515	112.4924	118.5896	124.6829	130.8122	136.215
8	1.005953	123.8296	0.0505	105.8132	111.3408	117.6065	123.8296	130.0508	136.3108	141.8304
9	0.9726703	129.0319	0.0494	110.7256	116.3321	122.6981	129.0319	135.3741	141.7659	147.4097
10	0.9259285	134.5261	0.0483	115.9394	121.6183	128.0811	134.5261	140.9941	147.5265	153.3056
11	0.8709366	140.2546	0.0471	121.4109	127.153	133.7043	140.2546	146.8446	153.5163	159.4317
12	0.7864277	145.6985	0.0459	126.7219	132.4818	139.0781	145.6985	152.3837	159.1764	165.2191
13	0.6403107	150.054	0.0448	131.1631	136.8598	143.4237	150.054	156.7913	163.6794	169.8422
14	0.4087217	152.8829	0.0439	134.2866	139.839	146.2961	152.8829	159.6418	166.62	172.9215
15	9.21E-02	154.3862	0.0434	136.1767	141.5427	147.8587	154.3862	161.1742	168.279	174.7797
16	-0.2981704	155.088	0.0433	137.2422	142.4185	148.5987	155.088	161.9501	169.2603	176.0668
17	-0.7474532	155.4885	0.0436	137.9298	142.9321	148.9998	155.4885	162.4876	170.1076	177.3626
18	-1.245018	155.8691	0.0441	138.5318	143.3747	149.3494	155.8691	163.0645	171.106	178.9799

Table 6: L, M, and S parameters and z scores for body mass index for age: Girls 5-18 years

Age (years)	L	M	S	-3	-2	-1	0	+1	+2	+3
5	-1.316355	14.28225	0.124455	10.64999	11.52073	12.73504	14.28225	16.34813	19.29299	23.1849
6	-1.295107	14.48154	0.1336074	10.59961	11.51742	12.81065	14.48154	16.75474	20.08363	24.6564
7	-1.271399	14.76302	0.1436743	10.58912	11.56153	12.94669	14.76302	17.28437	21.08764	26.54634
8	-1.244076	15.17345	0.1537666	10.66504	11.70079	13.19136	15.17345	17.97824	22.33202	28.85958
9	-1.211343	15.70309	0.1635322	10.82009	11.9279	13.53684	15.70309	18.82103	23.78566	31.52752
10	-1.1718	16.38014	0.1724944	11.07576	12.26688	14.00987	16.38014	19.83751	25.4508	34.46587
11	-1.127197	17.21308	0.1801707	11.44243	12.7286	14.6212	17.21308	21.02709	27.2931	37.5202
12	-1.085506	18.1688	0.1863086	11.90672	13.29525	15.34651	18.1688	22.34407	29.24636	40.58678
13	-1.052943	19.17317	0.1910228	12.42545	13.91608	16.12451	19.17317	23.69967	31.21144	43.59388
14	-1.030102	20.10006	0.1945962	12.91704	14.49921	16.84849	20.10006	24.94189	33.0029	46.33165
15	-1.015225	20.85428	0.1974296	13.31562	14.97182	17.43581	20.85428	25.95918	34.48891	48.65601
16	-1.006793	21.44717	0.1999406	13.62151	15.33605	17.89193	21.44717	26.77471	35.72105	50.6913
17	-0.999124	21.86006	0.2024003	13.81217	15.5706	18.19708	21.86006	27.36817	36.6647	52.34075
18	-0.988643	22.11129	0.20491	13.89387	15.68488	18.36492	22.11129	27.7613	37.33541	53.56886

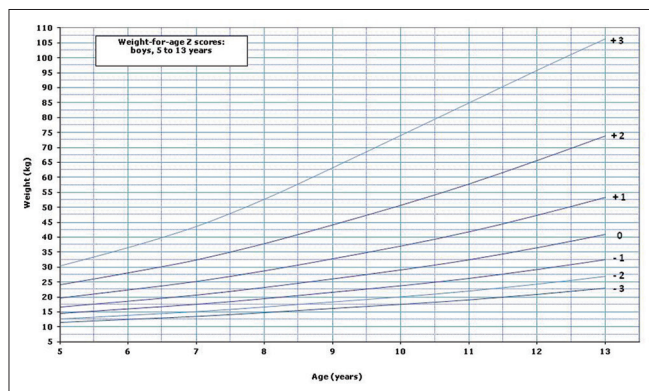


Figure 1: Weight for age z scores for boys

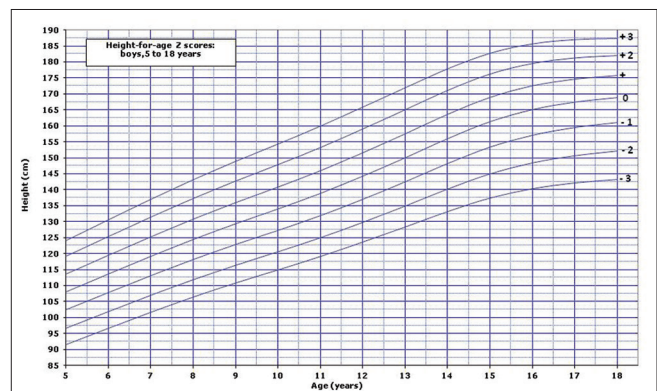


Figure 2: Height for age z scores for boys

The z score (standard deviation score) is considered the best system for presentation and analysis of anthropometric data both at the individual and population levels.^[3] The LMS parameters and z score growth reference is an important tool for research and

health care. Children and adolescents are growing subjects and regular evaluation of their growth and nutritional status is mandatory. This is especially true for those affected by chronic medical conditions known to affect growth and nutrition such as inflammatory bowel

