Body Composition in Japanese Girls with Adolescent Idiopathic Scoliosis

Masayuki Miyagi[1], Wataru Saito[1], Takayuki Imura[1], Toshiyuki Nakazawa[1], Eiki Shirasawa[1], Ayumu Kawakubo[1], Kentaro Uchida[1], Tsutomu Akazawa[2], Kazuhide Inage[3], Seiji Ohtori[3], Gen Inoue[1] and Masashi Takaso[1]

1) Department of Orthopaedic Surgery, School of Medicine, Kitasato University, Sagamihara, Japan
2) Department of Orthopaedic Surgery, St. Marianna University School of Medicine, Kawasaki, Japan
3) Department of Orthopaedic Surgery, Graduate School of Medicine, Chiba University, Chiba, Japan

Abstract:

Introduction: There are few reports on body composition, particularly muscle mass, in patients with adolescent idiopathic scoliosis (AIS). The purpose of this study was to measure body composition including muscle mass and estimated bone mass of patients with AIS using bioelectrical impedance analysis (BIA) and to clarify the relationship between the degree of scoliosis and body composition.

Methods: The subjects were 210 girls (mean age 14.0 years, range 10-18 years) whose body composition was evaluated using BIA (Tanita MC-780). Body mass index (BMI), percent body fat (%BF), lean muscle mass index (LMI: muscle mass/height^2), and estimated bone mass index (eBoneMI: estimated bone mass/height^2) were determined by age and compared with those of previous reports. We divided 111 subjects whose bone maturation was complete into two groups for comparison of body composition metrics: those with Cobb angle <40° (moderate scoliosis group) and those with Cobb angle ≥40° (severe scoliosis group). The relationships between Cobb angle and each body composition parameter were evaluated.

Results: Age-adjusted BMI, %BF, and LMI tended to be low at all ages compared with means for the healthy Japanese population as previously reported. BMI, LMI, and eBoneMI were significantly lower in the severe scoliosis group compared with those in the moderate scoliosis group ($p<0.05$). In addition, all BMI, LMI, and eBoneMI were weakly correlated with Cobb angle ($r= -0.20, -0.26$, and -0.24).

Conclusions: On the basis of the results of this study, patients with AIS are thinner, with lower BMI, %BF, and LMI compared with healthy girls of the same age. Furthermore, factors such as lower BMI, lower muscle mass, and lower estimated bone mass were correlated with progressive scoliosis.

Keywords:

Adolescent idiopathic scoliosis, Muscle mass, Bioelectrical impedance analysis

Spine Surg Relat Res 2021; 5(2): 68-74
dx.doi.org/10.22603/ssrr.2020-0088

Introduction

Adolescent idiopathic scoliosis (AIS) is the most common type of scoliosis, especially affecting females from 10 to 18 years old. An estimated prevalence rate of 1-3% has been reported for children[1]. In Japan, our previous epidemiologic study reported an estimated prevalence rate of 0.87% in schoolchildren aged 11-14 years[2]. There are many theories about the factors that might affect the onset and progression of AIS, including hormonal imbalances[3,4] and mechanical factors[5]. However, the cause of AIS still remains unclear. Recently, specific genes, including LBX1[6], BNC2[7], and GPR126[8], have been implicated in the etiology of AIS. Patients with AIS are usually thin girls. Several authors have reported many patients with AIS with osteopenia[9-14]. However, there are few reports on body composition, particularly muscle mass.

To evaluate bone and muscle mass, dual-energy X-ray absorptiometry (DXA) is usually used, but there are some concerns including radiation exposure and availability of the equipment. On the other hand, bioelectrical impedance analysis (BIA), which can determine muscle mass and esti-

Corresponding author: Masayuki Miyagi, masayuki008@aol.com
Received: May 9, 2020, Accepted: July 21, 2020, Advance Publication: August 31, 2020

mated bone mass, is emerging as a popular alternative to DXA due to its easy installation and superior cost-effectiveness. Further, muscle mass measured by BIA has been reported to correlate strongly with results using DXA[15].

The purpose of this study was to measure body composition including muscle mass and estimated bone mass of patients with AIS using the BIA method and to clarify the relationship between the degree of scoliosis and body composition.

