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Reference Values of Body Composition Indices: The Korean National Health and Nutrition Examination Surveys

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Purpose: An increase in the prevalence of obesity has been observed in children and adolescents. As remarkable changes in body composition occur with growth during the adolescent period, it is important that changes in body composition be monitored. The purpose of this study was to propose reference percentile values for body composition indices including body mass index (BMI) in children and adolescents in Korea. **Materials and Methods:** This study was performed using data from the Fourth and Fifth Korea National Health and Nutrition Examination Surveys. Body composition data were obtained using dual-energy X-ray absorptiometry. The percentile curves of body composition indices were constructed by the LMS method. **Results:** A total of 2123 children and adolescents between the ages of 10 and 19 years were included in this study. We obtained the percentile curves for BMI and body composition indices. **Conclusion:** The reference values for body composition from this study could help with assessing body composition in Korean adolescents.

Key Words: Body mass index, percent body fat, fat mass index, fat-free mass index, adolescent

INTRODUCTION

The prevalence of childhood obesity has increased worldwide, including Asia, due to changes in lifestyle and diet patterns.[1-6] Childhood obesity has been shown to be associated with the risk of adult obesity and the other diseases associated with metabolic dysregulation, such as cardiovascular disease or type 2 diabetes.[1,2,4-7] Body mass index (BMI) has been widely used as a marker of adiposity;[8] however, BMI is limited in differentiating body fat from lean mass.[9-11] Thus, the body compositions of children with the same BMI values could differ by age, race, gender, and pubertal stage during the adolescent period.[2-5,12,13]

It is important to discriminate normal from abnormal development based on reference values rather than absolute values of body composition indices because body composition changes rapidly with rapid growth during the adolescent period.

The purpose of this study was to propose reference percentile values for body composition indices in children and adolescents in Korea.

MATERIALS AND METHODS

Study population

This study was performed using data from the Fourth and Fifth Korea National Health and Nutrition Examination Surveys (KNHANES) conducted by the Korea Centers for Disease Control and Prevention. KNHANES has been conducted periodically and includes a representative sample of the non-institutionalized civilian population of South Korea selected using a stratified, multi-stage, probability sampling method (rolling survey sampling). Data were collected through a health and nutrition interview and a health examination. Among the total of 4904 participants in KNHANES, 2123 children and adolescents (1113 males and 1010 females) who had results for anthropometric data and body composition analysis and who were between the ages of 10 and 19 years were included.

Measurement of anthropometrics and body composition

Participants' weight and height were measured in light clothing and without shoes. Weight was measured with a digital scale (GL-6000-20, CASKOREA, Seoul, Korea) to the nearest 0.1 kg, and height was measured to the nearest 0.1 cm with a stadiometer (SECA 225, SECA Deutschland, Hamburg, Germany). Body composition data [fat mass, fat-free mass, and percentage of body fat (PBF)] were measured in grams using dual-energy X-ray absorptiometry (DXA) using a Hologic Discovery DXA scanner (Discovery QDR 4500 W, Hologic, Inc., Denver, CO, USA). BMI, fat mass index (FMI), and fat-free mass index (FFMI) were calculated as body weight (kg), fat mass (kg), and fat-free mass (kg), respectively, divided by the square of the height in meters (kg/m^2).

Table 1. General Characteristics of the Study Population

	Male (n=1113)	Female (n=1010)
Age (yrs)	14.2±2.8	14.3±2.9
Body weight (kg)	56.9±15.5	50.4±11.1
Height (cm)	163.8±13.0	157.2±8.1
BMI (kg/m^2)	20.9±3.8	20.2±3.5
FMI (kg/m^2)	5.0±2.5	6.5±2.2
FFMI (kg/m^2)	15.7±2.3	13.6±1.6
PBF (%)	23.3±8.1	31.6±5.8

BMI, body mass index; FMI, fat mass index; FFMI, fat free mass index; PBF, percent body fat.
Values are presented as mean±SD.

Data analysis

The mean and standard deviation of anthropometric and body composition values were calculated. We calculated age- and gender-specific percentiles using the Lambda-Mu-Sigma (LMS) method (LMS Chartmaker Pro, version 2.5, Medical Research Council, Cambridge, UK) to estimate the skewness (L), median (M), and coefficient of variation (S). For statistical analysis, we used SPSS software, version 17.0, for Windows (SPSS Inc., Chicago, IL, USA).

Ethics statement

The study protocol was approved by the Institutional Review Board of the Korea Centers for Disease Control and Prevention (approval number; 2008-04EXP-01-C, 2009-01CON-03-2C, 2010-02CON-21-C, and 2011-02CON-06-C). Written consent was obtained from the subjects prior to participation.

