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Growth reference for Saudi school-age children and adolescents: LMS parameters and percentiles

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BACKGROUND: Information on LMS parameters and percentiles reference for Saudi children and adolescents is not available.

OBJECTIVE: To report the L, M, and S parameters and percentile reference graphs for growth.

DESIGN: Field survey of a population-based sample of Saudi school-age children and adolescents (5-18 years of age).

SETTING: A stratified listing of the Saudi population.

SUBJECTS AND METHODS: Data from the national study of healthy children were reanalyzed using the Lamba-Mu-Sigma (LMS) methodology. The LMS parameters of percentiles for weight, height, and body mass index for age were calculated for children and adolescents from 5 to 18 years of age.

MAIN OUTCOME MEASURE: The main outcomes were the LMS parameters and percentiles of growth.

RESULTS: There were 19 299 and 9827 (50.9%) were boys. The data for weight, height, and BMI for age for boys and girls are reported for the 3rd, 5th, 10th, 25th, 50th, 75th, 90th, 95th, and 97th percentiles including LMS parameters for each percentile and age. Figures corresponding to each table are color coded (blue for boys and pink for girls).

CONCLUSIONS: This report provides a reference for growth and nutrition of Saudi school-age children and adolescents. The detailed LMS and percentile tables and graphs provide essential information for clinical assessment of nutritional status and growth in various clinical conditions and for research.

**LIMITATIONS:** This report does not reflect regional variations in growth.

Growth charts have long been used worldwide to assess nutritional status. However, regular revisions were performed to account for secular changes in growth and to take advantage of modern statistical techniques.[1] The American growth charts, including the previous 1978 National Center for Health Statistics (NCHS) and the current revised National Center for Disease Control reference growth charts (CDC 2000), which reflect the growth of children of the United States, are commonly used.[2,3] However, in an attempt to provide growth charts more applicable to populations other than the United States, the World Health Organization (WHO) created the WHO Growth Reference Charts for School-age Children and Adolescents in 2007.[4] Despite the common use of the CDC 2000 and WHO growth reference charts in some countries, others developed local growth reference more suitable to their population.[5-8]

In Saudi Arabia, growth charts from a representative sample of children have been published in the form of charts only.[9] Therefore, the objective of this article is to report detailed percentile values of commonly used growth parameters, including LMS values, in children and adolescents from 5 to 18 years of age.

SUBJECTS AND METHODS

The methodology has been reported in a previous study.[9] In brief, multistage probability sampling was used to se-
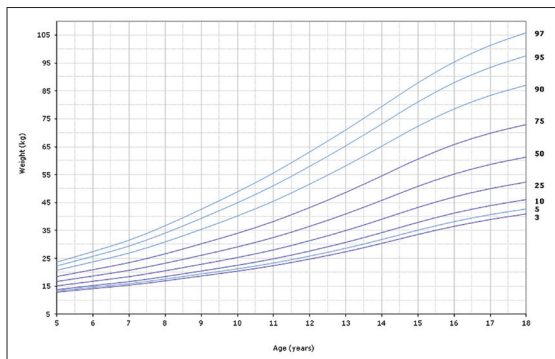
Figure 1. Weight-for-age percentiles for boys, 5 to 18 years.

Figure 2. Height-for-age percentiles for boys, 5 to 18 years.

lect a representative sample from each region of the country. Only healthy children were included. Weight is expressed in kilograms (kg) and length/height in centimeter (cm). As in previous analysis, the age was converted in Gregorian to facilitate comparison with growth charts of other populations.
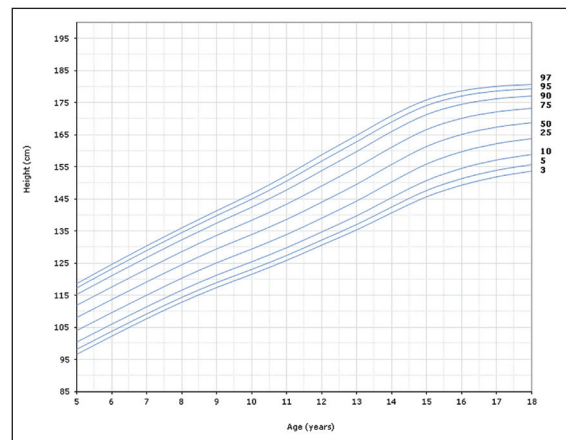
Statistical methods