Materials and Methods

Ethical approval from our Institutional Review Board was obtained for this study, which was conducted in accordance with the ethical principles specified in the 1964 Declaration of Helsinki and its later amendments.

Patient population

Two hundred ten consecutive girls (mean age 14.0 years, range 10-18 years) with AIS seen at our institute from July 2016 to March 2018 were included in the current study. The diagnosis of AIS was confirmed clinically and radiologically using a standing frontal view of the whole spine and defined by a Cobb angle >10°. Subjects with a history of connective tissue abnormalities, neuromuscular diseases, mental retardation, or any other congenital spinal deformities were excluded.

Radiographic measurements

In addition to the Cobb angle, we also measured the degree of ossification of the iliac apophysis by X-ray, evaluating for the Risser sign, a 5-point staging scale for assessing bone maturation. We measured three parts of scoliosis curve including proximal thoracic (PT) curve, main thoracic (MT) curve, and thoracolumbar/lumbar (TL/L) curve. Then, the scoliosis curve with the greatest magnitude of Cobb angle is defined as the major curve, and we chose the Cobb angle of the major curve as the Cobb angle. Further, we reviewed menarcheal status from the medical records as another criterion for bone maturation.

Body composition measurements

In our institute, we measured body composition in all patients with AIS at every visit to our institute from July 2016. In the present study, we collected retrospective data at the first time measurement of body composition. All patients underwent BIA (MC-780A; TANITA, Tokyo, Japan) measurements at our institute for assessment of body composition at the same day of radiographic measurements. We calculated body composition parameters as follows:

- Body mass index (BMI): defined as the body weight divided by the square of the body height (kg/m^2).
- Percent body fat (%BF): defined as the body fat mass divided by body weight (%).
- Lean muscle mass index (LMI): corrected lean muscle mass defined as lean muscle mass divided by the square of the body height (kg/m^2).
- Estimated bone mass index (eBoneMI): corrected estimated bone mass defined as estimated bone mass divided by the square of the body height (kg/m^2).

Body height was adjusted by using the largest Cobb angle to correct for scoliosis (Bjure's formula), as previously reported[16].

Degree of scoliosis and body composition

In a second analysis, 111 subjects whose bone maturation was completed were included to evaluate characteristics in patients with severe scoliosis. We considered completed bone maturation as Risser stage 5 or Risser stage 4 plus 2 years after menarche. The 111 subjects were divided into two groups: patients whose Cobb angle was <40° (moderate scoliosis group), and patients whose Cobb angle was ≥40° (severe scoliosis group). BMI, %BF, LMI, and eBoneMI were compared between groups. To evaluate the relationships between the degree of scoliosis and body composition, we analyzed correlations between Cobb angle and each body composition parameter. Further, to evaluate the differences in patient characteristics due to the curve patterns of scoliosis, we divided the patients into two groups based on their curve patterns: patients with PT or MT curve, in which PT curve or MT curve is the major curve of scoliosis, and patients with TL/L curve, in which TL/L curve is the major curve of scoliosis. We then performed a subanalysis to compare the BMI, %BF, LMI, and eBoneMI between the moderate scoliosis group and severe scoliosis group.

Statistical analysis

The comparisons of body composition parameters between moderate and severe scoliosis groups were performed using Student's t-tests. A p-value <0.05 was considered significant. Correlations between Cobb angle and body composition parameters were evaluated using Pearson's correlation coefficients. Correlation coefficients between 0.20 and 0.40 were considered weak, those between 0.40 and 0.70 were considered moderate, and those between 0.70 and 1.00 were considered high.

Results

Body composition in AIS girls by age

Table 1 shows Cobb angles and body composition parameters by age. BMI and %BF gradually increased by age, except for 14-year-old girls. On the other hand, LMI and eBoneMI gradually increased until 14 years old, but increase stopped in girls ≥15 years.

Degree of scoliosis and body composition

Table 2 shows the mean age, Cobb angle, and body composition parameters of 111 subjects whose bone maturation was completed.

