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Peer bullying in adolescents with idiopathic scoliosis treated with bracing: a case–control study

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Abstract

This study aimed to evaluate peer bullying in patients with adolescent idiopathic scoliosis (AIS) treated with bracing and to examine associated self-esteem and social anxiety compared with age- and sex-matched healthy controls. This case-control study was conducted at a tertiary university hospital between January 2023 and June 2025. The brace group consisted of 31 adolescents (22 girls, 9 boys) with AIS treated with a Chêneau brace, of whom 24 were current and 7 were former brace users. The control group comprised 32 age- and sex-matched healthy adolescents (21 girls, 11 boys). Psychosocial assessment was performed using the Rosenberg Self-Esteem Scale (RSES), the Child and Adolescent Bullying Scale-9 Short Form (CABS-9), and the Social Anxiety Scale for Adolescents (SAS-A). Intergroup comparisons were analyzed with the Mann-Whitney U test, and correlations within the brace group were examined using Spearman's correlation analysis. Current and former brace users were also analyzed separately in an exploratory analysis. The mean duration of brace use was 17.1 (±10.2) months, the mean Cobb angle was 31.1° (±4.4°), and the mean self-reported daily brace-wear time was 21.2 (±1.2) hours. Adolescents in the brace group had significantly higher CABS-9 scores than controls (19.6±5.9 vs. 12.5±6.3, $p<0.001$). CABS-9 scores were similar in current and former brace users ($p=0.981$), and both subgroups scored higher than controls. In contrast, RSES and SAS-A scores did not differ significantly between groups (RSES, $p=0.238$; SAS-A, 50.8±11.0 vs. 51.3±10.2, $p=0.826$). Within the brace group, brace duration was positively correlated with CABS-9 scores ($r=0.397$, $p=0.027$), while age was negatively correlated with SAS-A scores (r=-0.396, $p=0.027$). Adolescents with AIS treated with bracing had significantly greater exposure to peer bullying than healthy controls, while social anxiety and self-esteem did not differ significantly between groups. In exploratory analyses, longer brace duration was associated with greater bullying exposure, and younger age was associated with higher social anxiety within the brace group. Because no non-braced AIS group was included, these findings cannot distinguish the effect of bracing from that of scoliosis itself. These findings support specific attention to peer bullying during routine follow-up of adolescents receiving brace treatment for AIS.

Keywords Adolescent idiopathic scoliosis · Brace treatment · Peer bullying · Social anxiety · Self-esteem · Psychosocial impact

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Introduction

Adolescent idiopathic scoliosis (AIS) is a complex three-dimensional deformity of the spine, radiographically defined by a Cobb angle of 10° or more in the coronal plane. It is most common in otherwise healthy girls and tends to progress during skeletal growth[1]. Management depends on curve severity and remaining growth potential: bracing is used for moderate curves, whereas surgery is required for more severe curves[2]. In skeletally immature patients with curves of 20°–45°, bracing is the primary treatment to prevent curve progression, applying external corrective forces to the trunk through a rigid orthosis[3]. Many brace designs are available, but thoracolumbo-sacral orthoses (TLSOs) are the most widely used[4]. Brace treatment has been associated with reduced quality of life, most frequently in the domains of self-image, mental health, and vitality[5].

Bullying may take verbal, physical, social, or cyber forms and has detrimental effects on children and adolescents[6]. Adolescents who are already vulnerable because of a medical condition may be particularly susceptible[7]. Beyond emotional distress, bullying can lead to poorer health outcomes, reduced treatment adherence, anxiety, and depression[8], as well as low self-esteem, school avoidance, and lower academic performance[9]. Children with disabilities are at substantially greater risk of being bullied than their peers, and students receiving special education services report markedly higher rates of victimization than those in general education settings[10,11].

Although the psychosocial consequences of brace treatment in AIS, including effects on quality of life, body image, social functioning, and emotional well-being, have been widely investigated, the specific relationship between brace treatment and peer bullying remains insufficiently explored. A qualitative study of adolescents undergoing brace treatment described school-related concerns, teasing, ridicule, and feeling different from peers, but bullying was not quantitatively assessed using a dedicated validated instrument[12]. More recently, peer victimization was evaluated in adolescents with AIS as a broader diagnostic group, with greater victimization reported than in healthy controls[13]. However, to our knowledge, no previous case-control study has specifically quantified bullying exposure in a brace-treated AIS cohort using a validated bullying scale and compared these findings with age- and sex-matched healthy controls.

