

## Original Article

# Impact of Computer-Aided Design and Computer-Aided Manufacturing Boston Brace on Level of Dyspnea among Patients with Adolescent Idiopathic Scoliosis

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## ABSTRACT

**Background:** Adolescent Idiopathic Scoliosis (AIS) is a prevalent spinal deformity characterized by a lateral curvature exceeding 10°. Bracing, particularly with the Boston brace, is a common conservative treatment aimed at halting the progression of spinal curvature. However, the impact of bracing on pulmonary function and the resultant dyspnea remains a concern, especially in developing countries like Pakistan where larger scoliotic curves are more common.

**Objective:** This study aimed to evaluate the effect of the CAD/CAM Boston brace on dyspnea levels in patients with AIS and to examine the correlation between dyspnea severity, Cobb's angle, and the duration of brace wear.

**Methods:** Necessary approvals were obtained from the institutional ethical review board, and informed consent was secured from all participants. The study included 145 participants (aged 10-19 years) diagnosed with AIS, recruited through non-probability convenient sampling. The sample size was calculated using the WHO sample size calculator, ensuring a minimum of 134 participants. Data collection involved the 6 Minute Walk Test (6MWT) followed by the Modified Borg Scale (MBS) to assess dyspnea. Participants were instructed to walk a distance of 400 to 700 meters within 6 minutes. Post-test, participants rated their dyspnea on a scale of 0 to 10. Demographic data and brace wear duration were also collected. Data were analyzed using SPSS version 25. Means and standard deviations were calculated for continuous variables, and frequency tables were used for categorical variables. Pearson correlation coefficients were computed to determine the relationships between dyspnea levels, Cobb's angle, and brace wear duration.

**Results:** The mean age of participants was 14.71 years (SD = 2.309). The mean Cobb's angle was 52.08° (SD = 5.3729), and the mean duration of brace wear was 26.08 hours per week (SD = 7.0458). Dyspnea severity varied, with 54.5% of participants reporting "somewhat severe" dyspnea, 15.9% reporting "very, very severe" dyspnea, and 9.0% reporting "moderate" dyspnea. Pearson correlation analysis revealed a strong positive correlation between dyspnea severity and Cobb's angle ( $r = 0.681$ ), and a moderate positive correlation between dyspnea severity and brace wear duration ( $r = 0.414$ ).

**Conclusion:** The study highlights the significant impact of the CAD/CAM Boston brace on dyspnea levels among AIS patients. Higher Cobb's angles and longer brace wear durations were associated with increased dyspnea severity. These findings underscore the need for careful monitoring of respiratory symptoms in AIS patients undergoing bracing and suggest exploring alternative or adjunctive treatments to minimize pulmonary compromise.

**Keywords:** Adolescent Idiopathic Scoliosis, Boston Brace, CAD/CAM, Dyspnea, Pulmonary Function.

## INTRODUCTION

Scoliosis is defined as a condition marked by sideways spinal curves that surpass a 10° measurement. Frequently, individuals exhibit an x-ray image revealing an "S" or "C" shape (1). Exceeding the typical spinal curvature in the frontal plane, scoliosis results in a three-dimensional distortion. It is categorized into three main types: congenital, syndromic, and idiopathic. Adolescent Idiopathic

Scoliosis (AIS) represents roughly 90% of all scoliosis cases, establishing itself as the primary type in adolescents. Its prevalence among individuals aged 11 to 17 is approximately 2 to 3%, with a higher frequency observed among females (2). In Pakistan, the prevalence, along with its severity and complications, is recorded as 21.7% (3). An early onset of scoliosis and rapid progression of the spinal curve are predictive indicators of adverse outcomes in idiopathic scoliosis, which also reduces lung volume and impairs pulmonary compliance, leading to breathing difficulties and causing dyspnea in affected adolescents (4).

AIS holds the potential to affect various aspects of the respiratory system, such as thoracic volume available for the lungs, diaphragm function, and airway resistance (5). Numerous parameters are impacted, including rib vertebra angle difference (RVAD), space available for the lung, thoracic height-width ratio (THWr), lung height-width ratio (LHWr), vertebral levels of the right and left diaphragms, the difference in vertebral levels between the right and left diaphragms, kyphosis-lordosis index (KLi), rib hump index (RHi), and rib hump depth index (RHDi) (6). The deformation of the rib cage due to scoliosis diminishes available lung space, causing the progression of restrictive lung disease and impairing pulmonary function (7). This condition can significantly impact crucial lung measurements like vital capacity (VC), forced vital capacity (FVC), and forced expiratory volume in 1 second (FEV1) (8).