Table 1. Cobb Angle and Body Composition Parameters by Age.

years	N	Cobb Angle		BMI		% BF		LMI		eBoneMI	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
10	8	24.23	13.04	15.38	1.206	13.65	4.946	12.54	0.582	0.703	0.061
11	19	27.70	10.56	16.49	1.474	16.68	3.771	12.92	0.728	0.770	0.065
12	30	32.13	14.96	17.42	2.386	19.73	5.731	13.07	0.937	0.793	0.092
13	33	29.68	12.47	17.31	1.837	19.02	4.975	13.12	0.738	0.818	0.067
14	36	31.23	11.85	18.98	2.838	23.23	6.377	13.55	0.833	0.851	0.065
15	32	34.61	12.68	18.39	1.855	22.99	4.938	13.26	0.728	0.821	0.074
16	18	33.47	14.17	18.52	1.552	24.00	3.116	13.28	0.93	0.772	0.083
17	21	28.24	12.22	18.89	2.059	24.02	4.084	13.51	1.021	0.780	0.086
18	13	35.55	17.41	19.47	3.331	25.18	6.711	13.58	1.128	0.800	0.107

Table 2. Comparison of Cobb Angle and Body Composition Parameters in Adolescent Japanese Girls with Moderate Versus Severe Idiopathic Scoliosis Whose Bone Maturation was Completed.

	Total (N=111)					Thoracic curve (N=58)					Thoracolumbar curve (N=53)				
	Moderate (N=87)		Severe (N=24)		Comp	Moderate (N=44)		Severe (N=14)		Comp	Moderate (N=43)		Severe (N=10)		Comp
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
years	15.34	1.60	15.46	1.72	NS	15.36	1.64	15.21	1.53	NS	15.33	1.57	15.80	1.99	NS
Cobb angle	26.17	8.34	50.14	10.29	*	27.96	8.33	50.27	10.40	*	24.34	8.04	48.21	12.29	*
BMI (kg/m^2)	18.96	2.38	18.00	1.96	*	19.06	2.21	17.88	1.96	NS	18.86	2.56	18.16	1.92	NS
%BF (%)	23.75	5.24	23.07	4.63	NS	23.94	5.03	23.04	4.64	NS	23.55	5.51	23.11	4.86	NS
LMI (kg/m^2)	13.53	0.91	12.99	0.80	*	13.58	0.89	12.91	0.91	*	13.49	0.95	13.10	0.66	NS
eBoneMI (kg/m^2)	0.820	0.084	0.779	0.088	*	0.830	0.082	0.773	0.095	*	0.810	0.086	0.787	0.081	NS

*$p<0.05$, NS: not significant

The BMI was significantly lower in the severe scoliosis group than that in the moderate scoliosis group ($p<0.05$). Additionally, the LMI and eBoneMI were significantly lower in the severe scoliosis group than those in the moderate scoliosis group ($p<0.05$). There was no significant difference in the %BF between the two groups ($p>0.05$). In the comparison of patients with PT or MT curve, the LMI and eBoneMI were significantly lower in the severe scoliosis group than those in the moderate scoliosis group ($p<0.05$). There was no significant difference in the BMI or %BF between the severe scoliosis group and moderate scoliosis group ($p>0.05$). Conversely, in the comparison of patients with TL/L curve, there was no significant difference in any of the body composition parameters between the severe scoliosis group and moderate scoliosis group ($p>0.05$) (Table 2).

A significant ($p<0.05$) weak negative correlation was detected between Cobb angle and BMI ($r= -0.200$; Fig. 1A). Further, LMI and eBoneMI were also significantly and negatively, but weakly, correlated with Cobb angle ($r= -0.268$, $r= -0.242$; Fig. 1C, D). In contrast, %BF was not significantly correlated with Cobb angle Fig. 1B).