RESULTS

A total of 2123 children and adolescents were eligible and constituted the study population. The characteristics of each group in the study population according to gender and age are shown in Table 1. The sample size and the smoothed estimates of body composition indices, including BMI, PBF, FMI, and FFMI of each group, according to gender and age, are shown in Table 2. The children and adolescents were evenly distributed in each age and gender groups (Table 2). The smoothed estimates for the 3rd, 5th, 10th, 25th, 50th, 75th, 85th, 90th, 95th, and 97th percentiles of values for BMI, PBF, FMI, and FFMI for children and adolescents in each age group for both genders are presented as values (Table 2) and percentile curves (Figs. 1-4).

The PBF and FMI values for females were higher, although BMI and FFMI were lower, than those for males (Table 2). The pattern of changes in BMI and FFMI were similar in both genders, increasing gradually with age, whereas changes in FMI and PBF differed by gender (Figs. 1-4). Both PBF and FMI showed a tendency to decrease in males and increase in females with age (Table 2, Figs. 2 and 3).

In both genders, a tendency was noted toward greater in-

Table 2-1. LMS Parameters for Z-Scores and Percentiles for Body Composition Indices among Adolescents Aged 10–19 Years: LMS Parameters for Z-Scores and Percentiles for Body Mass Index (BMI)

			BMI percentile (kg/m^2)												
Gender/ age	n	Mean±SD	L	M	S	3rd	5th	10th	25th	50th	75th	85th	90th	95th	97th
Males															
10	118	18.9±3.4	-0.85	18.45	0.17	13.80	14.26	15.03	16.49	18.45	20.90	22.47	23.66	25.67	27.14
11	128	19.8±3.7	-0.86	19.06	0.17	14.28	14.75	15.54	17.04	19.06	21.58	23.20	24.43	26.49	28.01
12	132	20.1±3.8	-0.85	19.57	0.17	14.68	15.16	15.97	17.51	19.57	22.14	23.78	25.04	27.13	28.67
13	110	20.6±3.6	-0.83	20.07	0.17	15.07	15.57	16.40	17.97	20.07	22.68	24.34	25.60	27.71	29.25
14	141	21.4±4.1	-0.80	20.53	0.17	15.45	15.95	16.80	18.40	20.53	23.14	24.81	26.07	28.15	29.68
15	105	21.0±3.3	-0.74	20.84	0.17	15.72	16.23	17.09	18.71	20.84	23.44	25.08	26.31	28.33	29.79
16	93	21.8±4.1	-0.68	21.15	0.16	16.00	16.52	17.39	19.02	21.15	23.72	25.33	26.52	28.47	29.87
17	108	22.2±3.4	-0.63	21.45	0.16	16.29	16.82	17.69	19.33	21.45	23.98	25.54	26.69	28.57	29.92
18	86	21.6±3.4	-0.61	21.67	0.16	16.56	17.09	17.96	19.57	21.67	24.14	25.67	26.79	28.60	29.88
19	92	22.6±3.7	-0.62	22.01	0.15	16.94	17.47	18.33	19.94	22.01	24.45	25.95	27.05	28.83	30.08
Females															
10	108	17.7±2.4	-0.94	17.48	0.15	13.65	14.04	14.68	15.89	17.48	19.40	20.62	21.53	23.03	24.11
11	110	18.9±3.3	-0.93	18.27	0.15	14.21	14.62	15.30	16.58	18.7	20.33	21.63	22.60	24.21	25.38
12	96	19.4±3.5	-0.93	19.03	0.15	14.77	15.20	15.91	17.26	19.03	21.20	22.56	23.59	25.29	26.52
13	124	20.4±3.1	-0.94	19.75	0.15	15.36	15.80	16.54	17.92	19.75	21.99	23.40	24.46	26.22	27.49
14	107	20.8±3.4	-1.00	20.20	0.15	15.78	16.23	16.97	18.36	20.20	22.46	23.89	24.97	26.75	28.06
15	88	20.5±3.0	-1.12	20.46	0.15	16.11	16.55	17.27	18.64	20.46	22.71	24.15	25.25	27.07	28.42
16	96	21.5±3.2	-1.31	20.67	0.14	16.42	16.84	17.54	18.88	20.67	22.92	24.38	25.49	27.39	28.81
17	99	21.2±3.5	-1.54	20.68	0.14	16.57	16.97	17.64	18.93	20.68	22.91	24.39	25.54	27.52	29.04
18	67	21.2±3.6	-1.78	20.60	0.14	16.64	17.02	17.66	18.90	20.60	22.82	24.31	25.50	27.59	29.23
19	115	21.3±3.5	-2.03	20.54	0.14	16.72	17.08	17.69	18.88	20.54	22.74	24.26	25.49	27.70	29.50

The LMS parameters are the skewness (L), median (M), and coefficient of variation (S).