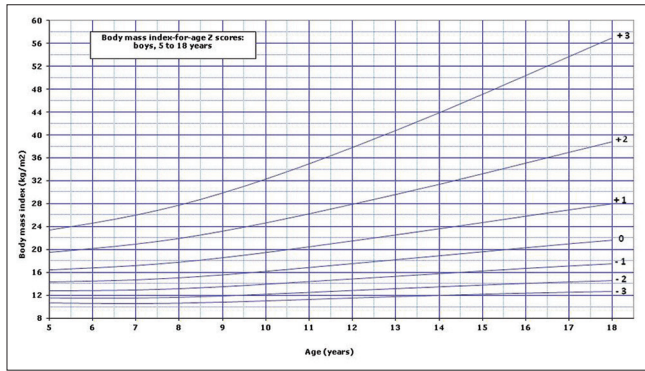


Figure 3: Body mass index for age z scores for boys

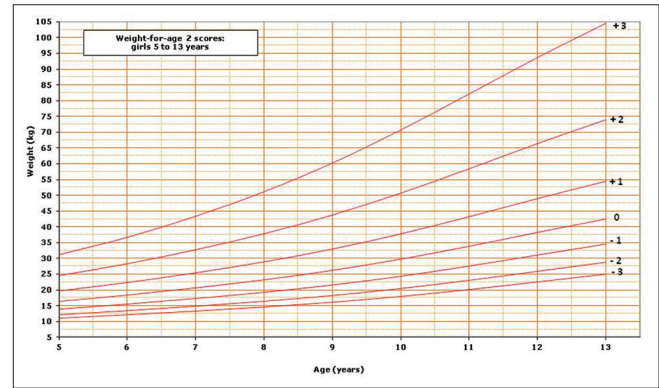


Figure 4: Weight for age z scores for girls

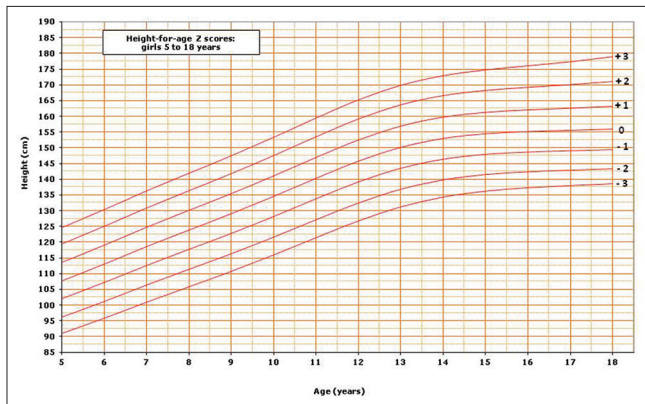


Figure 5: Height for age z scores for girls

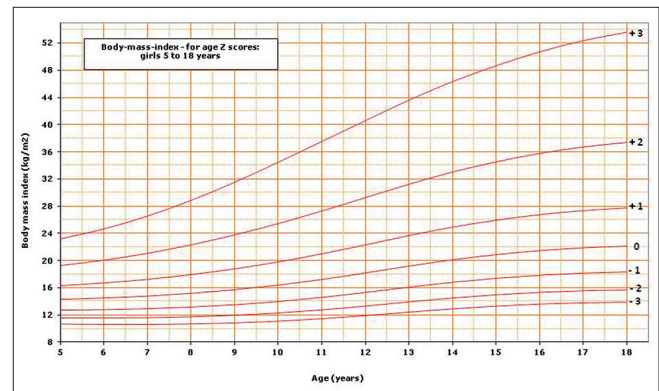


Figure 6: Body mass index for age z scores for girls

disease. In addition, availability of the LMS parameters of z scores allows the incorporation of growth charts in electronic hospital and clinic records.

To our knowledge, neither L, M, and S parameters nor z-score tables and corresponding growth charts have been reported in Saudi school-age children and adolescents. Z score reference data presented in this report include the most commonly used growth indicators such as weight for age, height for age, and BMI for age. Because of the pubertal growth spurt, weight for age is not an accurate measure of nutritional status beyond 11–12 years. Therefore, this indicator was not calculated beyond 13 years of age. The availability of this reference allows not only more accurate assessment but also comparison with other populations using their local growth chart references. In addition, the application of WHO definition of growth and nutritional disorders in Saudi school-age children and adolescents, individuals or groups, is now possible using the Saudi z-score reference described in this article. Accordingly, short stature is defined by z score < -2 standard deviation (SD), overweight by BMI $> +1$ SD, obesity by BMI $> +2$ SD, and thinness by BMI < -2 SD.^[22]

CONCLUSION

The availability of L, M, and S parameters' z scores tables and charts for height for age, BMI for age, and to lesser extent weight for age for school-age children and adolescent is an important landmark for research and health care. This population-based reference provides a tool for more accurate assessment of nutritional status and growth of Saudi school-age children and adolescents in various clinical conditions and research.

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Conflicts of interest

There are no conflicts of interest.

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