Discussion

In Japanese girls with AIS, BMI and %BF gradually increased with age. LMI and eBoneMI increased until age 15 years, after which increases slowed. This is the first report about body composition using the BIA method in Japanese girls with AIS. Several investigators have reported the mean value of body composition parameters using the BIA method in healthy Japanese girls[17-20]. Fig. 2 shows BMI by age in Japanese girls with AIS from the present study and in healthy Japanese girls as previously reported. BMI in Japanese girls with AIS tend to be low at all ages compared with that in healthy Japanese girls[17-20]. Fig. 3 shows %BF by age and Fig. 4 shows LMI by age in Japanese girls with AIS from the present study and healthy Japanese girls as previously reported. %BF and LMI in Japanese girls with AIS also tend to be low at all ages compared with those in healthy Japanese girls[17,19,20]. Tam et al. reported that Chinese girls with AIS had lower BMI, lower muscle mass, and lower body fat compared with healthy controls[21]. Ramirez et al.[22] and Barrios et al.[23] reported low BMI, low body fat, and low estimated muscle mass in Spanish girls with AIS. Further, Watanabe et al. suggested that low BMI might be associated with AIS based on Japanese junior high school students who planned a secondary screening for scoliosis[24]. These studies indicate that low BMI, low %BF, low lean muscle mass, and low estimated bone mass may be a general condition in AIS across different populations including Japanese girls.

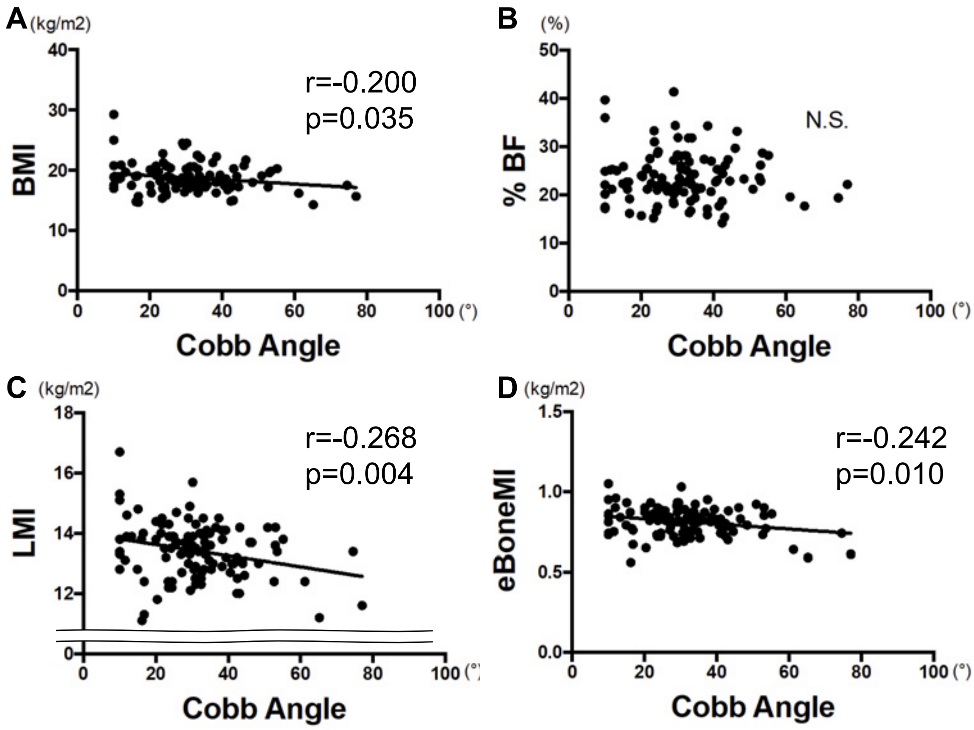

Figure 1. The relationships between the Cobb angle and (A) body mass index (BMI), (B) percent body fat (%BF), (C) lean mass index (LMI), or (D) estimated bone mass index (eBoneMI).
N.S.: Not significant
BMI, LMI, and eBoneMI were significantly but weakly correlated with the Cobb angle.