Table 2-2. LMS Parameters for Z-Scores and Percentiles for Body Composition Indices among Adolescents Aged 10–19 Years: parameters for Z-Scores and Percentiles for Percent Body Fat (PBF)

			PBF percentile (%)												
Gender/ age	n	Mean±SD	L	M	S	3rd	5th	10th	25th	50th	75th	85th	90th	95th	97th
Males															
10	118	28.2±8.0	0.44	28.00	0.29	14.87	16.27	18.55	22.76	28.00	33.86	37.26	39.67	43.40	45.92
11	128	28.1±8.3	0.37	26.88	0.31	14.03	15.36	17.56	21.66	26.88	32.82	36.33	38.83	42.74	45.40
12	132	26.7±8.4	0.30	25.18	0.32	12.97	14.20	16.26	20.15	25.18	31.04	34.54	37.07	41.05	43.79
13	110	23.7±7.7	0.24	22.96	0.33	11.74	12.85	14.71	18.27	22.96	28.51	31.88	34.33	38.22	40.92
14	141	21.9±7.7	0.18	20.92	0.33	10.72	11.71	13.38	16.61	20.92	16.11	29.30	31.63	35.38	37.99
15	105	20.0±6.8	0.12	19.69	0.33	10.23	11.14	12.67	15.66	19.69	24.61	27.67	29.92	33.57	36.14
16	93	20.7±7.1	0.06	19.43	0.33	10.31	11.18	12.65	15.53	19.43	24.25	27.28	29.53	33.18	35.78
17	108	20.7±6.3	0.01	19.46	0.32	10.57	11.41	12.84	15.64	19.46	24.21	27.21	29.45	33.12	35.73
18	86	20.3±6.1	-0.05	19.27	0.32	10.71	11.52	12.90	15.58	19.27	23.88	26.82	29.03	35.65	35.25
19	92	19.8±6.4	-0.11	18.87	0.31	10.73	11.49	12.80	15.35	18.87	23.30	26.15	28.30	31.84	34.41
Females															
10	108	30.3±5.4	0.92	29.99	0.20	18.93	20.29	22.41	25.98	29.99	34.04	36.24	37.73	39.95	41.40
11	110	30.2±6.3	0.91	29.95	0.20	19.05	20.40	22.48	25.99	29.95	33.95	36.11	37.59	39.78	41.21
12	96	29.3±6.2	0.88	30.09	0.19	19.44	20.74	22.77	26.21	30.09	34.04	36.18	37.63	39.81	41.22
13	124	30.7±6.1	0.79	30.80	0.19	20.42	21.67	23.63	26.98	30.80	34.72	36.87	38.33	40.53	41.97
14	107	32.6±5.6	0.65	31.71	0.18	21.70	22.88	24.74	27.97	31.71	35.61	37.77	39.25	41.49	42.97
15	88	32.0±5.1	0.49	32.31	0.17	22.74	23.85	25.61	28.68	32.31	36.16	38.32	39.81	42.08	43.59
16	96	33.3±5.4	0.37	32.79	0.17	23.49	24.55	26.24	29.23	32.79	36.61	38.77	40.28	42.59	44.13
17	99	33.3±5.0	0.32	32.95	0.17	23.73	24.78	26.45	29.41	32.95	36.77	38.94	40.46	42.79	44.34
18	67	33.3±6.1	0.36	32.69	0.17	23.40	24.46	26.14	29.13	32.69	36.51	38.68	40.19	42.50	44.04
19	115	32.1±5.8	0.46	32.05	0.17	22.65	23.73	25.45	28.47	32.05	35.85	37.98	39.46	41.72	43.22

The LMS parameters are the skewness (L), median (M), and coefficient of variation (S).

Table 2-3. LMS Parameters for Z-Scores and Percentiles for Body Composition Indices among Adolescents Aged 10–19 Years: Parameters for Z-Scores and Percentiles for Fat Mass Index (FMI)