The L, M, and S method was used to synthesize the distribution of growth parameters as a function of age. The LMS parameters are the median (M), the generalized coefficient of variation (S), and the power in the Box-Cox transformation (L). The method models the entire distribution taking into account degree of skewness (L), central tendency (M), and dispersion (S). The parameters L, M and S were calculated according to the method of maximum penalized likelihood.[10] Percentiles for all the anthropometric measures were calculated using the following formula.[11]

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

Where the 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 this study, we have calculated the 3rd, 5th,10th, 25th, 50th, 75th, 90th, 95th and the 97th percentiles for weight, height, and added the 85th percentile for body mass index, commonly used to define overweight. The LMS Chart Maker Light 2.1 (Medical Research Council, London, UK) was used to process the data and Q-test was used to assess the goodness of fit of all L, M, and S models.[12]

This analysis is based on data from health profile of Saudi children and adolescents study funded and approved by King Abdul Aziz City for Science and Technology, Riyadh, Saudi Arabia.

RESULTS

The sample size consisted of 19 299 Saudi children and adolescents from 5 to 18 year of age. All were Saudi nationals and 9 827 (50.9 %) were boys. For boys, the L, M, and S parameters and percentiles for weight for age, height for age, and BMI for age are presented in the

Tables 1 to 3, respectively, and the **Figures 1 to 3** represent plots corresponding to the tables. Similarly, **Tables 4 to 6** show L, M, and S parameters and percentiles for girls, including weight for age, height for age, and BMI for age. **Figures 4 to 6** are plots of the data in **Tables 4 to 6**.

DISCUSSION

Worldwide variations of human growth are well known, suggesting that the use of growth references from another population is potentially risky.[13] Previous studies from Saudi Arabia demonstrated marked differences in growth between Saudi children and their American counterparts.[14-16] More recently reported differences between Saudi and both CDC 2000 and WHO growth charts confirm previous studies.[17,18] The implication of these differences are considerable with the potential of overestimation of prevalence of short stature and malnutrition potentially resulting in unnecessary referrals and patient and parent anxiety.

The percentile system is commonly used in clinics and hospitals for the assessment of growth and nutrition in clinical setting.[19] The percentile ranks of individuals define the nutritional and growth status in comparison with peers of the same age and gender. Children and adolescents are growing subjects and regular evaluation of their growth and nutritional sta-
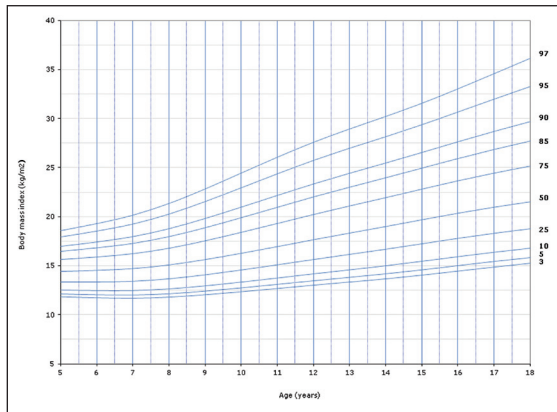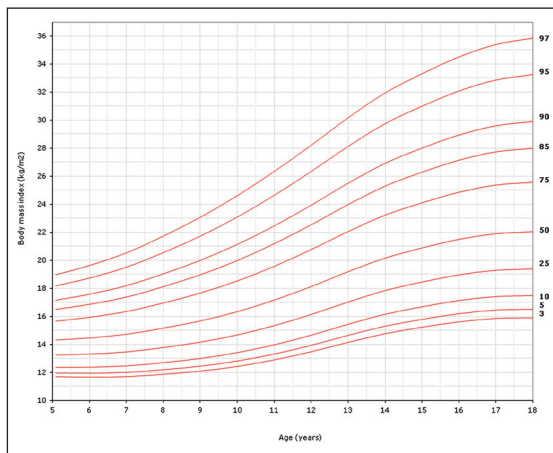
Figure 3. Body mass index-for-age percentiles for boys, 5 to 18 year
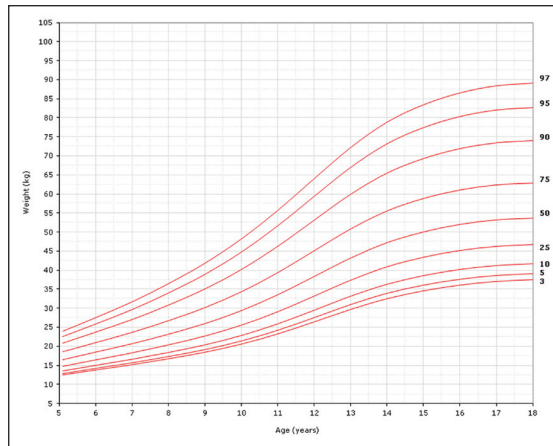
Figure 4. Weight-for-age percentiles for girls, 5 to 18 years.
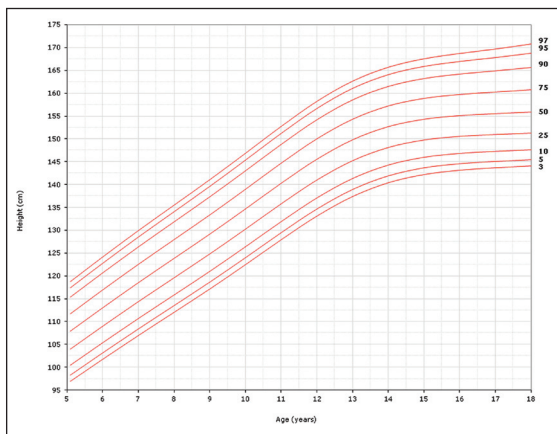
Figure 5. Height-for-age percentiles for girls, 5 to 18 years.

