Open Journal of Orthopedics, 2026, 16(3), 89-101
https://www.scirp.org/journal/ojo
ISSN Online: 2164-3016
ISSN Print: 2164-3008

Development of an Objective Method for Evaluating Waistline Asymmetry in Adolescent Idiopathic Scoliosis

Mami Sugano, Kazu Kobayakawa*, Soichiro Sakai, Kazuya Yokota, Kiyoshi Tarukado, Keiichiro Iida, Hirokazu Saiwai, Kenichi Kawaguchi, Yasuharu Nakashima

Department of Orthopaedic Surgery, Kyushu University, Fukuoka City, Japan
Email: *kobayakawa.kazu.000@m.kyushu-u.ac.jp

How to cite this paper: Sugano, M., Kobayakawa, K., Sakai, S., Yokota, K., Tarukado, K., Iida, K., Saiwai, H., Kawaguchi, K. and Nakashima, Y. (2026) Development of an Objective Method for Evaluating Waistline Asymmetry in Adolescent Idiopathic Scoliosis. *Open Journal of Orthopedics*, **16**, 89-101.
https://doi.org/10.4236/ojo.2026.163010

Received: January 23, 2026
Accepted: February 27, 2026
Published: March 2, 2026

Abstract

Purpose: Quantitative evaluation of appearance deformation is important for patients with adolescent idiopathic scoliosis (AIS), in whom the accompanying appearance deformation, such as waistline asymmetry, can affect psychology. This study was conducted to develop an objective method to evaluate waistline asymmetry in patients with AIS and to investigate the factors affecting waistline asymmetry before and after surgery. *Methods:* This study included 35 patients who underwent posterior spinal fusion for idiopathic scoliosis at our institute between March 2020 and October 2021. The left-right difference in the waist area was measured for each patient from X-ray images, and the value corrected for the entire waist area was defined as the waistline asymmetry index (WAI), which increased in conjunction with the difference between the left and right waist areas. We further investigated the factors that correlated with WAI. *Results:* The WAI significantly decreased after surgery in most cases; however, in cases where the vertebra distal to the lower instrumented vertebra was located to the left of the central sacral line preoperatively, the WAI worsened postoperatively. The WAI was positively correlated with lateral shifts of the thorax and apical vertebrae. The Lenke classification had no significant effect on the WAI before and after surgery. *Conclusion:* We successfully developed a method to measure waistline asymmetry before and after surgery. The application of this method showed that the deviation of the lower instrumented vertebrae from the central sacral line influenced the exacerbation of waistline asymmetry after surgery.

Keywords

Adolescent Idiopathic Scoliosis (AIS), Waistline Asymmetry, Lower

Instrumented Vertebrae, Apical Vertebrae

1. Introduction

For adolescent patients with AIS, deformity and cosmetic truncal imbalance can be significant concerns [1]. Trunk deformities often raise concerns about body development, negatively influence patient self-image, and adversely affect patients' psychological well-being [2]. Patients with scoliosis have deformities of the spine and rib cage that are reflected as postural distortions of the trunk; and, scapular asymmetry, shoulder angle, and waist asymmetry account for 75% of the perception of trunk deformity [3]. A previous study showed that waistline asymmetry was generally improved after scoliosis surgery in AIS patients, but some patients experienced no improvements [4]. Therefore, it is important to clarify why the asymmetry does not improve, and objective assessment of the asymmetry is crucial. Several studies have evaluated waistline asymmetry using the left-right difference in waist constriction as an index [5] [6]. Antonia *et al.* evaluated waist height angle, right/left waist angles, and right/left waistline distance ratio on photographs. However, the point of waist constriction could not be identified in many cases. In some cases, the waistline is nearly straight and not curved so that the point of the vertex of the angle is virtually non-existent. In other cases, the waistline is rounded and the peak point of the curve is unclear. In these cases, waist angles or waistline distance cannot be defined. Therefore, a universal method for measurement of the waistline that does not rely on waist constriction is needed, but there is no report on such a useful method. In the present study, we aimed to establish an objective evaluation method for the waistline, simply quantifying the shape of the waist. We also investigated the factors affecting waistline asymmetry before and after surgery by using the new method.