			FMI percentile (kg/m^2)												
Gender/ age	n	Mean±SD	L	M	S	3rd	5th	10th	25th	50th	75th	85th	90th	95th	97th
Males															
10	118	5.5±2.5	-0.02	5.11	0.46	2.18	2.43	2.86	3.76	5.11	6.95	8.21	9.19	10.87	12.13
11	128	5.7±2.7	-0.07	5.03	0.46	2.16	2.39	2.81	3.69	5.03	6.90	8.20	9.22	11.00	12.35
12	132	5.6±2.7	-0.11	4.81	0.47	2.07	2.29	2.69	3.52	4.81	6.65	7.95	8.98	10.80	12.21
13	110	5.0±2.4	-0.14	4.47	0.48	1.93	2.13	2.49	3.27	4.47	6.21	7.46	8.46	10.25	11.65
14	141	4.9±2.6	-0.17	4.15	0.48	1.80	1.99	2.32	3.03	4.15	5.77	6.95	7.91	9.62	10.97
15	105	4.3±2.1	-0.19	3.97	0.47	1.75	1.92	2.24	2.91	3.97	5.51	6.64	7.55	9.21	10.51
16	93	4.7±2.5	-0.20	4.00	0.46	1.79	1.97	2.28	2.95	4.00	5.52	6.63	7.53	9.16	10.45
17	108	4.7±2.1	-0.21	4.08	0.45	1.86	2.04	2.36	3.03	4.08	5.59	6.68	7.57	9.16	10.42
18	86	4.5±2.0	-0.21	4.09	0.44	1.91	2.09	2.4	3.07	4.09	5.57	6.62	7.47	9.00	10.20
19	92	4.6±2.2	-0.22	4.08	0.43	1.94	2.12	2.43	3.08	4.08	5.51	6.52	7.34	8.80	9.93
Females															
10	108	5.4±1.6	0.03	5.19	0.34	2.74	2.98	3.37	4.13	5.19	6.50	7.33	7.95	8.97	9.70
11	110	5.8±2.2	0.04	5.39	0.33	2.85	3.09	3.50	4.30	5.39	6.75	7.61	8.25	9.30	10.05
12	96	5.8±2.1	0.05	5.64	0.33	3.00	3.25	3.67	4.50	5.64	7.04	7.92	8.58	9.65	10.42
13	124	6.3±2.1	0.01	5.99	0.32	3.26	3.52	3.96	4.82	5.99	7.45	8.37	9.05	10.17	10.96
14	107	6.9±2.1	-0.05	6.34	0.31	3.56	3.83	4.27	5.14	6.34	7.83	8.78	9.49	10.65	11.49
15	88	6.6±1.9	-0.15	6.57	0.30	3.83	4.08	4.52	5.39	6.57	8.07	9.04	9.77	10.98	11.85
16	96	7.2±2.2	-0.25	6.76	0.29	4.04	4.30	4.73	5.58	6.76	8.27	9.26	10.01	11.27	12.20
17	99	7.1±2.2	-0.34	6.78	0.29	4.12	4.37	4.79	5.62	6.78	8.30	9.30	10.08	11.39	12.37
18	67	7.2±2.5	-0.40	6.66	0.29	4.07	4.31	4.71	5.52	6.66	8.17	9.18	9.96	11.31	12.33
19	115	6.9±2.3	-0.45	6.46	0.29	3.95	4.18	4.57	5.34	6.46	7.94	8.95	9.73	11.10	12.15

The LMS parameters are the skewness (L), median (M), and coefficient of variation (S).

Table 2-4. LMS Parameters for Z-Scores and Percentiles for Body Composition Indices among Adolescents Aged 10–19 Years: Parameters for Z-Scores and Percentiles for Fat Free Mass Index (FFMI)

			FFMI percentile (kg/m^2)												
Gender/ age	n	Mean±SD	L	M	S	3rd	5th	10th	25th	50th	75th	85th	90th	95th	97th
Males															
10	118	13.2±1.3	-0.64	13.12	0.10	10.94	11.18	11.57	12.26	13.12	14.08	14.64	15.05	15.68	16.11
11	128	13.9±1.5	-0.37	13.72	0.11	11.30	11.57	12.01	12.78	13.72	14.77	15.37	15.80	16.74	16.92
12	132	14.4±1.7	-0.09	14.41	0.11	11.72	12.03	12.51	13.38	14.41	15.54	16.18	16.63	17.33	17.79
13	110	15.3±1.9	0.17	15.24	0.11	12.26	12.61	13.15	14.11	15.24	16.44	17.12	17.95	18.31	18.79
14	141	16.3±1.8	0.37	15.99	0.11	12.79	13.17	13.76	14.79	15.99	17.24	17.94	18.42	19.16	19.64
15	105	16.4±1.6	0.54	16.47	0.11	13.14	13.54	14.16	15.24	16.47	17.76	18.46	18.95	19.68	20.16
16	93	16.8±2.0	0.63	16.80	0.11	13.38	13.79	14.44	15.54	16.80	18.09	18.80	19.29	20.02	20.50
17	108	17.2±1.9	0.62	17.03	0.11	13.59	14.01	14.65	15.76	17.03	18.33	19.04	19.53	20.27	20.75
18	86	17.0±2.0	0.53	17.23	0.11	13.82	14.23	14.87	15.97	17.23	18.54	19.26	19.76	20.50	21.00
19	92	17.7±1.9	0.40	17.55	0.11	14.17	14.57	15.20	16.28	17.55	18.87	19.60	20.10	20.87	21.37
Females															
10	108	12.2±1.2	-0.53	12.13	0.10	10.06	10.29	10.66	11.32	12.13	13.03	13.56	13.93	14.52	14.92
11	110	12.9±1.5	-0.73	12.74	0.11	10.59	10.82	11.20	11.88	12.74	13.70	14.27	14.68	15.32	15.77
12	96	13.4±1.7	-0.94	13.25	0.11	11.04	11.28	11.66	12.36	13.25	14.26	14.86	15.30	16.00	16.49
13	124	13.9±1.4	-1.14	13.57	0.10	11.37	11.60	11.98	12.68	13.57	14.60	15.23	15.69	16.43	16.95
14	107	13.7±1.4	-1.32	13.67	0.10	11.50	11.73	12.10	12.79	13.67	14.70	15.34	15.81	16.56	17.10
15	88	13.7±1.3	-1.49	13.71	0.10	11.58	11.80	12.16	12.84	13.71	14.74	15.38	15.86	16.63	17.19
16	96	14.2±1.7	-1.62	13.77	0.10	11.66	11.88	12.24	12.91	13.77	14.81	15.45	15.93	16.72	17.30
17	99	13.9±1.5	-1.69	13.78	0.10	11.69	11.91	12.26	12.92	13.78	14.81	15.46	15.94	16.74	17.32
18	67	13.9±1.5	-1.72	13.82	0.10	11.74	11.96	12.31	12.97	13.82	14.85	15.50	15.98	16.78	17.36
19	115	14.2±1.5	-1.73	13.93	0.10	11.84	12.06	12.41	13.07	13.93	14.96	15.61	16.09	16.89	17.47