Figure 6. Body mass index-for-age percentiles for girls, 5 to 18 years

tus is mandatory. This is especially true for those affected by chronic medical conditions potentially affecting growth and nutrition. In addition, the LMS parameters and tables of percentiles allow the incorporation of growth charts in electronic hospital and clinic records.

The L, M, and S parameters and growth percentile reference has recently been reported in Saudi preschool children.[20] However, to our knowledge, no reference has been reported for Saudi school-age children and adolescents. In this report, growth indicators (weight for age, height for age, and BMI for age) are presented, allowing more accurate assessment of growth and nutritional status. Regular follow up of growth parameter percentiles at different ages helps detection and definition of malnutrition. For example, a flat growth line crossing more than one percentile curve in a weight for age or below the 3rd percentile define failure to

grow, also called failure to thrive. Similarly, height for age dropping below the 3rd percentile is a sign of short stature. In addition, the BMI is increasingly used to define thinness (BMI < 5th percentile), overweight (BMI > 85th percentile) and obesity (BMI > 95th percentile).[21]

In conclusion, the availability of L, M, and S parameters, percentiles tables, and reference charts for height for age, BMI for age and to lesser extent weight for age for school-age children and adolescents is important for research and health care.

Acknowledgment

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"Growth reference for Saudi school-age children and adolescents: LMS parameters and percentiles" (TABLES 1 TO 6)

Table 1. L, M, and S parameters and percentiles for weight for age: boys 5 to 18 years.

Age (y)	L	M	S	3rd	5th	10th	25th	50th	75th	90th	95th	97th
5	-1.046774	16.65079	0.1550993	12.90855	13.28112	13.89993	15.07723	16.65079	18.60172	20.80742	22.40426	23.58309
6	-1.032594	18.64088	0.1685233	14.17041	14.60824	15.33896	16.74133	18.64088	21.03668	23.80084	25.83963	27.36547
7	-1.015487	20.66037	0.1819188	15.40283	15.90975	16.75961	18.4042	20.66037	23.55329	26.95761	29.51515	31.45556
8	-0.991157	23.2016	0.1951612	16.96528	17.558	18.55585	20.5014	23.2016	26.71622	30.92749	34.14503	36.61717
9	-0.9524795	26.06358	0.2080576	18.68911	19.38161	20.55156	22.84711	26.06358	30.30098	35.4506	39.43634	42.52811
10	-0.8979311	29.04166	0.2201021	20.42467	21.22672	22.58539	25.26373	29.04166	34.05786	40.20527	44.99669	48.73124
11	-0.8295125	32.4206	0.2305578	22.38467	23.31419	24.89148	28.00907	32.4206	38.29382	45.50162	51.1186	55.49237
12	-0.7531365	36.42373	0.2388563	24.73617	25.81763	27.65393	31.28576	36.42373	43.24885	51.58274	58.03479	63.02903
13	-0.678714	40.85276	0.2446715	27.37162	28.62171	30.74394	34.93716	40.85276	48.66688	58.12203	65.36768	70.92835
14	-0.6195751	45.73953	0.2479675	30.36456	31.79524	34.22245	39.01013	45.73953	54.57247	65.16076	73.1944	79.31055
15	-0.5869272	50.75983	0.2490815	33.55655	35.16184	37.88363	43.24485	50.75983	60.58089	72.28175	81.10396	87.78738
16	-0.5862568	55.13887	0.2485967	36.47562	38.21821	41.17227	46.98918	55.13887	65.78262	78.45399	88.00129	95.23035
17	-0.6082383	58.58773	0.2471192	38.90816	40.74362	43.85572	49.98706	58.58773	69.84454	83.28848	93.45201	101.1684
18	-0.6401284	61.25766	0.2451296	40.89868	42.79431	46.00937	52.34879	61.25766	72.95528	86.9922	97.65765	105.788