2. Materials and Methods

This research has been approved by the IRB of the authors' affiliated institutions. The data used in this research were anonymized. Patient informed consent was waived considering the retrospective nature of the research.

A total of 35 patients with AIS who underwent posterior spinal fusion between March 2020 and October 2021 at our hospital were included.

Radiological parameters were measured on whole-spine anteroposterior radiographs obtained before and 1 - 2 weeks after surgery. Cases for which soft tissue shadows or the outer rib edges were not fully included in the radiograph of view were excluded.

We established a method for evaluating waistline asymmetry using whole-spine anteroposterior radiographs in the standing position using the orthopedic measurement software OP-A v2.101 FUJIFILM.

During image manipulation, we drew a line perpendicular to the ground through the center of the sacrum, a line horizontal to the ground through the center of the L1 vertebral body, and a line horizontal to the ground through the superior anterior iliac spine. If the right and left superior anterior iliac spines were not on the same horizontal line, the upper superior anterior iliac spine was used. The center of the L1 vertebral body was defined as the intersection of the lines connecting the opposite vertices of the vertebral body. We drew the shapes surrounded by these lines and outlined the soft tissue shadow in the lumbar region (**Figure 1**).

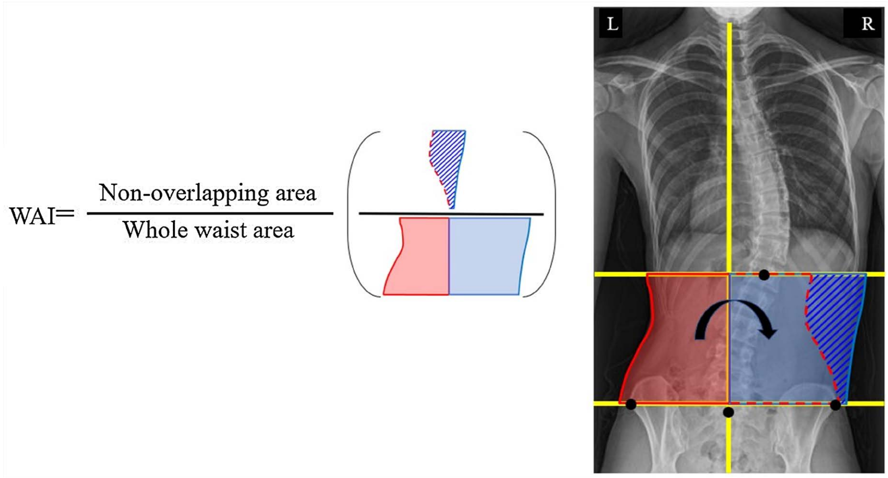

Figure 1. Shapes corresponding to the waist were drawn. The left shape is filled in red and the right shape is in blue. The area that did not overlap was then measured (diagonal line area) and subsequently divided by the whole waist area. The resulting value was defined as the waistline asymmetry index (WAI).

The left shape of the central sacral line was flipped to the right so that it overlapped with the right shape of the central sacral line. The area of the region not included in the overlap between the left-right difference was measured (**Figure 1**). To correct for waist size, the left-right difference in area was divided by the area of the shape corresponding to the waist, which was defined by the outlines of the soft tissue shadow in the lumbar region and the two horizontal lines, which passed through each center of the L1 vertebral body and the superior anterior iliac spine. We defined the value as the waistline asymmetry index (WAI), which represents the left-right difference in the area corrected by physique.