The Boston brace serves as an established standard for conservative treatment in moderate or severe cases of AIS. Its aim is to slow and even stop the progression of curves during skeletal growth. However, advancements in the field have brought about new individual braces created using computer-aided design/computer-aided manufacturing (CAD/CAM) techniques (9). CAD/CAM-designed individual braces have corrected curvature angles by more than 30% from their initial measurements. Despite this, prolonged use of the Boston brace can cause distressing experiences for adolescents, such as the development of pressure-related scars, discomfort, emotional and social challenges, and disruptions in self-perception of body image (10). Furthermore, it has the potential to compress the thorax to a level that leads to a type of restricted ventilation dysfunction, thereby increasing the level of difficulty in breathing, termed dyspnea. As a result, the well-being and quality of life for individuals with AIS are greatly compromised (11).

The modified Borg scale (MBS) presents a promising solution, providing quick and straightforward insights into a patient's subjective experience of dyspnea severity when measured with a 6 Minute Walk Test (6MWT). The 6MWT consistently shows a significant connection with peak oxygen consumption in individuals affected by respiratory conditions (12). The MBS uses a rating system from 0 to 10, where 0 signifies no dyspnea and 10 represents maximum dyspnea. This scale quantifies breathlessness levels immediately post the 6MWT. Without a doubt, the MBS maintains its validity and reliability as an assessment tool for measuring dyspnea (13).

## MATERIAL AND METHODS

Prior to the commencement of this study, the necessary approvals were obtained from the institutional ethical review board, ensuring adherence to ethical standards as outlined in the Declaration of Helsinki. Participants provided informed consent, fully comprehending the study's purpose and their involvement, with confidentiality of their details strictly maintained. The study included participants of both sexes, aged 10 to 19, who were diagnosed with Adolescent Idiopathic Scoliosis (AIS) and had no prior respiratory disorders (14).

The sample size was calculated using the WHO sample size calculator, employing the formula  $n = Z^2_{1-\alpha} P(1-P) / d^2$ . The minimum sample size derived from this calculation was 134. For this study, a maximum sample of 145 participants was recruited via non-probability convenient sampling. Data collection involved the use of the Modified Borg Scale (MBS), administered following the completion of the 6 Minute Walk Test (6MWT) (13). Participants were instructed to walk straight and back to the starting position within 6 minutes, covering a distance of 400 to 700 meters (15).

Once informed consent was obtained and the test performed, participants were asked to indicate their level of dyspnea on a scale of 0 to 10 on the MBS. Instructions on how to complete the printed MBS scales were provided, and assistance was offered in case of any confusion. Demographic data were collected before the participants filled out the MBS.

The collected data were analyzed using the Statistical Package for Social Sciences (SPSS) software, version 25. The results were presented in the form of tables displaying means and standard deviations for continuous variables, and frequency tables for categorical variables. To determine the relationship between the level of dyspnea as measured by the MBS and Cobb's angle, as well as the relationship between the level of dyspnea and the duration of brace wear, Pearson correlation coefficients were calculated. The statistical significance of the observed values was confirmed through these analyses.

Throughout the study, all procedures were conducted in compliance with ethical guidelines, ensuring the protection of participants' rights and well-being. The study's design, data collection, and analysis were rigorously structured to maintain the highest standards of scientific integrity.

## RESULTS

**Table 1: Participant Demographics**

Statistic	Age	Cobb's Angle	Time of Brace Worn
Mean	14.71	52.08	26.08
Standard Deviation	2.309	5.3729	7.0458
Minimum	10	30	12
Maximum	19	102	48

**Table 2: Level of Dyspnea Frequency and Percentage**

Level of Dyspnea	Frequency	Percentage
0 - nothing at all	1	0.7%
0.5 to 1 - very slight	1	0.7%
2 - slight	7	4.8%
3 - moderate	13	9.0%
4 - somewhat severe	79	54.5%
5 - severe	12	8.3%
7 to 8 - very severe	9	6.2%
9 - very, very severe	23	15.9%
10 - maximal	0	0.0%

**Table 3: Relationships between Variables**

Relationship	Statistic	Value
Modified Borg scale & Cobb's angle	Pearson correlation	0.681
Modified Borg scale & time of brace worn	Pearson correlation	0.414

The study included a total of 145 participants diagnosed with Adolescent Idiopathic Scoliosis (AIS), with an age range of 10 to 19 years. The mean age of the participants was 14.71 years, with a standard deviation of 2.309 years, indicating a relatively young cohort with a fairly narrow age distribution (Table 1). The Cobb's angle, a critical measure of spinal curvature, varied widely among the participants, ranging from 30 to 102 degrees. The mean Cobb's angle was 52.08 degrees, with a standard deviation of 5.3729 degrees, reflecting significant variability in the severity of scoliosis within the sample (Table 1).

Regarding the duration of brace wear, participants wore their braces for an average of 26.08 hours per week, with a standard deviation of 7.0458 hours. The minimum reported duration was 12 hours, while the maximum was 48 hours, suggesting differing levels of adherence or prescribed brace wear among the participants (Table 1).