The LMS parameters are the skewness (L), median (M), and coefficient of variation (S).

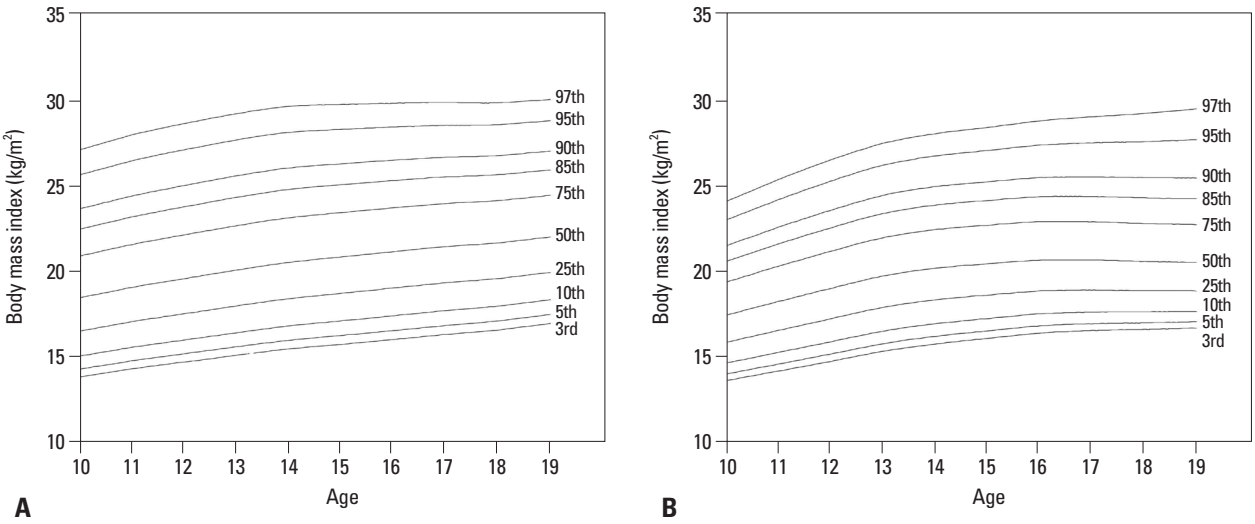

Fig. 1. Smoothed LMS percentile curves for body mass index in both genders. Curves are for the 3rd, 5th, 10th, 25th, 50th, 75th, 85th, 90th, 95th, and 97th percentiles for body mass index (kg/m^2) in male (A) and female (B) adolescents. The LMS parameters are the skewness (L), median (M), and coefficient of variation (S).

