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A case-control study of body composition, prevalence and curve severity of the patients with adolescent idiopathic scoliosis in the east part of China

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Abstract

Objective

The purpose of the study is to investigate the characteristics of prevalence and curve severity in the patients with AIS and the body composition alterations between the patients with AIS and the healthy controls.

Methods

The information of the study sample was obtained from a screening database. The AIS cohort was paired with an age-and-gender matched healthy cohort. The stratification of BMI and curve severity were conducted according to the criteria developed by the U.S. Center for Disease Control and the Scoliosis Research Society. The prevalence and curve severity of the patients with AIS were investigated. Multi-group comparison of body composition parameters were conducted according to BMI between the patients with AIS and healthy controls.

Results

1,202 patients with AIS and an age-and-gender matched cohort were recruited from local schools. The underweighted cases had the highest prevalence of AIS and significant higher Cobb angle as compared to other three BMI subgroups; despite the patients with AIS had lower body weight, body fat mass, percentage of body fat and fat free mass as compared with healthy controls, converse results were observed in the underweighted cases after stratification according to BMI.

Conclusion

Based on the sporadic body composition of the patients with AIS observed in the current study, it is predictable that the pathophysiological alternations may be different before and after the onset of scoliosis. Well-designed human or animal studies for underweighted cases would be helpful to release the mechanisms of the pathophysiological alternations and better predict the development of AIS.

Keywords

Adolescent idiopathic scoliosis; Body composition; Body mass index; Body weight; Underweight.

Introduction

Adolescent idiopathic scoliosis (AIS) is a complex three-dimensional spinal deformity with effecting patients throughout their peripubertal growth period. The etiology of AIS appears to be genetic [1], however the mechanisms by which the curves develop are still unknown. The Meta-analysis by Zhang et al. reported a pooled prevalence of scoliosis was 1.02% in mainland China [2]. To devise effective preventive and therapeutic management, it is important to elucidate the etiopathogenesis of AIS.

There has been a long-term debate as to whether there is a real connection between the debut of AIS and the body composition alternations. Numerous growth studies attempted to answer this question with different samples [1, 3-19]. Among them, several investigators confirmed the lower body weight, taller stature, larger arm span, lower body mass index (BMI), delayed menarche and lower bone mass in the patients with AIS than the healthy controls. Sadat-Ali et al. compared girls with AIS and their healthy siblings and found that scoliosis caused osteopenia and osteoporosis among the affected girls whereas their siblings had higher BMI and bone mineral density [17]. Nonetheless, some researchers failed to find any significant association. A study screened 3631 children found that height and weight in non-scoliotic children were not statistically different from their scoliotic counterparts [16]. In addition, Dangerfield et al. even reported an inverse result that girls with scoliosis were shorter than the healthy controls [18]. The general consensus as to these previously observed characteristic anthropometric alterations in the patients with AIS has not been reached.

Despite body composition alterations in the patients with AIS are increasingly clarified, to the best of our knowledge, only a few studies have investigated the difference in the body composition between the patients with AIS and their non-scoliotic counterparts [20, 21].

Conflicting findings were reported with small sample size in these studies. Therefore, the purpose of the current study aimed at investigating the differences of body composition alterations between the patients with AIS and an age-and-gender matched healthy controls based on a relatively large screening database, as well as the prevalence and curve severity of the patients with AIS according to the BMI subgroups.

Methods

Design

The present observational, cross-sectional case control study received approval from the Chinese Ethics Committee for Registering Clinical Trials.

Study population

Every primary and secondary school student undergoing nine-year compulsory education in mainland China is required to receive a comprehensive medical evaluation annually granted by the National Health and Family Planning Commission of the People's Republic of China. For the purpose of early detection and management of AIS, a school screening of AIS was undergoing parallelly with the annual medical evaluation among students aged 10-16 years in Wuxi City, Jiangsu Province. All schools were enrolled with no special consideration for geographic, economic or ethical representation. Ethical approval was obtained and informed written consents were also obtained from all the subjects or from their legal guardians before screening.

Physical examinations, Adam's forward bending test (FBT) combined with determination of angle of trunk inclination (ATI) by Scoliometer were performed during school-based screening phase. Those who had ATIs of 5° or above were referred for X-ray examination. Participants diagnosed as the patients with AIS (Cobb angle≥10° confirmed with the whole spine X-ray film) in our hospital were enrolled in this study. An age-and-gender matched healthy control (ATI<5° confirmed with the Scoliometer) was also paired from the screening database. Subjects in both cohorts with history of congenital deformities, neuromuscular diseases, skeletal dysplasia, endocrine diseases or cardiorespiratory dysfunctions were excluded from the study.

Measurements of anthropometric parameters

Anthropometric parameters including body height, body weight, BMI, percentage of body fat (PBF), body fat mass (BFM) and fat free mass (FFM) were measured and calculated. Body height was recorded to the nearest 0.1 cm without shoes standing against a wall-mounted ruler. Body weight was measured to the nearest 0.1 kg in light clothes without shoes. BMI was calculated as body weight in kilograms divided by body height in meters squared. The PBF, the percentage of BFM by body weight, was measured with a hand-to-hand bioelectrical impedance meter (Omron Body Fat Analyzer HBF-306; Omron, Japan) [22]. The BFM is the total quantity of lipids that extracted from fat and other cells and the FFM is the weight of the remaining components once BFM has been excluded from body weight.