We used the WAI to evaluate waistline asymmetry in all patients, including cases in which the concave position could not be identified. Cases in which the relevant outlines of soft tissue shadows were not included in the X-ray images were excluded. As a factor that might affect the WAI, we developed an evaluation method for thoracic shift, following a previously described method [7]. Two lines were drawn horizontal to the ground through each rib edge of the most peripherally displaced ribs and measured the intersections of the lines and opposite rib edges (**Figure 2**). The shapes outlined by these four lines were regarded as the thorax. Next, we considered the midpoints of the two points on the horizontal lines, defining the distance from each midpoint to the line perpendicular to the ground through the center of the sacrum as the proximal and distal thoracic shifts, with the mean distance of these defined as the thoracic shift. We further defined the angle between the perpendicular line and the line connecting these two midpoints as the thoracic tilt. As Qiu *et al.* previously reported that the distance from the center of the apical vertebra reflects the position of the patient's waist [7], we measured the distance from the center of the proximal thoracic apical vertebra, main thoracic apical vertebra, and lumbar/thoracolumbar apical vertebra to the center sacral line. The distance was defined as the apical shift. The Cobb angles of the proximal thoracic, main thoracic, and lumbar/thoracolumbar curves were also measured.

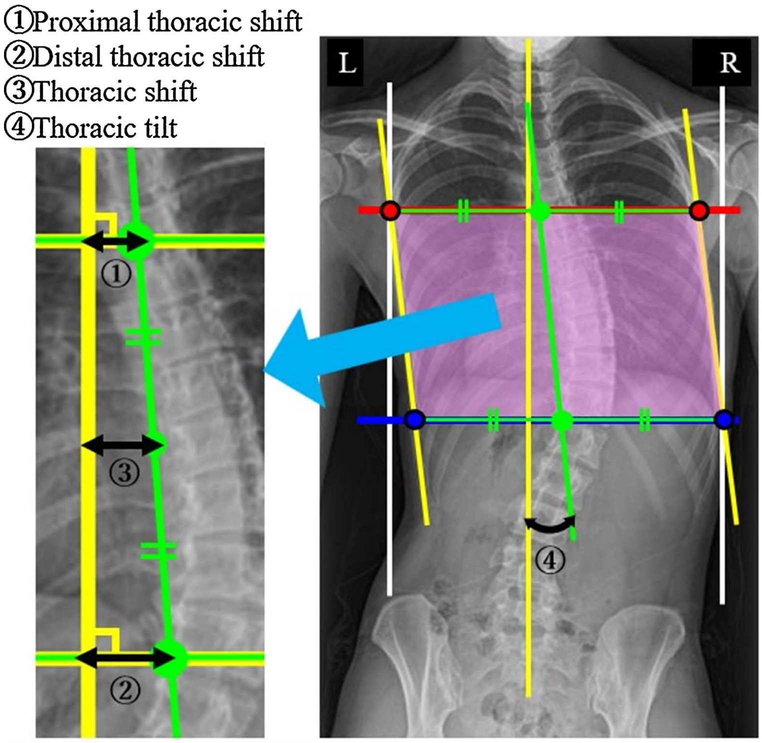

Figure 2. Two lines were drawn horizontally to the ground through each edge of the most peripherally displaced ribs, and intersections of the lines and rib edges were pointed. We defined the distance from each midpoint to the line perpendicular to the ground through the center of the sacrum as the proximal thoracic shift ①, distal thoracic shift ②, and the mean distance of these as the thoracic shift ③. We further defined the angle between the perpendicular line and the line connecting these two midpoints as the thoracic tilt ④.

All factors were measured before and after the surgery. The WAI was compared between a group of 35 patients with AIS and a control group consisting of 10 healthy adolescents with Cobb angle < 10˚.

We demonstrated the intra-observer and inter-observer reliability of WAI measurements to validate the reproducibility of this new method. Three orthopedic surgeons (Observer 1, Observer 2, and Observer 3) were familiarized with the computer program and trained in how to measure the WAI on a computer monitor. Observer 1 measured the WAI on 12 radiographs on two separate occasions, with an interval of at least two weeks, to assess intra-observer reliability. The WAI measurements were also independently performed on the same 12 radiographs by Observers 1, 2, and 3 to assess inter-observer reliability. Intra-observer and inter-observer agreement were assessed using the intraclass correlation coefficient (ICC).

We further collected patient information regarding factors that may affect WAI, including patient age, sex, Lenke classification, upper instrumented vertebra (UIV), lower instrumented vertebra (LIV), and number of instrumented vertebrae (LIV-UIV + 1).