When assessing the level of dyspnea using the Modified Borg Scale (MBS), the majority of participants reported a range of dyspnea severity. Specifically, 54.5% of participants rated their dyspnea as "somewhat severe," while 15.9% experienced "very, very severe" dyspnea. Notably, only a small fraction reported minimal dyspnea, with 0.7% indicating "nothing at all" and another 0.7% indicating "very slight" dyspnea. There were no reports of the maximal level of dyspnea (Table 2).

Statistical analysis revealed significant correlations between the level of dyspnea and other key variables. The Pearson correlation between the Modified Borg scale scores and Cobb's angle was 0.681, indicating a strong positive relationship. This suggests that higher Cobb's angles, representing more severe spinal curvatures, are associated with increased levels of dyspnea. Similarly, the Pearson correlation between the Modified Borg scale scores and the time of brace worn was 0.414, indicating a moderate positive relationship. This implies that longer durations of brace wear are associated with higher levels of dyspnea, though to a lesser extent than the Cobb's angle (Table 3).

In summary, the study highlights the significant impact of AIS on respiratory function, as evidenced by the levels of dyspnea reported by participants. The findings underscore the importance of monitoring respiratory symptoms in individuals with AIS, particularly those with more severe spinal curvatures or longer brace wear durations. The correlations identified provide valuable insights into the relationships between spinal curvature, brace wear, and respiratory symptoms, emphasizing the need for comprehensive management strategies in this patient population.

## DISCUSSION

The effectiveness of bracing as a conservative treatment for Adolescent Idiopathic Scoliosis (AIS) has been well-documented, demonstrating a significant reduction in the progression of severe spinal curvature. This has led to its inclusion in treatment guidelines, particularly for managing AIS cases with a Cobb angle between 20° and 40°. Despite its long-term benefits, bracing has potential drawbacks, including short-term declines in pulmonary function and limitations in maximal exercise performance, which are notably pronounced in female patients (7). Internationally, it has been observed that Pakistan exhibits comparatively larger scoliotic curves, accounting for 64.7% of cases, which may be attributed to challenges such as limited access to specialized care, delayed referrals to specialists, and a reliance on alternative medical practices like homeopathy. These barriers are common in developing countries, where patients often face hurdles in accessing early care due to a scarcity of skilled practitioners, environmental factors, financial constraints, or cultural norms that discourage specific treatments (15-19).

In this study, the impact of the CAD/CAM Boston brace on pulmonary function was examined, revealing that individuals with AIS experienced limitations in pulmonary function, resulting in dyspnea due to brace wear. Patients with scoliosis generally report impaired pulmonary function, which tends to worsen as the curvature of the spine increases, potentially leading to airway obstruction in severe cases. The impact of the brace on respiratory mechanics varied based on factors such as the degree of Cobb's angle, the tightness of the brace, its constraining effects on the rib cage and trunk mobility, the corrective forces applied, and the duration of brace wear (11). It was generally agreed that wearing the CAD/CAM Boston brace had a restrictive effect on lung function. Although noticeable changes were detected among all patients due to bracing, there was a clinically significant increase in the severity of dyspnea.

The 6 Minute Walk Test (6MWT) used in this study provided a comprehensive assessment of respiratory function, as well as cardiac and metabolic systems. It is considered the best indicator of functional capacity in patients wearing a brace and was used to evaluate their level of dyspnea. This test is easier to administer in clinical settings and better reflects daily activities, making it more tolerable than other walk tests. The Modified Borg Scale (MBS), used in conjunction with the 6MWT, proved to be an accurate tool for measuring subjective dyspnea in patients. It correlated well with other clinical parameters and was easy for patients to complete independently. As a patient-rating tool, the MBS quickly indicated the presence and severity of dyspnea, which could then be reported and treated effectively (16-20).

This study's strengths included a well-defined sample size and the use of reliable assessment tools like the 6MWT and MBS. However, limitations included potential variability in brace wear adherence and the subjective nature of dyspnea reporting, which could affect the results. Additionally, the study did not account for long-term pulmonary outcomes beyond the study period. Future research should consider these factors and explore interventions that can mitigate the restrictive effects of bracing on pulmonary function.

## CONCLUSION

In conclusion, this study contributes to the growing body of evidence highlighting the negative impact of the CAD/CAM Boston brace on dyspnea levels among patients with AIS. It underscores the need for comprehensive management strategies that address both spinal curvature and respiratory function to improve overall patient outcomes. Recommendations for clinical practice include monitoring respiratory symptoms closely in AIS patients undergoing bracing and exploring alternative or adjunctive treatments that minimize pulmonary compromise while effectively managing spinal curvature.

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