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Short Communication

Growth standard charts for Japanese children with mean and standard deviation (SD) values based on the year 2000 national survey

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Introduction

Growth charts are essential and universally used for evaluating growth and development of children in both clinical settings and in public health examinations (1, 2). We previously reported the growth standards for Japanese children with percentile values based on the year 2000 national survey data (3), which were established by the lambda-mu-sigma (LMS) method (4). These standards have been widely used mainly in public health examinations. In clinical practices, Japanese physicians preferably assess growth with standard deviation (SD) scores, because many physicians feel that percentiles are not suitable for monitoring children with extreme growth retardation. Considering this, we created practical growth charts with mean and SD values, based on the criteria of the national medical aid program for specific pediatric chronic diseases by using the eye-fitting method (5). Although these charts have been widely used in clinical settings, they do not reflect the correct distributions of height and weight for Japanese children, especially the weight chart. Weight is not usually distributed normatively, but the practical weight chart was made with the assumption of a normal distribution. To this end, we saw the need for growth standards that can be used appropriately both for clinical and public health purposes. Therefore, we reanalyzed the previously reported growth standard charts with percentile values (3) and constructed the growth standards with mean and SD values for Japanese children, which would be applicable not only for clinical practices but also for public health examinations.

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Table 1 Age distribution of the numbers of measurements used for analysis

Age (yr)	Height		Weight	
	Male	Female	Male	Female
0	6,637	6,335	18,891	17,965
1	1,534	1,486	1,534	1,484
2	483	480	483	481
3	471	431	472	432
4	476	436	476	436
5	31,765	31,558	31,761	31,558
6	22,094	21,982	22,094	21,982
7	21,895	21,905	21,894	21,905
8	21,920	21,969	21,920	21,969
9	21,971	21,973	21,971	21,967
10	21,978	21,950	21,978	21,950
11	22,002	22,024	22,003	22,024
12	36,230	36,507	36,229	36,507
13	36,278	36,527	36,277	36,526
14	36,376	36,541	36,375	36,539
15	21,017	20,982	21,018	20,980
16	21,078	20,996	21,077	20,990
17	21,017	20,990	21,017	20,985
Total	345,222	345,072	357,470	356,680

Methods

We used the same datasets as those in our previous report (3). In short, we used the data obtained from the national survey in year 2000. The data included 18,550 anthropometric measurements of babies and infants surveyed by the Ministry of Health, Labour and Welfare and 695,600 anthropometric measurements of school children surveyed by the Ministry of Education, Culture, Sports, Science and Technology. Table 1 shows the age distribution of the numbers of measurements used for the analysis. To establish the growth charts, the LMS method (4) was used, with the assumption that the data could be transformed to a normal distribution by utilizing a suitable power transformation (L), and the distribution was summarized by the median (M) and coefficient of variation (S). The three curves (L, M, and S) were fitted and smoothed by polynomial functions with several knots, which were determined by inspecting the curves to be fitted (6). The polynomial functions were determined by the least sum of the squared residuals. The adjustments for ridges of near adult ages were performed by Quo's method (7).

The values of L, M, and S were constrained to change smoothly with age, and fitted values could be used to construct any required centile curves. The SD score (Z-score) of each measurement (y value) could be calculated from the L, M and S curves, using values appropriate for the age and gender, with the following equation: $Z = [(y/M)^{L-1}] / (L \times S)$, or $Z = \ln (y/M)/S$ if $L = 0$.

Results

The values of smoothed L, M, and S for height and weight are shown in Tables 2 and 3, respectively. With these values, growth charts with mean and SD values were constructed, and these charts are presented in Fig. 1 (a, height for males; b, height for females) and Fig. 2 (a, weight for males; b, weight for females).