Statistical Analysis: JMP software was used for statistical analyses. Correlation analysis was performed between the WAI and each factor. Statistical significance was set at $P < 0.05$.

3. Results

Overall, 35 patients (31 female and 4 male) were enrolled, including 16 with Lenke type 1, 6 with Lenke type 2, 3 with Lenke type 3, 1 with Lenke type 4, 7 with Lenke type 5, and 2 with Lenke type 6. There was no association between sex and the WAI before or after surgery (**Table 1**). The Lenke classification had no significant effect on the WAI before and after surgery (**Table 2**, **Table 3**). The mean age of the participants at the time of surgery was 20.3 (17.5 - 23.1) years. There was no association between age and the WAI before surgery (**Table 4**). The mean height of the participants at the time of surgery was 156.6 cm (148.8 - 164.3), the mean weight was 48.3 kg (41.9 - 54.8), and the mean BMI was 19.7 (17.6 - 21.8). There was no association between these physical features and WAI before surgery (**Table 4**). UIV was from T2 to T11, LIV was from T11 to L4, and the mean number of instrumented vertebrae was 8.94 (8.01 - 9.87). There was no association between these factors and the WAI before or after surgery (**Tables 2-4**).

We found no significant association between the Cobb angles of the proximal thoracic curve/the main thoracic curve and the WAI before and after surgery; however, the Cobb angles of the lumbar/thoracolumbar curve and the WAI before or after surgery were significantly correlated (**Table 5**). Furthermore, the proximal thoracic, distal thoracic, and thoracic shifts before surgery were significantly correlated with the preoperative WAI (**Table 5**). In addition, there was a correlation between the WAI and thoracic tilt before surgery (**Table 5**). There was no significant

Table 1. Correlations between waistline asymmetry index before/after surgery and each factor. Statistical analysis was performed by t-test.

Variable	WAI Before Surgery (mean ± SEM)	P value	WAI After Surgery (mean ± SEM)	P value
Sex				
Male	0.171 ± 0.082	0.212	0.088 ± 0.010	0.167
Female	0.116 ± 0.011		0.060 ± 0.006	

Table 2. Correlations between waistline asymmetry index before surgery and each factor. Statistical analysis was performed using one-way ANOVA.

Variable	WAI Before Surgery (mean ± SEM)	One Way ANOVA
Lenke classification		
1	0.124 ± 0.016	F = 0.985
2	0.123 ± 0.046	P value = 0.444
3	0.064 ± 0.019	
4	0.045	
5	0.155 ± 0.024	
6	0.090 ± 0.025	
UIV		
Th2	0.127 ± 0.031	F = 1.158
Th3	-	P value = 0.358
Th4	0.070 ± 0.045	
Th5	0.088 ± 0.023	
Th6	0.111 ± 0.022	
Th7	0.154 ± 0.021	
Th8	-	
Th9	0.254	
Th10	0.157 ± 0.039	
Th11	0.101 ± 0.000	
LIV		
Th11	0.075 ± 0.034	F = 1.987
Th12	0.067 ± 0.015	P value = 0.110
L1	0.159 ± 0.031	
L2	0.159 ± 0.023	
L3	0.121 ± 0.021	
L4	0.115	

Table 3. Correlations between waistline asymmetry index after surgery and each factor. Statistical analysis was performed using one-way ANOVA.

Variable	WAI After Surgery (mean ± SEM)	One Way ANOVA
Lenke classification		
1	0.065 ± 0.008	F = 2.430
2	0.065 ± 0.011	P value = 0.059
3	0.040 ± 0.017	
4	0.129	

Continued

5	0.042 ± 0.014	
6	0.096 ± 0.008	
UIV		
Th2	0.072 ± 0.011	F = 2.297
Th3	-	P value = 0.057
Th4	0.103 ± 0.014	
Th5	0.060 ± 0.013	
Th6	0.059 ± 0.014	
Th7	0.059 ± 0.011	
Th8	-	
Th9	0.114	
Th10	0.017 ± 0.007	
Th11	0.040 ± 0.009	
LIV		
Th11	0.073 ± 0.023	F = 0.405
Th12	0.067 ± 0.013	P value = 0.842
L1	0.062 ± 0.006	
L2	0.064 ± 0.015	
L3	0.052 ± 0.013	
L4	0.089	

Table 4. Correlations between waistline asymmetry index before/after surgery and each factor. The regression analytical technique was used to find the correlation. Statistical analysis was performed by Pearson's correlation analysis.