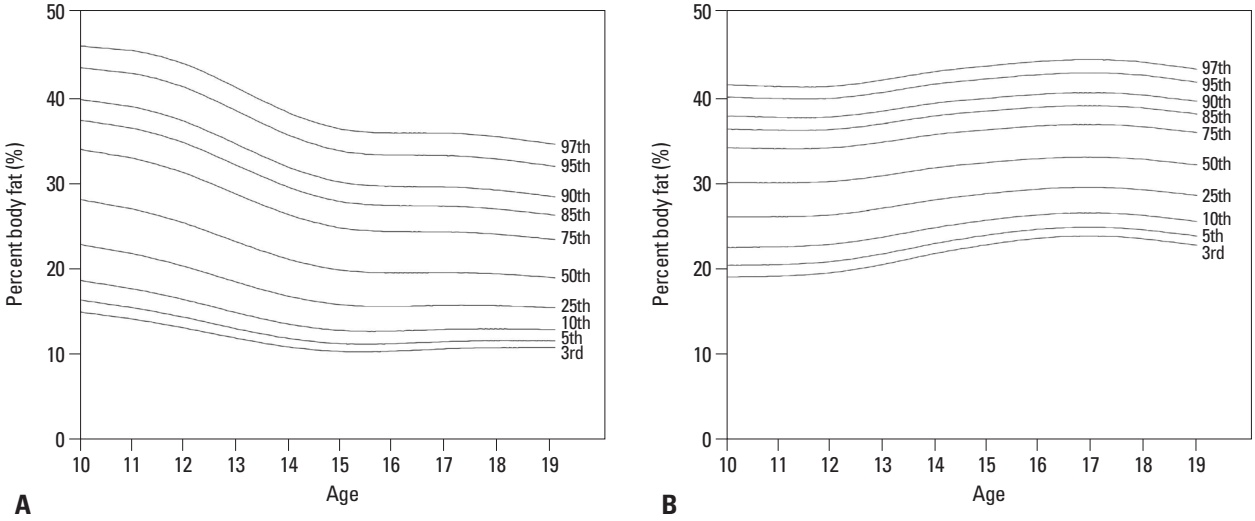

Fig. 2. Smoothed LMS percentile curves for percent body fat in both genders. Curves are for the 3rd, 5th, 10th, 25th, 50th, 75th, 85th, 90th, 95th, and 97th percentiles for percent body fat (%) in male (A) and female (B) adolescents. The LMS parameters are the skewness (L), median (M), and coefficient of variation (S).

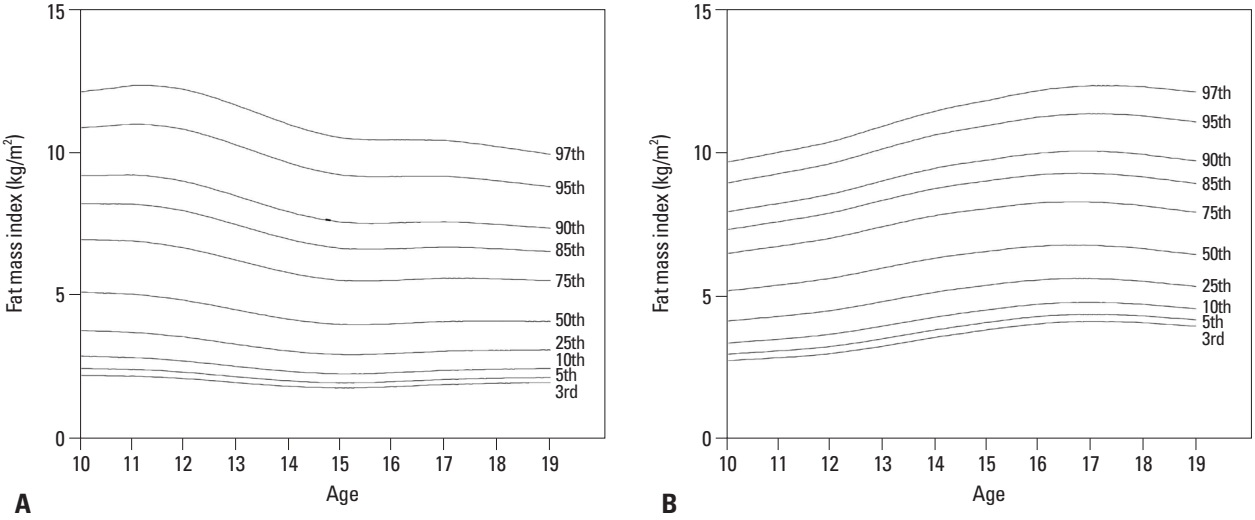

Fig. 3. Smoothed LMS percentile curves for fat mass index in both genders. Curves are for the 3rd, 5th, 10th, 25th, 50th, 75th, 85th, 90th, 95th, and 97th percentiles for fat mass index (kg/m^2) in male (A) and female (B) adolescents. The LMS parameters are the skewness (L), median (M), and coefficient of variation (S).