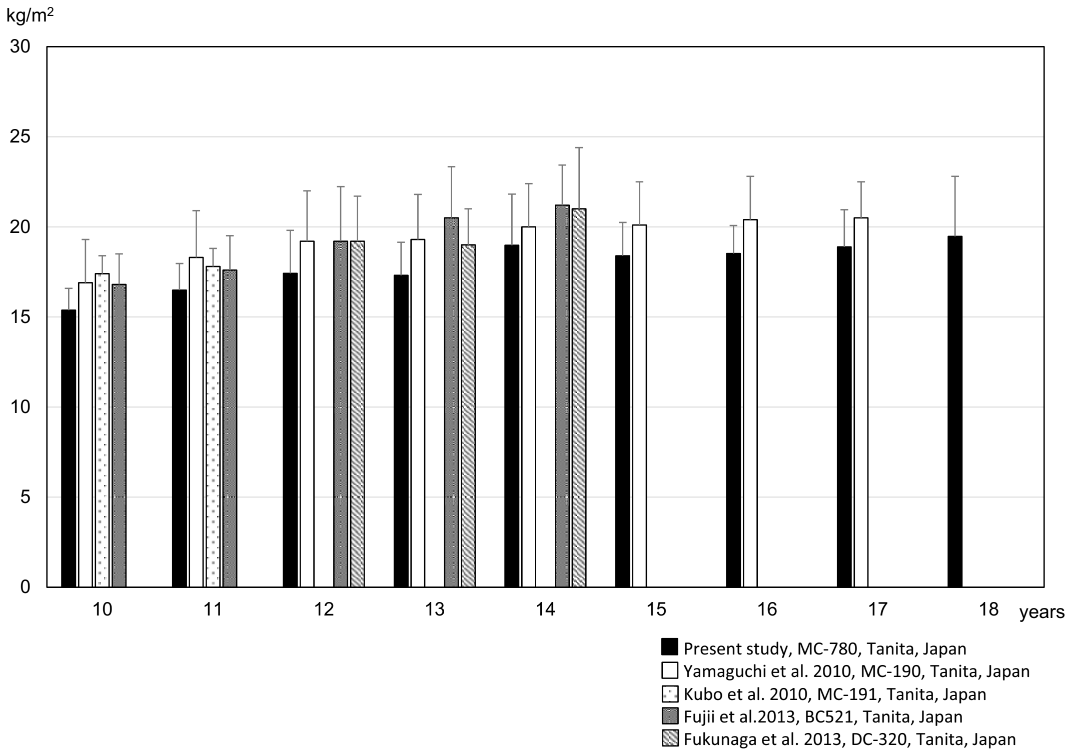

Figure 2. Body mass index (BMI) in adolescent Japanese girls with idiopathic scoliosis (present study) and healthy Japanese girls (previous reports).

In the present study, BMI, LMI, and eBoneMI in patients with AIS with Cobb angle ≥40° were significantly lower than those in patients with AIS with Cobb angle <40°. Lower BMI, LMI, and eBoneMI were correlated with a larger Cobb angle in Japanese girls with AIS. Matusik et al. reported patients with severe scoliosis with Cobb angle ≥40°