Variable	WAI Before Surgery	
	P	r
Age	0.444	0.212
Height	0.801	0.044
Weight	0.319	0.174
BMI	0.245	0.202
Number of instrumented vertebrae	0.066	0.716

correlation between the WAI before surgery and the shift in the proximal thoracic apical vertebra and lumbar/thoracolumbar apical vertebra, but there was a correlation between the WAI before surgery and the shift in the main thoracic apical vertebra (**Table 5**). Finally, the WAI after surgery did not have a significant correlation with the shift of the apical vertebra of the main thoracic curve after surgery but with a shift in the apical vertebra of the proximal thoracic and lumbar thoracolumbar curves (Table 5). The biggest apical vertebra shift, which is the biggest absolute value of the three shifts (the apical vertebra of the proximal thoracic, main thoracic, and lumbar thoracolumbar), was significantly correlated with the WAI before and after surgery. The biggest apical vertebra shift before surgery was 58.89 ± 3.66 (mean ± SEM) and the shift after surgery was 27.75 ± 1.71. Moreover, 72.2% of the biggest apical vertebra shift before surgery was main thoracic apical vertebra, and 66.7% of the shift after surgery was lumbar thoracolumbar apical vertebra. These indicate that in some cases the biggest apical vertebra was main thoracic before surgery, and it changed to lumbar thoracolumbar after surgery. Actually, the biggest apical vertebra shift may also accurately reflect the WAI. Together, these results indicate that the lateral shift of the thorax and apical vertebrae was correlated with WAI, and the greater the lateral shift, the greater the asymmetry of the waistline (Table 5).

Table 5. Correlations between waistline asymmetry index before/after surgery and the radiological measures. The regression analytical technique was used to find the correlation. Correlations between WAI before surgery and radiological measures before surgery were calculated using the positive and negative values of each measure. Cobb angles (proximal thoracic curve, main thoracic curve, and lumbar/thoracolumbar curve), absolute value of thoracic shift (proximal thoracic shift, distal thoracic shift, and mean distance of these), absolute magnitude of thoracic tilt, absolute magnitude of shift of apical vertebra (thoracic apical vertebra, main thoracic apical vertebra, lumbar/thoracolumbar apical vertebra), and the greatest absolute magnitude of shift as the apical lateral shift before surgery. Statistical analysis was performed by Pearson's correlation analysis.

Variable	WAI Before Surgery		WAI After Surgery	
	P	r	P	r
Cobb angle				
Proximal thoracic	0.978	−0.005	0.878	0.028
Main thoracic	0.252	0.199	0.088	0.293
Lumbar/thoracolumbar	0.04	−0.349	0.011	0.451
Thoracic shift (mm)				
Proximal	<0.001	0.727	<0.001	0.702
Distal	<0.001	0.843	<0.001	0.836
Mean	<0.001	0.861	<0.001	0.795
Thoracic tilt	0.016	0.409	0.081	−0.3
Apical vertebra shift (mm)				
Proximal thoracic	0.612	−0.092	0.024	0.385
Main thoracic apical vertebra	<0.001	0.593	0.295	0.182
Lumbar/thoracolumbar	0.06	0.381	<0.001	0.644
The largest apical vertebral shift (mm)	<0.0001	0.907	<0.001	0.595

Next, we compared the WAI before surgery with the WAI after surgery. For each case, we subtracted the WAI after surgery from the WAI before surgery, and assessed whether waistline asymmetry improved after surgery. When the difference value was positive, waistline asymmetry improved after surgery, and when the value was negative, the asymmetry worsened after surgery. Overall, the mean WAI decreased after surgery ($P < 0.0001$), and waistline asymmetry significantly improved after surgery (Table 6). However, waistline asymmetry worsened in 23% of patients after surgery. To investigate the deterioration of waistline asymmetry after surgery, we divided the patients into two groups: improved and worsened.