Table 2. L, M, and S parameters and percentiles for height for age: boys 5 to 18 years.

Age (y)	L	M	S	3rd	5th	10th	25th	50th	75th	90th	95th	97th
5	1.484274	107.9784	5.40E-02	96.72755	98.17271	100.3781	104.0118	107.9784	111.8757	115.3279	117.3701	118.6872
6	1.139618	113.6109	5.22E-02	102.3724	103.7914	105.971	109.5992	113.6109	117.6028	121.1796	123.3131	124.6959
7	0.9419675	119.1193	5.06E-02	107.8147	109.2292	111.4093	115.0578	119.1193	123.1889	126.8584	129.0574	130.4867
8	0.9449131	124.4657	4.94E-02	112.9265	114.3706	116.5963	120.3204	124.4657	128.6186	132.3627	134.6062	136.0643
9	0.9488391	129.4396	4.91E-02	117.5055	118.9993	121.3014	125.1531	129.4396	133.7335	137.6041	139.9232	141.4304
10	0.6246465	133.9074	4.98E-02	121.5972	123.117	125.4709	129.4415	133.9074	138.4299	142.5483	145.0346	146.6579
11	9.42E-02	138.638	5.08E-02	125.9425	127.4751	129.8681	133.9576	138.638	143.4659	147.9409	150.6791	152.4818
12	-7.27E-02	144.0198	5.19E-02	130.6711	132.2703	134.774	139.0717	144.0198	149.1572	153.9494	156.8961	158.8421
13	0.2517995	149.6053	5.24E-02	135.4007	137.1248	139.8117	144.3891	149.6053	154.9613	159.9034	162.9168	164.8965
14	0.9325199	155.8014	5.17E-02	140.697	142.5861	145.4981	150.3728	155.8014	161.2428	166.1509	169.0929	171.0054
15	1.843215	161.4386	4.97E-02	145.703	147.7542	150.8666	155.9498	161.4386	166.7743	171.4564	174.2076	175.9748
16	2.715764	165.1562	4.69E-02	149.2968	151.4456	154.6555	159.7773	165.1562	170.2502	174.6213	177.1498	178.7593
17	3.411383	167.4663	4.42E-02	151.8744	154.0466	157.2535	162.2847	167.4663	172.2878	176.3651	178.7004	180.1785
18	3.980551	168.8105	0.0417342	153.6481	155.8031	158.9572	163.8451	168.8105	173.3751	177.1976	179.3726	180.7441

Table 3. L, M, and S parameters and percentiles for body mass index for age: boys 5 to 18 years.