Table 2 LMS values of height for Japanese children

Age (yr)	Male			Female		
	L	M	S	L	M	S
0	2.300	49.0	0.0417	1.200	48.5	0.0390
0.25	2.212	61.5	0.0378	1.159	60.1	0.0361
0.5	2.124	67.7	0.0351	1.117	66.2	0.0341
0.75	2.036	71.6	0.0335	1.076	70.2	0.0327
1	1.948	74.8	0.0328	1.034	73.5	0.0318
1.25	1.861	77.8	0.0328	0.993	76.6	0.0316
1.5	1.773	80.7	0.0332	0.952	79.5	0.0317
1.75	1.685	83.4	0.0340	0.910	82.2	0.0321
2	1.597	85.8	0.0348	0.869	84.6	0.0328
2.5	1.421	89.7	0.0364	0.786	88.4	0.0344
3	1.245	93.5	0.0378	0.703	91.8	0.0361
3.5	1.069	97.1	0.0386	0.620	95.4	0.0376
4	0.894	100.4	0.0392	0.538	99.4	0.0389
4.5	0.718	103.6	0.0397	0.455	103.2	0.0399
5	0.542	106.8	0.0403	0.372	106.7	0.0406
5.5	0.366	110.1	0.0410	0.289	109.7	0.0411
6	0.190	113.3	0.0417	0.206	112.7	0.0414
6.5	0.015	116.4	0.0423	0.124	115.5	0.0416
7	–0.161	119.5	0.0426	0.041	118.3	0.0418
7.5	–0.337	122.4	0.0426	–0.042	121.2	0.0421
8	–0.513	125.1	0.0424	–0.114	124.1	0.0428
8.5	–0.689	127.8	0.0421	–0.036	127.2	0.0438
9	–0.864	130.4	0.0420	0.213	130.4	0.0451
9.5	–1.040	133.1	0.0424	0.599	133.8	0.0466
10	–1.216	135.9	0.0435	1.055	137.2	0.0477
10.5	–1.392	138.8	0.0453	1.506	140.6	0.0481
11	–1.401	142.0	0.0476	1.879	144.0	0.0472
11.5	–0.965	145.4	0.0500	2.118	147.2	0.0447
12	–0.275	149.0	0.0519	2.190	150.0	0.0410
12.5	0.428	153.1	0.0526	2.090	152.1	0.0367
13	0.931	157.0	0.0517	1.843	153.8	0.0342
13.5	1.090	160.5	0.0491	1.498	155.1	0.0324
14	0.865	163.4	0.0453	1.124	155.9	0.0314
14.5	0.323	165.6	0.0414	0.801	156.6	0.0310
15	–0.370	167.3	0.0382	0.602	157.0	0.0310
15.5	–0.982	168.6	0.0358	0.579	157.3	0.0310
16	–1.267	169.5	0.0344	0.742	157.5	0.0310
16.5	–1.031	170.1	0.0340	1.032	157.7	0.0310
17	–0.516	170.5	0.0340	1.295	157.8	0.0310
17.5	0.000	170.8	0.0340	1.250	157.8	0.0310

Discussion

We established growth standard charts with mean and SD values for Japanese children. They were constructed by the LMS method, which we believe is one of the most widely applied approaches (8). In addition, growth charts constructed by the LMS method allowed us to draw any kind of centile curve and convert measurements into an exact SD score (Z-score) by using the resulting L, M, and S curves. This means that values shown by percentiles can

Table 3 LMS values of weight for Japanese children

Age (yr)	Male			Female		
	L	M	S	L	M	S
0	0.774	3.00	0.149	0.754	2.95	0.146
0.25	0.490	6.31	0.131	0.375	5.86	0.126
0.5	0.262	7.93	0.119	0.083	7.32	0.113
0.75	0.082	8.80	0.110	–0.139	8.14	0.106
1	–0.062	9.38	0.105	–0.303	8.72	0.103
1.25	–0.177	9.91	0.102	–0.422	9.26	0.102
1.5	–0.269	10.4	0.101	–0.506	9.82	0.102
1.75	–0.344	11.0	0.102	–0.563	10.4	0.104
2	–0.408	11.5	0.103	–0.602	11.0	0.105
2.5	–0.513	12.5	0.108	–0.646	12.1	0.110
3	–0.607	13.5	0.113	–0.677	13.1	0.114
3.5	–0.703	14.5	0.119	–0.718	14.0	0.118
4	–0.804	15.5	0.123	–0.778	15.1	0.122
4.5	–0.913	16.5	0.127	–0.861	16.1	0.127
5	–1.026	17.5	0.131	–0.960	17.1	0.131
5.5	–1.136	18.5	0.134	–1.068	18.2	0.137
6	–1.236	19.6	0.138	–1.171	19.4	0.142
6.5	–1.321	20.9	0.142	–1.259	20.6	0.148
7	–1.384	22.2	0.146	–1.319	21.9	0.154
7.5	–1.420	23.5	0.152	–1.344	23.2	0.159
8	–1.429	25.0	0.159	–1.328	24.5	0.164
8.5	–1.407	26.4	0.166	–1.269	25.9	0.169
9	–1.358	28.0	0.174	–1.169	27.4	0.174
9.5	–1.284	29.6	0.182	–1.037	29.2	0.180
10	–1.191	31.4	0.189	–0.884	31.2	0.185
10.5	–1.084	33.4	0.195	–0.722	33.6	0.190
11	–0.971	35.6	0.200	–0.572	36.3	0.194
11.5	–0.862	38.1	0.204	–0.448	39.0	0.195
12	–0.764	40.7	0.206	–0.368	41.5	0.194
12.5	–0.686	43.6	0.205	–0.346	43.8	0.187
13	–0.636	46.3	0.201	–0.389	45.8	0.176
13.5	–0.619	49.0	0.196	–0.496	47.5	0.164
14	–0.642	51.6	0.187	–0.653	48.8	0.154
14.5	–0.705	54.0	0.178	–0.830	49.8	0.147
15	–0.809	55.9	0.169	–0.976	50.6	0.142
15.5	–0.952	57.5	0.161	–1.012	51.2	0.139
16	–1.127	58.8	0.155	–1.072	51.6	0.138
16.5	–1.325	59.7	0.151	–1.132	51.9	0.137
17	–1.534	60.4	0.147	–1.192	52.1	0.135
17.5	–1.739	60.9	0.141	–1.252	52.3	0.134

easily be converted to those with SD scores.