We measured WAI of a control group consisting of 10 healthy adolescents with Cobb angle < 10˚. WAI of healthy cases was 0.0230 ± 0.0041 (mean ± SEM) and was significantly lower than that of AIS patients ($P < 0.0001$).

The ICC for the intra-observer reliability of WAI measurements was 0.992, and the ICC for the inter-observer reliability of WAI measurements by the three observers was 0.987.

The Lenke classification did not significantly correlate with a decrease in the WAI after surgery (Table 7). However, when classified by the lumbar spine modifier, 88% of cases in the worsened group were type C. We therefore investigated factors that might be related to the worsening of WAI, focusing on the lateral shift of the vertebra located distal to the LIV, which would be correlated with the lateral thoracic shift after surgery. We defined the vertebra located distal to the LIV as

Table 6. Correlations between waistline asymmetry index before surgery and WAI after surgery. Statistical analysis was performed by t-test.

Variable	WAI (mean ± SEM)	P value
WAI		
Before surgery	0.121 ± 0.012	<0.0001
After surgery	0.062 ± 0.006	

Table 7. Correlations between waistline asymmetry index difference (WAI before surgery - WAI after surgery) and Lenke classification. Positive WAI value shows WAI improved by surgery. Statistical analysis was performed by one-way ANOVA.

Variable	WAI Difference (mean ± SEM)	One Way ANOVA
Lenke classification		
1	0.059 ± 0.016	F = 1.939
2	0.058 ± 0.048	P value = 0.118
3	0.024 ± 0.027	
4	−0.084	
5	0.113 ± 0.023	
6	−0.007 ± 0.033	

LIV-1 and measured the lateral shift of LIV-1 to the central sacral line after surgery. We further defined the shift located right of the central sacral line as positive and left of the line as negative. As a result, the worsening of WAI significantly correlated with the LIV-1 shift to the central sacral line: the more left to the central sacral line LIV-1 was located after surgery, the worse the WAI after surgery. Before surgery, LIV-1 of the WAI-improved group was located near the median, while that of the worsened group was significantly located to the left of the central sacral line (Figure 3). Similarly, after surgery, LIV-1 of the WAI-improved group was located near the median whereas that of the worsened group was located on the left (Figure 3). In both groups, the LIV-1 lateral shift showed no significant change after surgery (Figure 4). We further discovered that an LIV-1 shift to the central sacral line was a risk factor for worsening of waistline asymmetry after surgery, with a cut-off value of a 17 mm shift to the left (Figure 4). These results indicated that if the LIV-1 is located more than 17 mm to the left of the central sacral line before surgery, the waistline asymmetry is likely to worsen after surgery. This LIV-1 shift to the "left" applies not specifically to right-sided main thoracic curves, and it is universally applicable regardless of curve convexity.

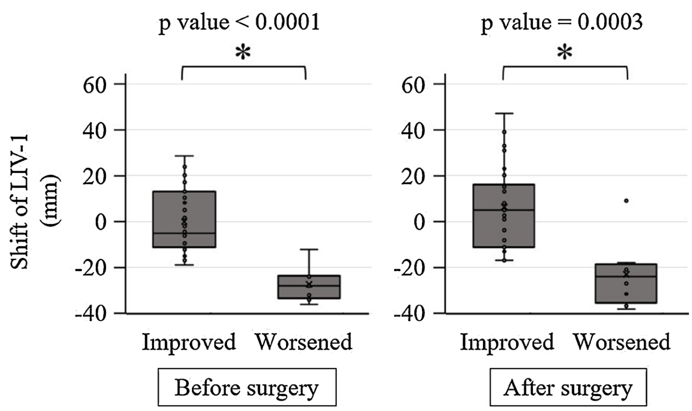

Figure 3. Comparison of the LIV-1 shift to the center sacral line between the groups whose WAI improved or worsened after surgery. Statistical analysis was performed by t test.