Age (y)	L	M	S	3rd	5th	10th	25th	50th	75th	85th	90th	95th	97th
5	-1.1546	14.425	0.11715	11.85398	12.12153	12.56001	13.37456	14.42514	15.67127	16.44123	17.01084	17.93816	18.60128
6	-1.1749	14.535	0.12861	11.74748	12.03238	12.50179	13.38225	14.53462	15.92714	16.80206	17.45674	18.53642	19.31935
7	-1.1943	14.712	0.13997	11.70181	12.00415	12.50487	13.45289	14.71178	16.26175	17.25246	18.00262	19.25692	20.18026
8	-1.2098	15.083	0.15111	11.81397	12.13688	12.67425	13.70075	15.08292	16.81615	17.9431	18.80676	20.27145	21.36678
9	-1.2071	15.628	0.16196	12.0571	12.40471	12.98559	14.10385	15.62799	17.57034	18.85257	19.84589	21.55233	22.84696
10	-1.1782	16.265	0.17227	12.36124	12.7369	13.36675	14.5866	16.26476	18.42953	19.87483	21.00345	22.96081	24.46162
11	-1.1235	16.946	0.18163	12.69091	13.09729	13.78019	15.10806	16.94554	19.33282	20.93661	22.1942	24.38563	26.07443
12	-1.0488	17.642	0.18983	13.0272	13.46638	14.20533	15.64509	17.6423	20.2427	21.9916	23.36342	25.75361	27.59449
13	-0.9647	18.314	0.1968	13.3455	13.81801	14.61342	16.1639	18.31431	21.10948	22.98428	24.45111	26.99756	28.94971
14	-0.8892	18.98	0.20253	13.67167	14.1767	15.02697	16.68413	18.97991	21.95556	23.94398	25.49473	28.17519	30.21912
15	-0.8478	19.666	0.20714	14.04488	14.57897	15.47866	17.23341	19.66593	22.81892	24.92463	26.56565	29.39888	31.55593
16	-0.8615	20.334	0.21081	14.45751	15.01265	15.94931	17.78165	20.33412	23.66469	25.90323	27.65583	30.69856	33.02959
17	-0.9132	20.943	0.21387	14.86774	15.43648	16.39831	18.28857	20.94259	24.4459	26.82817	28.70968	32.01193	34.57371
18	-0.9786	21.486	0.21658	15.25003	15.82811	16.80817	18.74401	21.4863	25.15499	27.68465	29.704	33.29661	36.1284

Table 4. L, M, and S parameters and percentiles for weight for age: girls 5 to 18 years.

Age (y)	L	M	S	3rd	5th	10th	25th	50th	75th	90th	95th	97th
5	-0.938951	16.42919	0.1685386	12.4482	12.84134	13.49605	14.74714	16.42919	18.52782	20.9147	22.65023	23.93477
6	-0.9157015	18.45433	0.178501	13.77099	14.2287	14.99332	16.46255	18.45433	20.96522	23.85503	25.97861	27.56234
7	-0.8899531	20.6649	0.1893735	15.16592	15.69748	16.58836	18.31021	20.6649	23.66574	27.16288	29.76165	31.71543
8	-0.8623634	23.17324	0.1999672	16.73087	17.34735	18.38368	20.39738	23.17324	26.74599	30.95694	34.11781	36.51143
9	-0.8322223	25.97128	0.2097031	18.4657	19.17783	20.37801	22.72062	25.97128	30.18894	35.205	39	41.88993
10	-0.7994724	29.38699	0.2178778	20.61651	21.44358	22.84008	25.57478	29.38699	34.35965	40.30696	44.82735	48.28041
11	-0.7663324	33.57265	0.2237808	23.31085	24.27543	25.90588	29.10424	33.57265	39.41382	46.41186	51.73588	55.8042
12	-0.7413344	38.38703	0.2270551	26.48859	27.60592	29.49531	33.20366	38.38703	45.16304	53.27594	59.44133	64.14745
13	-0.731925	43.22614	0.2279888	29.77024	31.03381	33.17061	37.36462	43.22614	50.88586	60.05038	67.00912	72.31693
14	-0.7383584	47.25764	0.2272233	32.59572	33.97274	36.30124	40.87108	47.25764	55.60431	65.59375	73.18195	78.97207
15	-0.7550535	50.08248	0.2255488	34.66291	36.11118	38.55988	43.36541	50.08248	58.86646	69.39174	77.39851	83.51566
16	-0.777939	52.04097	0.2236553	36.16599	37.65651	40.17663	45.12304	52.04097	61.09903	71.97591	80.2705	86.62072
17	-0.80327	53.22288	0.2218783	37.13643	38.64573	41.19784	46.20867	53.22288	62.42283	73.50063	81.97466	88.47912
18	-0.8281887	53.68508	0.2202955	37.59686	39.10506	41.65562	46.66542	53.68508	62.90914	74.04828	82.59687	89.17638

Table 5. L, M, and S parameters and percentiles for height for age: girls 5 to 18 years.