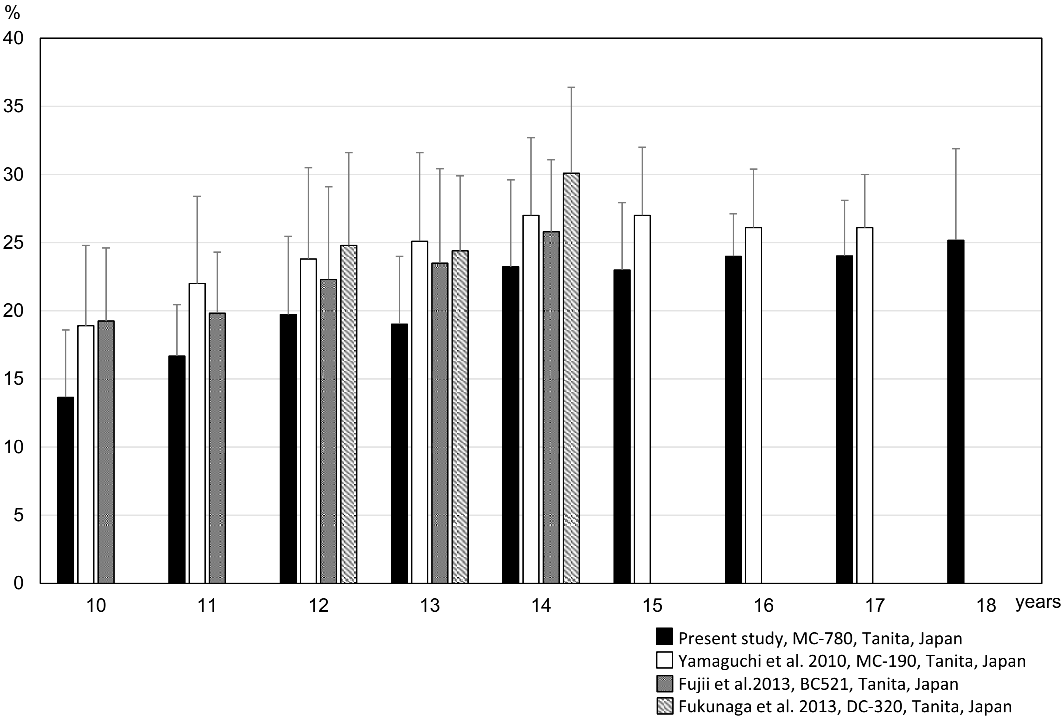

Figure 3. Percent body fat (%BF) in adolescent Japanese girls with idiopathic scoliosis (present study) and healthy Japanese girls (previous reports).

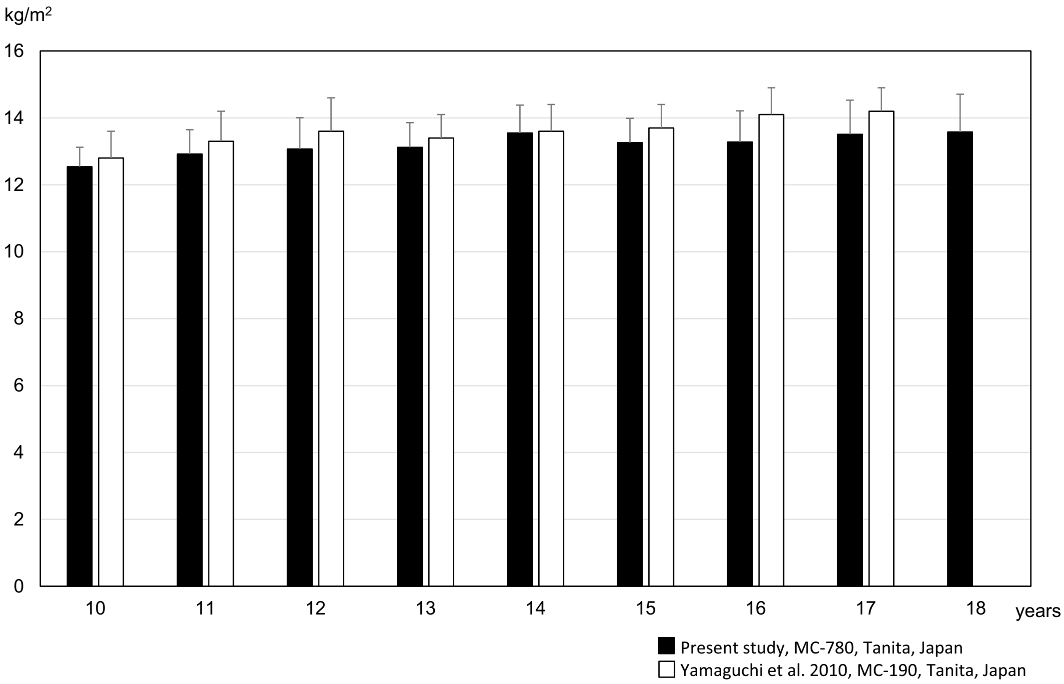

Figure 4. Lean muscle mass index (LMI) in adolescent Japanese girls with idiopathic scoliosis (present study) and healthy Japanese girls (previous report).

had high BMI, high fat mass, and low muscle mass in a European population, suggesting that high fat mass and low muscle mass might be correlated with progressive scoliosis[25]. Regarding the BMI, the discrepancy with the present study suggested that this aspect of body composition in AIS girls may vary by race. In addition, low BMI in patients with severe scoliosis might be specific for Japanese girls. However, AIS girls with severe scoliosis had low muscle mass in both studies, indicating that at least low muscle mass might be associated with scoliosis severity across populations. Interventions based on new aims such as muscle training might be effective for prevention of progressive scoliosis.