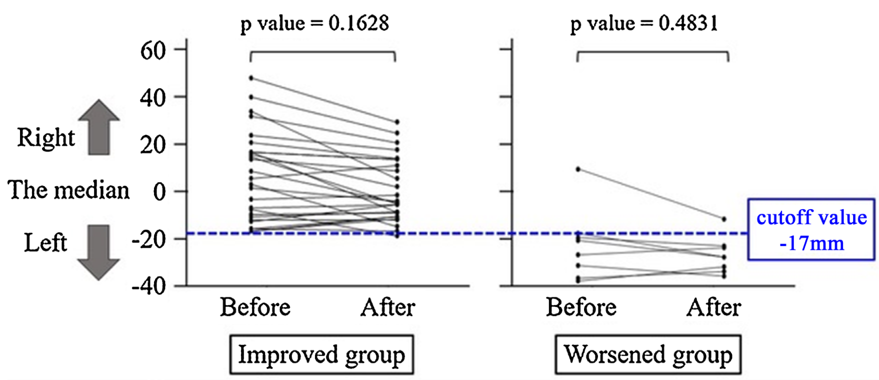

Figure 4. The LIV-1 lateral shift did not significantly change after surgery in either of the groups with improved and worsened WAI after surgery. The cutoff value of the LIV-1 shift before surgery was −17 mm. Statistical analysis was by t-test, and the cutoff value was found by using the ROC curve.

4. Discussion

In the study, we developed the WAI as an evaluation method for waistline asymmetry in patients with AIS before and after surgery and applied this method to assess patient outcomes. Our investigation revealed that before surgery, there was a correlation between the WAI and lumbar/thoracolumbar Cobb angle, thoracic shift, thoracic tilt, and distance from the main thoracic apical vertebra. After surgery, there was a correlation between the WAI and lumbar/thoracolumbar Cobb angle, thoracic shift, and distance from the proximal thoracic apical vertebra and lumbar/thoracolumbar apical vertebra. In addition, we discovered that an LIV-1 located more than 17 mm left to the center sacral line before surgery was a risk factor for worsening of WAI after surgery.

To date, waistline asymmetry has been evaluated based on waist constriction [5] [6]; however, in cases where the points of waist constriction are unclear, evaluating waistline asymmetry is difficult. Using WAI, a universal quantitative measure to evaluate waistline asymmetry in all patients with AIS, we were able to investigate the factors linked with asymmetry before/after surgery. Actually, we discovered that the remaining lateral shift of LIV-1 after surgery was related to the worsening of WAI. This shift in LIV-1 levels did not change significantly after surgery. Therefore, if the LIV-1 was located to the left before surgery, the WAI was likely to worsen after surgery. In other words, when choosing the fusion level before surgery, we were able to predict the risk of worsening of WAI after surgery by measuring the lateral shift in LIV-1. To lower the risk of worsening WAI, the LIV-1 should be located less to the left of the central sacral line.

Regarding decisions related to the level of the LIV, there are various aspects. In terms of the risk of adding-on, previous studies have stated that the LIV should be a stable vertebra or lower than the last touched vertebra [8] [9]. However, in terms of biomechanics, extending the fusion level to the distal region would worsen the lumbar spine mobility. Moreover, disc degeneration tends to occur in patients with fewer mobile segments in the lower lumbar spine [10]. This study showed that a more distal fusion level will reduce the lateral shift of LIV-1, resulting in a lower risk of worsening of WAI. In this way, we decided on the fusion level by many factors such as lumbar spine mobility, risk of disc degeneration, and risk of adding on. Although determining the fusion level before surgery remains controversial, the new method considering WAI may be a useful option.

Using the WAI, we were able to predict the risk of waistline worsening after surgery by measuring the shift in the LIV-1 beforehand. We usually evaluate the degree of deformity on the X-ray images by Cobb angle, but it does not necessarily reflect postural distortions of the trunk directly. WAI would be useful for making new criteria for trunk deformation. Evaluating scoliosis progress by WAI will enable us to understand the patients' psychological well-being concerning scoliosis and to predict the satisfaction of patients with surgery.