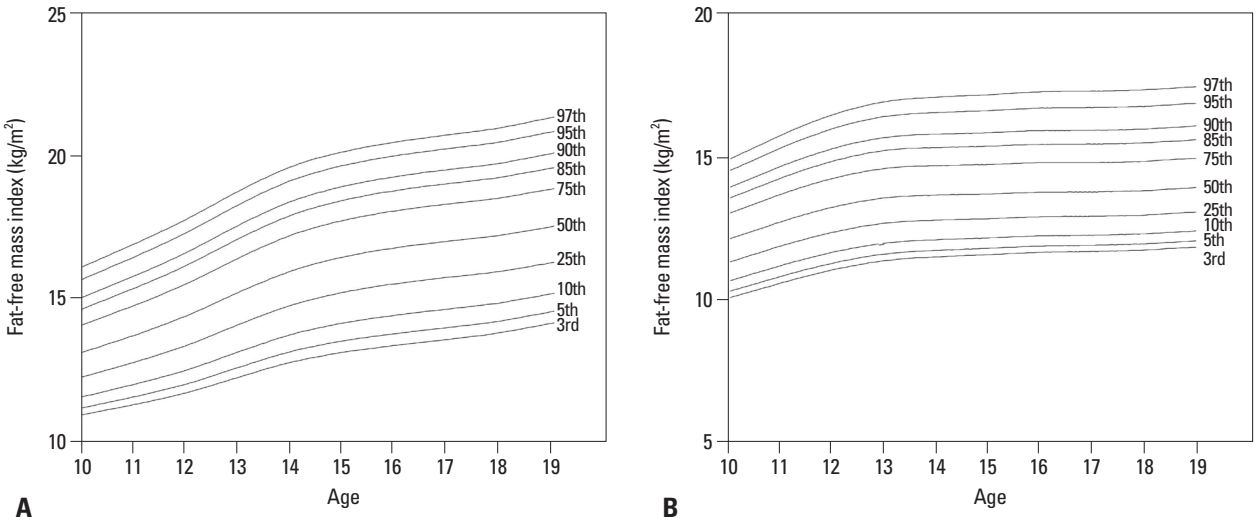

Fig. 4. Smoothed LMS percentile curves for fat-free mass index in both genders. Curves are for the 3rd, 5th, 10th, 25th, 50th, 75th, 85th, 90th, 95th, and 97th percentiles for fat-free mass index (kg/m^2) in male (A) and female (B) adolescents. The LMS parameters are the skewness (L), median (M), and coefficient of variation (S).

Table 3. Changes in Mean Values of Body Composition at Various Percentiles between the Ages of 10 and 19 Years

Percentile	3rd	5th	10th	25th	50th	75th	85th	90th	95th	97th
Male										
BMI	3.14	3.21	3.3	3.45	3.56	3.55	3.48	3.39	3.16	2.94
PBF	-4.14	-4.78	-5.75	-7.41	-9.13	-10.56	-11.11	-11.37	-11.56	-11.51
FMI	-0.24	-0.31	-0.43	-0.68	-1.03	-1.44	-1.69	-1.85	-2.07	-2.2
FFMI	3.23	3.39	3.63	4.02	4.43	4.79	4.96	5.05	5.19	5.26
Female										
BMI	3.07	3.04	3.01	2.99	3.06	3.34	3.64	3.96	4.67	5.39
PBF	3.72	3.44	3.04	2.49	2.06	1.81	1.74	1.73	1.77	1.82
FMI	1.21	1.2	1.2	1.21	1.27	1.44	1.62	1.78	2.13	2.45
FFMI	1.78	1.77	1.75	1.75	1.8	1.93	2.05	2.16	2.37	2.55

BMI, body mass index; PBF, percent body fat; FMI, fat mass index; FFMI, fat-free mass index.

creases in the higher percentiles of FFMI, compared with lower percentiles (Table 3). Furthermore, the increase in FFMI in males (3.23–5.26 kg/m^2) of 10–19 years of age was approximately twice that in females (1.75–2.55 kg/m^2) at each percentile (Table 3). The changes in PBF between 10- and 19-year-olds showed a greater decrease in males and a smaller increase in females at higher percentiles of PBF (Table 3). The changes in FMI between the ages of 10 and 19 years showed a greater decrease in males and a greater increase in females at higher percentiles of FMI (Table 3).

DISCUSSION

We identified reference values for BMI, FMI, and FFMI of a normal adolescent population aged 10 to 19 years in Korea using data from the KNHANES.

The mean BMI value and the 85th and 90th percentile values on the LMS curve in this study were higher than the BMI values in the 2007 Korean National Growth Chart, which used data of a 2005 national survey.[14] The values of BMI below the 85th percentile showed a tendency to be lower in the present study than those in the 2007 Korean National Growth Chart.[14] The difference between the 3rd percentile and 97th percentiles for BMI were 13.14–14.23 kg/m^2 in this study and 11.28–13.08 kg/m^2 in 2007 for males and 10.46–12.78 kg/m^2 in this study and 9.53–11.24 kg/m^2 in 2007 for females. The polarization, the increased range of BMI values, among children and adolescents in Korea is greater than that in the 2007 report.