Age (y)	L	M	S	3rd	5th	10th	25th	50th	75th	90th	95th	97th
5	0.9887214	107.8352	5.39E-02	96.89977	98.27086	100.3825	103.912	107.8352	111.7599	115.2937	117.4091	118.7831
6	1.021588	113.0171	5.28E-02	101.7718	103.1839	105.3575	108.9872	113.0171	117.0439	120.6655	122.8318	124.2382
7	1.047814	118.522	0.051654	106.9798	108.4309	110.6634	114.3892	118.522	122.6479	126.3557	128.5722	130.0106
8	1.046376	123.8421	5.05E-02	112.0533	113.5352	115.8153	119.6207	123.8421	128.0569	131.8449	134.1094	135.5791
9	1.01275	129.1633	4.94E-02	117.1632	118.6694	120.9882	124.8615	129.1633	133.4632	137.3318	139.6463	141.1491
10	0.9565817	134.6863	4.82E-02	122.4892	124.0165	126.3698	130.3064	134.6863	139.0724	143.0252	145.393	146.9317
11	0.8806756	140.31	0.0471158	127.9437	129.4875	131.8689	135.8596	140.31	144.7774	148.8122	151.2332	152.8079
12	0.7635555	145.5699	4.60E-02	133.1145	134.6625	137.0543	141.0729	145.5699	150.0999	154.2049	156.6741	158.2826
13	0.5740123	149.8175	0.0449087	137.392	138.9255	141.3011	145.3088	149.8175	154.3848	158.5453	161.0578	162.6984
14	0.286931	152.6869	4.41E-02	140.3951	141.8969	144.2317	148.1941	152.6869	157.2761	161.4898	164.0497	165.7275
15	-0.1007422	154.3053	4.37E-02	142.1866	143.6478	145.93	149.8333	154.3053	158.9247	163.2127	165.8397	167.5707
16	-0.5813157	155.1001	4.37E-02	143.1323	144.5521	146.7822	150.632	155.1001	159.7814	164.1887	166.919	168.7308
17	-1.140942	155.5257	4.42E-02	143.6594	145.041	147.2248	151.0356	155.5257	160.3117	164.8976	167.7792	169.7091
18	-1.765896	155.8763	4.49E-02	144.071	145.417	147.5594	151.3422	155.8763	160.8071	165.6338	168.7209	170.813

Table 6. L, M, and S parameters and percentiles for body mass index for age: girls 5 to 18 years.

Age (y)	L	M	S	3rd	5th	10th	25th	50th	75th	85th	90th	95th	97th
5	-1.312917	14.32989	0.1244782	11.68381	11.95329	12.39768	13.23284	14.32989	15.66306	16.50564	17.13892	18.18902	18.95529
6	-1.2939	14.48028	0.1335916	11.64918	11.93405	12.40551	13.29727	14.48028	15.93621	16.86706	17.57226	18.75246	19.62239
7	-1.27238	14.74155	0.1436224	11.68709	11.99053	12.4946	13.45457	14.74155	16.34713	17.3866	18.18098	19.52405	20.52522
8	-1.246668	15.17908	0.1536925	11.85864	12.18451	12.72778	13.76909	15.17908	16.96106	18.12861	19.02841	20.56485	21.72278
9	-1.214775	15.69607	0.1634513	12.08774	12.43806	13.02391	14.15329	15.69607	17.6683	18.97423	19.98816	21.73473	23.06392
10	-1.17507	16.35505	0.1724243	12.42587	12.80402	13.43804	14.66594	16.35505	18.53366	19.98798	21.12348	23.09243	24.60179
11	-1.129133	17.17908	0.1801299	12.89472	13.30453	13.99292	15.33042	17.17908	19.57733	21.1863	22.44677	24.64075	26.32944
12	-1.085184	18.14618	0.186309	13.48377	13.92795	14.67501	16.12963	18.14618	20.77105	22.53679	23.92236	26.33827	28.20093
13	-1.050285	19.2067	0.1910618	14.15941	14.6389	15.44607	17.02012	19.2067	22.05912	23.98107	25.49064	28.12516	30.158
14	-1.02617	20.1722	0.1946503	14.78322	15.29402	16.15452	17.83455	20.1722	23.22719	25.28849	26.90886	29.73912	31.92471
15	-1.01184	20.89756	0.1974603	15.24643	15.78093	16.68194	18.44307	20.89756	24.11151	26.28365	27.99302	30.98236	33.29374
16	-1.006032	21.50933	0.1999027	15.63638	16.1905	17.12522	18.95463	21.50933	24.86311	27.13513	28.92606	32.06425	34.49603
17	-1.002935	21.91292	0.2022514	15.87659	16.44464	17.40358	19.28292	21.91292	25.37526	27.72699	29.58424	32.84599	35.37991
18	-0.998486	22.05139	0.2046199	15.92218	16.49753	17.4695	19.37684	22.05139	25.58162	27.98535	29.88696	33.23357	35.83947