In the present study, we developed an objective method for evaluating waistline asymmetry in adolescent patients with AIS, and applied it to patient data. In this investigation, we found that the lateral shift of the thorax and apical vertebrae was correlated with waistline asymmetry. Further, we found that when the LIV-1 was located to the left of the central sacral line before surgery, the waistline asymmetry was more likely to worsen after surgery. One important limitation of this study is the relatively small sample size, which may reduce statistical power and limit the generalizability of our findings. Therefore, future validation studies using larger, multi-center cohorts are necessary to confirm the robustness and external validity of the present results. However, our study provides deeper insight into waistline asymmetry in AIS and indicates the possibility of a decision-making method for the improvement of waistline asymmetry after correction surgery.

Funding

This work was supported by JSPS KAKENHI Grant Number 23K27722.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Shindle, M.K., Khanna, A.J., Bhatnagar, R. and Sponseller, P.D. (2006) Adolescent Idiopathic Scoliosis: Modern Management Guidelines. *Journal of Surgical Orthopaedic Advances*, **15**, 43-52.

[2] Sharma, S., Bünger, C.E., Andersen, T., Sun, H., Wu, C. and Hansen, E.S. (2015) Do postoperative Radiographically Verified Technical Success, Improved Cosmesis, and Trunk Shift Corroborate with Patient Reported Outcomes in Lenke 1C Adolescent Idiopathic Scoliosis? *European Spine Journal*, **24**, 1462-1472. https://doi.org/10.1007/s00586-014-3688-x

[3] Raso, V.J., Lou, E., Hill, D.L., Mahood, J.K., Moreau, M.J. and Durdle, N.G. (1998) Trunk Distortion in Adolescent Idiopathic Scoliosis. *Journal of Pediatric Orthopaedics*, **18**, 222-226.

[4] Chau, W.W. and Ng, B.K.W. (2022) What Kind of Cosmetic Appearances Were Improved after Scoliosis Surgery in Adolescent Idiopathic Patients? A Longitudinal Long-Term Postoperative 7-Year Study Using Spinal Appearance Questionnaire. *Journal of Orthopedics and Joint Surgery*, **4**, 1-7.

[5] Matamalas, A., Bagó, J., Agata, E.D. and Pellisé, F. (2016) Validity and Reliability of Photographic Measures to Evaluate Waistline Asymmetry in Idiopathic Scoliosis. *European Spine Journal*, **25**, 3170-3179. https://doi.org/10.1007/s00586-016-4509-1

[6] Yamamoto, Y., Shigematsu, H., Kawasaki, S., Suga, Y., *et al.* (2022) Waistline Asymmetry Is Most Affects Self-Image in Patients with Adolescent Idiopathic Scoliosis. *Journal of Spine Surgery*, **13**, 1177-1185.

[7] Qiu, Y., Qiu, X.S., Ma, W.W., Wang, B., Yu, Y., *et al.* (2010) How Well Does Radiological Measurements Correlate with Cosmetic Indices in Adolescent Idiopathic Scoliosis with Lenke 5, 6 Curve Types? *Spine*, **35**, E882-E888. https://doi.org/10.1097/BRS.0b013e3181d6fdd7

[8] Cho, R.H., Yaszay, B., Bartley, C.E., Bastrom, T.P. and Newton, P.O. (2012) Which Lenke 1 A Curves Are at the Greatest Risk for Adding-On... and Why? *Spine*, **37**, 1384-1390. https://doi.org/10.1097/BRS.0b013e31824bac7a

[9] Cao, K., Watanabe, K., Kawakami, N., Tsuji, T., *et al.* (2014) Selection of Lower Instrumented Vertebra in Treating Lenke Type 2A Adolescent Idiopathic Scoliosis. *Spine*, **39**, E253-E261. https://doi.org/10.1097/BRS.0000000000000126

[10] Nohara, A., Kawakami, N., Seki, K., Tsuji, T., *et al.* (2015) The Effects of Spinal Fusion on Lumbar Disc Degeneration in Patients with Adolescent Idiopathic Scoliosis: A Minimum 10-Year Follow-Up. *Spine Deformity*, **5**, 462-468. https://doi.org/10.1016/j.jspd.2015.04.001