During the adolescent period, increases in BMI and FFMI were observed in both genders accompanying growth in height (Figs. 1 and 4). FFMI was higher in males and FMI was higher in females among both genders between the

ages of 10 and 19 years in this study (Table 2-3 and 2-4). Demerath, et al.[15] explained that boys experience greater gains in muscle and lean mass than in fat mass. In adolescents, normal changes in BMI were observed with growth and maturation, and the increase in BMI consisted of a greater increase in FFMI than in FM during the growth process.[11,13,16] Demerath, et al.[15] reported that FFMI was the predominant component of BMI (FFMI was 3–5 times greater than FMI) in both genders. Although greater changes and higher absolute values of FMI were observed in females than in males in the present study, the change in FFMI was also greater than the change in FMI in females (Table 3). In this study, a tendency toward a decrease in PBF among males was observed, accompanying the increases in BMI and FFMI between the ages of 10 and 19 years (Table 3). Schwandt, et al.[17] also reported a decrease in PBF in males, although they observed an increase in PBF in females with increasing age between the ages of 10 and 19 years. Park, et al.[18] reported that the differences in FMI and FFMI between genders became marked with acceleration of FFM gain in 6th grade Korean boys (13 years of age). In the present study, the differential changes in FMI by gender started around 13 years of age (Fig. 3), and greater changes in FFMI were observed in males between the ages of 12 and 14 years (1.58 kg/m^2 at the 50th percentile). Demerath, et al.[15] reported a tendency for FMI to increase dramatically only at higher BMI values. We could not evaluate the relationship between BMI and FMI; however, greater changes in FMI were observed in males (a greater decrease) and females (a greater increase) at higher FMI percentiles.

BMI is known as an indicator of adiposity; however, both FMI and FFMI affect BMI, making it impossible to differentiate body fat from lean mass using BMI alone.[9,10] Previously, gender and age were reported as affecting the relationship between BMI percentile and body composition indices (including FMI and FFMI), although changes in BMI percentile did not reflect changes in adiposity with increasing age, especially in males and children with lower BMI.[15] In the present study, decreases in FMI and PBF were observed despite increases in BMI, and a large increase in FFMI was observed in males. Thus, an increase in BMI was observed in both genders during the adolescent period along with remarkable growth in height and weight. Although Lindsay, et al.[19] reported that BMI showed a strong relationship with fat mass and BMI in adolescence was also related adiposity in adulthood, it is necessary to consider normal growth in evaluating obesity according to BMI in adolescents. The independent role of FFMI, as well as PBF and FMI, in predicting metabolic syndrome has been reported;[20,21] however, few reports have presented reference values for FMI and FFMI, with most focusing on PBF and BMI in the adolescent population.[14,17,22-26] Mooney, et al.[27] suggested the extremely low FFMI reflects advanced metabolic disease, and Park, et al.[28] reported that lower FFMI combined with higher FMI could indicate insufficient insulin secretion in diabetes. We suggest the use of percentile values for body composition indices in evaluating obesity or metabolic dysregulation, as the combination of decreased FFMI and increased FMI could also reflect metabolic dysregulation, as could an increase in the absolute value of FMI, especially in adolescence, when remarkable changes in body composition occur with growth. Moreover, higher body fat percentiles in Asians have been shown to be associated with decreased insulin sensitivity.[29]

The mean PBF values of children and adolescents in Korea were lower than those of children and adolescents in the US.[26] Although PBF values of children and adolescents in Germany[30] and in Turkey[24] were lower than those in Koreans, the PBF values of Germans were measured by different methods with bioelectrical impedance analysis. In the study by Ehtisham, et al.,[29] the BMI and PBF values in Asian adolescents of other regions, including Indians, Pakistanis, Bangladeshis, and Sri Lankans, were higher than those of white European (United Kingdom) adolescents. However, the BMI values between the ages of 14 and 17 years in this study (Table 2-1) were comparable or slightly lower than those in white European adolescents, although PBF values were higher.[29] Likewise, in the results of this study, Korean adolescents showed lower BMI and higher PBF, compared with Europeans, as did Asian adults in the study by Wang, et al.[31]

The 2007 Korean National Growth Chart[14] presented reference values for body weight, height, and BMI; however, there were no reference values for body composition indices. The proper acquisition of body composition during the adolescent period and the prevention of increases in PBF and BMI are necessary to reduce the risk of metabolic disease. Many children and adolescents at risk of metabolic syndrome cannot be detected when clinicians use only BMI percentile as a screening tool, especially in Asians with lower BMI and higher PBF. Accordingly, the percentile values of each body composition index, according to age and gender, could be helpful for evaluating body composition distribution in adolescents.

Some limitations of this study need to be addressed. We did not apply the survey sample weight to estimate percentile curves. This was a cross-sectional study. Despite these limitations the strength of current study is that a relatively large number of children and adolescent data, nationally representative data set from KNHANES, and body composition data measured by DXA with high quality were analyzed.

In conclusion, the percentiles for body composition indices for Korean adolescents aged 10–19 years from 2008 to 2011 were provided. The reference values from this study could help with the assessment of body composition in Korean adolescents.

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