The new height chart is comparable to the existing practical height chart within ± 2 SD lines (5), but the values outside that range are slightly different. Therefore, physicians should be cautious in their judgments when considering adaptation of their patients' measurements to the national medical aid program for specific pediatric chronic diseases.

On the other hand, the new weight chart is totally different from the existing practical weight chart (5). Although the practical chart

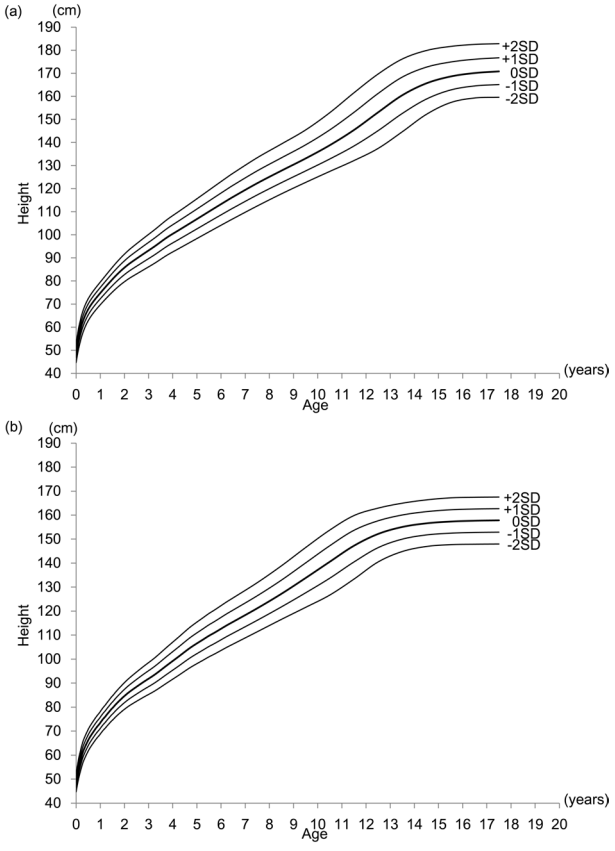

Fig. 1. Height growth charts with mean, ± 1 SD, and ± 2 SD lines (Z-score lines) for Japanese male (a) and female (b) children.

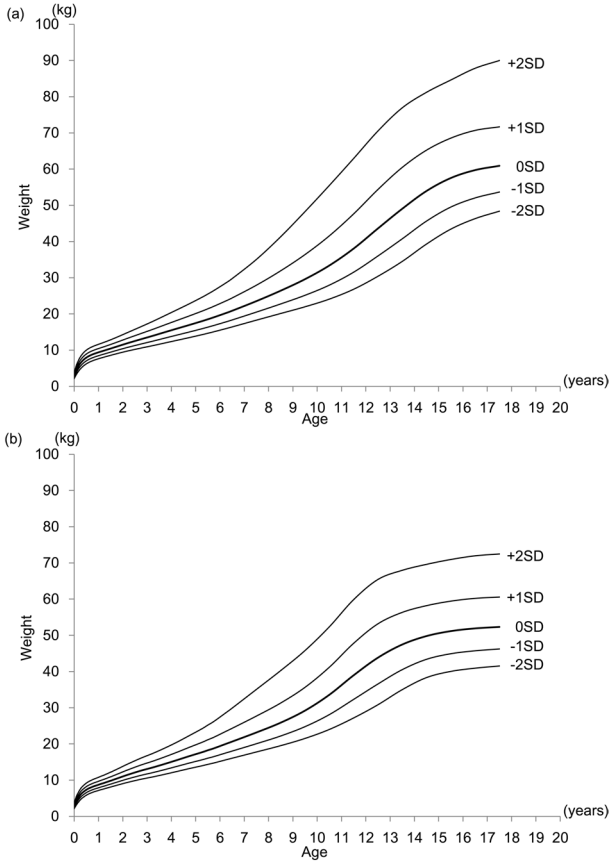

Fig. 2. Weight growth charts with mean, ± 1 SD, and ± 2 SD lines (Z-score lines) for Japanese male (a) and female (b) children. It should be noted that the intervals between neighboring lines are not equal because of the skewed distribution of weight.

was drawn under the hypothesis of a normal distribution for weight, the weight distribution is not generally normal. Thus, we constructed the new chart with mean and SD values to represent the actual weight distributions. Moreover, we could calculate SD scores from measurements using the L, M, and S values presented in this article, because the new chart is constructed by the LMS method. We recommend that physicians should use this new weight chart in their clinical practices.

In conclusion, our study provides growth standards for Japanese children with mean and SD values, which could be widely used in clinical practices and in public health examinations.

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