Measurements of Cobb angle

Based on the standing posterior-anterior whole spine X-ray film, the inclination of the end vertebrae, and indirectly the magnitude of the curve, is assessed by measuring the Cobb angle. The Cobb angle is formed by the inclination of the upper end plate of the upper end vertebra and the inclination of the lower end plate of the lower end vertebra. Final diagnosis of scoliosis, as defined by the Scoliosis Research Society [23], is based on Cobb angles of 10° or more measured by two independent observers (Ning Sun and Tao Wang). The intra-observer correlation coefficient in measuring the Cobb angle was 0.954 (95% CI: 0.932-0.976).

Data stratification

All the subjects enrolled in this study were classified according to the age-and-sex growth charts developed by the U.S. Center for Disease Control: underweight (BMI<5th percentile), normal weight (BMI≥5th and <85th percentile), overweight (BMI≥85th and <95th percentile and obesity (BMI≥95th percentile) [24].

Based on the severity of spinal deformity, the patients with AIS were classified into one of three subgroups. “Mild” indicated patient showed a Cobb angle of 10 to 24°; “moderate” indicated patient showed a Cobb angle of 25 to 40° and “severe” indicated patient showed a Cobb angle greater than 40° [23].

Statistical analysis

Numerical data are presented as mean followed by standard deviation, and categorical data are presented as frequency followed by the percentage of the total number in the sample. Anthropometric data including body height, body weight, BMI, PBF, BFM and FFM were compared between the patients with AIS and the healthy controls using independent samples *t-test*. Gender and Risser score were compared using *Chi-square* analysis. One-way ANOVA was adopted for the comparison between BMI subgroups and curve subgroups. The loss of statistical power within multi-group comparison was adjusted with Bonferroni’s method. SPSS 21.0 for Windows (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. $P<0.05$ was considered statistically significant.

Results

A total of 79,122 primary and secondary school students were screened. 1202 patients with AIS were classified according to the BMI subgroups and the curve subgroups and the corresponding prevalence were summarized in Table 1. The highest prevalence was found in underweighted cases and it decreased gradually with the increase of BMI in each curve subgroup. When analyzed according to curve severity, a similar trend was observed in each BMI subgroup.

Table 1 Prevalence of AIS by BMI and curve severity

Comparison of body composition parameters between curve subgroups were also performed in the patients with AIS. As shown in Table 2, though the absolute value of body weight, body height, BMI, BFM, PBF and FFM were higher in the severe cohort, no significant difference was detected across groups. When the curve severity was compared according to BMI subgroups, significant differences in Cobb angle were only found between the underweighted cases and the normal weights (Figure 1).

Table 2 Comparison of body composition parameters according to curve subgroups

Figure 1 Comparison of curve severity of the patients with AIS according to BMI subgroups

1,202 patients with AIS and an age-and-gender matched cohort were recruited from local schools. As shown in Table 3, the average Cobb angle in the patients with AIS was 18.68±8.16°. There are 919 and 269 students diagnosed as mild (10-24°) and moderate (25-40°) AIS respectively, only fourteen patients were found as severe cases (above 40°). Data of Risser score was also provided in Table 4.

The patients with AIS had significant lower body weight (*P*<0.001). Body height were not significantly different between AIS and controls (*P*=0.098). Lower BMI was found in the patients with AIS (*P*<0.001). In addition, the patients with AIS also had lower BFM (10.21±3.76 kg *vs.* 12.12±4.97 kg, *P*<0.001), lower PBF (20.40±5.11% *vs.* 22.48±6.01%, *P*<0.001), lower FFM (39.01±7.48 kg *vs.* 40.50±8.27, *P*<0.001) than healthy controls.

Table 3 Comparison of demographic and clinical data between the patients with AIS and healthy controls

Table 4 and 5 show the comparison of body composition parameters between the patients with AIS and healthy controls by BMI subgroups. The patients with AIS had higher body weight than the healthy controls (*P*=0.001) in the underweight cohort, but the difference became insignificant in the other three cohorts. Body height were comparable between the patients with AIS and healthy controls in all BMI subgroups. Regarding BMI, underweight patients with AIS had a significant higher value (*P*<0.001) while an inverse result was found in the obesity. Significant higher BFM were found in the patients with AIS from underweight cohort and healthy controls from the other three cohorts. Similar results were found in PBF except the comparison in the obesity cohort.

Table 4 Comparison of body composition parameters between the patients with AIS and healthy controls (For underweight and normal weight)

Table 5 Comparison of body composition parameters between the patients with AIS and healthy controls (For overweight and obesity)

Discussion

The current screening database contains relevant information either on the AIS cohort or the healthy cohort so that it provides us a chance to investigate the actual prevalence of AIS according to BMI and to detect the anthropometric characteristics in the patients with AIS. It also enables us to compare the anthropometric alterations between the patients with AIS and their non-scoliotic counterparts.