Our analysis of the differences in patient characteristics due to the curve patterns of scoliosis showed that the muscle mass and estimated bone mass were low in the severe scoliosis group than those in the moderate scoliosis group among patients with PT or MT of scoliosis but not in patients with TL/L curve of scoliosis. No reports have described the differences in patients' body composition characteristics due to the curve patterns of scoliosis. These findings at least indicate that patients with severe scoliosis characterized by PT or MT curve had low muscle mass and estimated bone mass. However, in patients with TL/L curve, the BMI, muscle mass, and estimated bone mass tended to be lower in those with severe scoliosis than those with moderate scoliosis, although the differences were not statistically significant. A more extensive study is needed.

Several authors have reported that 27-65% of patients with AIS have osteopenia regardless of race or ethnicity[9-14]. In the Japanese population, Ishida et al. reported that 65% of patients with AIS had low bone mineral density and 59% had high bone turnover[14]. However, in these studies, bone mass was evaluated using DXA, which subjects children to radiation. In the present study, the relationship between Cobb angle and estimated bone mass was evaluated by BIA, which does not involve radiation. Although further validation for bone mass evaluated by BIA is needed, BIA might be a useful tool for evaluating bone mass.

There were some limitations to this study. First, because this study is a small cross-sectional study, we could not establish any cause and effect relationships. In addition, there was very weak correlation between Cobb angle and BMI, LMI and eBoneMI. Besides body composition, several factors including age, physical activity, bone maturation, and mensturation status might affect the severity of scoliosis. Therefore, we need larger study samples and other statistical analysis including multivariate analysis. In the future, we would like to conduct a longitudinal study with larger samples study. Second, for the accurate correction of body composition, we needed the body height to be adjusted because degrees of scoliosis affected the error of body height. In the present study, we measured body height at first; then, we measured body composition using measured body height. Finally, when we analyzed body composition data, we corrected body composition by adjusting the body height. This would be normal manner for correction; however, for the accurate correction by body height, we may measure body composition using adjusted body height. There might be some error in the analysis of body composition.

In conclusion, based on the results of this study, patients with AIS are thinner, with lower BMI, %BF, and LMI compared with healthy girls of the same age in a Japanese population. Furthermore, the BMI, the LMI, and eBoneMI were significantly lower in the severe scoliosis group than those in the moderate scoliosis group.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

Ethical Approval: Ethical approval from the Institutional Review Board in Kitasato University was obtained for this study, which was conducted in accordance with the ethical principles specified in the 1964 Declaration of Helsinki and its later amendments. Approval code is B19-321.

Acknowledgement: This investigation was supported in part by JOA-Subsidized Science Project Research 2018-2.

We thank Mr. Makabe, Ms. Arai, Ms. Takakura, and Ms. Yamamoto for their assistance with this study.

Author Contributions: MM drafted the manuscript and participated in the design of the study. WS, TI, and TN participated in its design and coordination and drafted the manuscript. ES, AK, KU, and TA helped to revise the manuscript and carried out statistical analysis. KI and SO helped to revise the manuscript. GI and MT conceived the study and participated in its design and coordination. All authors have read and approved the final manuscript.