One of the striking findings of this study was that it demonstrated a potential association between AIS and BMI. The prevalence was highest in underweighted cases and decreased across the groups with the increase of the BMI (Table 1). Despite it seems the body component parameters were generally higher in more severe cases (Table 2), no significant result was detected. When compared between BMI subgroups, patients in the underweight group were significantly more severe than patients in other groups (Figure 1). Our findings were comparable with a recent published study [25], in which a similar strategy of data stratification as to BMI and the severity of spinal deformity was applied in 103,249 patients. The potential explanation might be the theory that the lower BMI in the patients with AIS is associated with decreased circulating leptin levels followed by the increased autonomic nervous system activity as compared to the healthy controls. This in turn launches the developmental disharmony between autonomic and somatic nervous systems followed by the spinal deformity as an adverse response [26]. Lower BMI may have interactions with decreased circulating leptin levels, increased autonomic nervous system activity as to the initiation of the scoliosis. After its onset, however, the progression of the spinal deformity may not be mainly attribute to the BMI. As summarized in the 2011 SOSORT guideline, there are four factors that are related to the risk of curve progression: age, gender, skeletal maturity and pattern of scoliotic curve presented [23]. Specifically, the pubertal growth spurt is the period of the most marked progression. Female and those who has a curve greater than 30° is more likely to progress. Therefore, it was not supervising that this study did not find a difference in body composition parameters between curve subgroups.

This study also found significantly lower body weight, BMI, BFM, PBM and FFM in the patients with AIS than the healthy controls (Table 3). These findings can be partially explained by its correlation with the leptin bioavailable. As shown in a recent study [27], in which 148 AIS female patients were studied with the body composition and leptin measurement, and they found the altered free leptin bioavailability in AIS girls was associated with lower body weight, lower BMI, lower BFM and lower PBM. Despite strong and positive correlations have been shown between leptin and BFM and PBF in the healthy population [28, 29], correlations between body composition parameters and serum leptin level, soluble leptin receptor level and free leptin index in AIS girls were slightly weaker than the healthy controls [27]. The initiation of the scoliosis might be due to the interactions between the production of leptin and nervous systems, however, our observations also suggested that the functions of leptin could be affected under the pathological conditions of AIS, and the mechanisms of leptin secretion and signaling in patients with AIS need to be further explored. Although muscle strength was not tested in our study, the decreased body composition parameters could also lead to a lower muscle strength in the patients with AIS [30, 31]. Several studies have reported that imbalanced strength of paraspinal muscle alone the concave and convex sides of the spine could lead to higher chances of curve progression [32, 33]. These evidence may also partial explain why the underweighted cases had the higher prevalence and more severe curve in the current study.

When the body composition parameters were compared between the patients with AIS and healthy controls according to BMI subgroups, an even more intriguing finding was that the underweight patients with AIS had significant higher body weight, BMI, BFM and PBF than the healthy control (Table 4), while the results in other three BMI subgroups (Table 4 and 5) were consistent with the general trend in Table 3. No solid evidence can be found to support the former observation and it might be due to the pathophysiological alternations at the genetic, molecular and cellular levels under the conditions of AIS as well as the sample size discrepancy (290 in patients with AIS *vs.* 74 in healthy controls). Therefore, the mechanisms behind this observation can be further investigated with well-designed human and animal studies.

To the best of our knowledge, it was the largest study to be carried out on AIS in eastern China, so that the sample can be stratified to study the characteristics of each subgroup. Another strength of the current study was that the BMI and curve severity subgroups were classified according to the criteria developed by the U.S. Center for Disease Control and the Scoliosis Research Society respectively. This allows better data fusion and outcome comparison among different studies in the future. The limitation with the current study was that some parameters (i.e. leptin level in the plasma, paraspinal muscle strength and bone density) directly or indirectly related to the body composition were not collected during the screening. This was mainly due to the huge workload during screening, and the time should be limited as a cross-sectional study. In addition, despite the AIS cohort was paired with an age-and-gender matched healthy cohort, the sample size discrepancy still occurred after the sample was stratified according to BMI. Therefore, it is suggested to further strict the pairing criteria so that the potential bias can be eliminated and the discussion can be focused on the observation itself.

In summary, the current study indicated that the underweighted cases had the highest prevalence of AIS and relatively more severe curve; despite the patients with AIS had sporadic body composition with lower body weight, BFM, PBF and FFM as compared with age-and-gender matched healthy controls, converse results were observed in the underweighted cases after stratification according to BMI. In light of these results, the pathophysiological alternations may be different before and after the onset of scoliosis. Based on the limitations of the current study, well-designed human or animal studies on underweighted cases would be helpful to release the mechanisms of the pathophysiological alternations and better predict the development of the disease. Integration of the data from different research sites would also help to detail the characteristics of BMI and curve severity in the patients with AIS. Furthermore, caution should be taken when applying the results in the current study to a different ethnic group.

Conflict of interest and funding

None.

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