References

1. Weinstein SL, Dolan LA, Cheng JC. Adolescent idiopathic scoliosis. Lancet. 2008;371(9623):1527-37.
2. Ueno M, Takaso M, Nakazawa T, et al. A 5-year epidemiological study on the prevalence rate of idiopathic scoliosis in Tokyo: school screening of more than 250,000 children. J Orthop Sci. 2011;16(1):1-6.
3. Willner S, Nilsson KO, Kastrup K, et al. Growth hormone and somatomedin A in girls with adolescent idiopathic scoliosis. Acta Paediatr Scand. 1976;65(5):547-52.
4. Qiu XS, Tang NL, Yeung HY, et al. Genetic association study of growth hormone receptor and idiopathic scoliosis. Clin Orthop Relat Res. 2007;462:53-8.
5. Castelein RM, van Dieën JH, Smit TH. The role of dorsal shear forces in the pathogenesis of adolescent idiopathic scoliosis-a hypothesis. Med Hypotheses. 2005;65(3):501-8.
6. Londono D, Kou I, Johnson TA, et al. A meta-analysis identifies adolescent idiopathic scoliosis association with LBX1 locus in multiple ethnic groups. J Med Genet. 2014;51(6):401-6.
7. Ogura Y, Takeda K, Kou I, et al. An international meta-analysis confirms the association of BNC2 with adolescent idiopathic scoliosis. Sci Rep. 2018;8(1):4730.
8. Xu JF, Yang GH, Pan XH, et al. Association of GPR126 gene polymorphism with adolescent idiopathic scoliosis in Chinese populations. Genomics. 2015;105(2):101-7.
9. Cook SD, Harding AF, Morgan EL, et al. Trabecular bone mineral density in idiopathic scoliosis. J Pediatr Orthop. 1987;7:168-74.
10. Thomas KA, Cook SD, Slalley TC. Lumbar spine and femoral neck bone mineral density in idiopathic scoliosis. A follow up-study. J Pediatr Orthop. 1992;12:235-40.
11. Cheng JCY, Guo X. Osteopenia in adolescent idiopathic scoliosis. A primary problem or secondary to the spinal deformity. Spine. 1997;22:716-21.
12. Chen JCY, Guo X. Persistent osteopenia in adolescent idiopathic scoliosis. A longitudinal follow up study. Spine. 1999;24:1218-22.
13. Hung VWY, Qin L, Cheung CSK, et al. Osteopenia: a new prognostic factor of curve progression in adolescent idiopathic scoliosis. J Bone Joint Surg Am. 2005;87:2709-16.
14. Ishida K, Aota Y, Mitsugi N, et al. Relationship between bone density and bone metabolism in adolescent idiopathic scoliosis.

Scoliosis. 2015;10:9.
15. Fujimoto K, Inage K, Eguchi Y, et al. Use of Bioelectrical Impedance Analysis for the Measurement of Appendicular Skeletal Muscle Mass/Whole Fat Mass and Its Relevance in Assessing Osteoporosis among Patients with Low Back Pain: A Comparative Analysis Using Dual X-ray Absorptiometry. Asian Spine J. 2018;12(5): 839-45.
16. Siu King Cheung C, Tak Keung Lee W, Kit Tse Y, et al. Abnormal peri-pubertal anthropometric measurements and growth pattern in adolescent idiopathic scoliosis: a study of 598 patients. Spine (Phila Pa 1976). 2003;28(18):2152-7.
17. Yamaguchi I, Miyama T, Nishizawa M, et al. Comparison of Age-related Changes in Body Composition of Children Between England and Japan. Journal of Japan Society for the Study of Obesity. 2010;Suppl:153. [In Japanese]
18. Kubo T, Suzuki K, Mimura Y, et al. Evaluation of partial body composition using bioelectrical impedance in Japanese children. Asia Pac J Clin Nutr. 2010;19(4):594-601.
19. Fujii K, Tanaka N, Mishima T. Verification regarding changing construction in accumulation of fat for BMI based on change with age estimated from body composition balance. J Hum Ergol (Tokyo). 2013;42(1-2):31-44.
20. Fukunaga Y, Takai Y, Yoshimoto T, et al. Influence of maturation on anthropometry and body composition in Japanese junior high school students. J Physiol Anthropol. 2013;32(1):5.
21. Tam EM, Liu Z, Lam TP, et al. Lower Muscle Mass and Body Fat in Adolescent Idiopathic Scoliosis Are Associated With Abnormal Leptin Bioavailability. Spine (Phila Pa 1976). 2016;41(11):940-6.
22. Ramírez M, Martínez-Llorens J, Sanchez JF, et al. Body composition in adolescent idiopathic scoliosis. Eur Spine J. 2013;22(2): 324-9.
23. Barrios C, Cortés S, Pérez-Encinas C, et al. Anthropometry and body composition profile of girls with nonsurgically treated adolescent idiopathic scoliosis. Spine (Phila Pa 1976). 2011;36(18): 1470-7.
24. Watanabe K, Michikawa T, Yonezawa I, et al. Physical Activities and Lifestyle Factors Related to Adolescent Idiopathic Scoliosis. J Bone Joint Surg Am. 2017;99(4):284-94.
25. Matusik E, Durmala J, Matusik P. Association of Body Composition with Curve Severity in Children and Adolescents with Idiopathic Scoliosis (IS). Nutrients. 2016;8(2):71.