Therefore, the primary aim of the present study was to evaluate peer bullying among adolescents with AIS treated with bracing and to examine its relationship with self-esteem, social anxiety, age, and duration of brace use.

Materials and methods

This research was structured as a case-control study and was conducted within the Department of Orthopedics and Traumatology at a tertiary university hospital from January 2023 to June 2025. The brace group included 31 adolescents with AIS (22 girls and 9 boys) who were either actively undergoing brace treatment or had previously used a brace. At the time of questionnaire administration, 24 participants were actively using a brace and 7 were no longer using a brace. Participants were recruited from a scoliosis and spine deformities outpatient clinic. Inclusion criteria for the brace group were idiopathic scoliosis treated with a brace and an age between 10 and 18 years at the time of questionnaire administration. Participants with known psychiatric disorders, intellectual disabilities, or other chronic systemic diseases were excluded. The control group consisted of 32 healthy adolescents (21 girls and 11 boys) recruited during the same study period from children and adolescents attending the same hospital for routine health check-up visits who had no active complaint or known disease. Controls were frequency-matched to the brace group for age and sex at the group level; individual (one-to-one) matching was not performed, and no additional matching criteria, such as socioeconomic status, school type, or grade, were applied. None had a history of scoliosis, brace treatment, trauma-related orthopedic treatment, or other chronic musculoskeletal conditions. Self-esteem was evaluated using the Rosenberg Self-Esteem Scale (RSES), exposure

to bullying using the Child and Adolescent Bullying Scale-9 Short Form (CABS-9), and social anxiety using the Social Anxiety Scale for Adolescents (SAS-A).

Scoliosis-specific clinical data for the brace group were obtained from clinical records and from patients and parents at the time of questionnaire administration. These included the Cobb angle of the major curve measured on the most recent standing posteroanterior radiograph, curve type according to the Lenke classification, brace type, age at brace initiation, total duration of brace treatment, self-reported average daily brace-wear time, and current brace status (current or former user). Brace compliance was assessed by patient and parent report at follow-up visits, and good compliance was defined as self-reported brace wear of at least 18 h per day; objective wear monitoring (e.g., temperature sensors) was not used. For former brace users, the reason for brace discontinuation and the time between discontinuation and questionnaire administration were recorded.

Exposure to bullying was assessed using the Turkish version of the CABS-9, validated by Kırıcı and Ekşi[14], a nine-item short form of the Child-Adolescent Bullying Scale developed by Vessey et al. using Rasch modeling[15]. Items are rated on a 4-point scale, giving total scores of 9 to 36, with higher scores indicating greater exposure to bullying. Scores were categorized according to the cut-points established in the scale development study, which divided the Rasch-calibrated score continuum into three hierarchical levels and provided a clinical description of each level: no-to-minimal exposure (total score 9–17; mean item score 1.0–1.9), exposure (18–26; mean item score 2.0–2.9), and high exposure (27–36; mean item score ≥ 3.0)[15]. Because both the exposure and high-exposure categories indicate bullying experiences beyond isolated incidents, these two categories were also combined (total score ≥ 18) for a dichotomous comparison. The Rosenberg Self-Esteem Scale (RSES), initially developed by Rosenberg and subsequently adapted into Turkish by Çuhadaroğlu, assesses overall self-worth through 10 items on a 4-point Likert scale; total scores range from 0 to 30, with scores < 15 indicating low self-esteem[16,17]. Social anxiety was assessed using the Social Anxiety Scale for Adolescents (SAS-A). This 22-item instrument (18 scored items and 4 filler items), originally developed by La Greca and Lopez and adapted into Turkish by Aydın and Tekinsav-Sütçü, employs a 5-point Likert scale (1="never" to 5="almost always"). Total scores range from 18 to 90; scores > 44 were classified as socially anxious and scores ≤ 44 as non-socially anxious[18,19].

Ethical approval for this study was obtained from the Clinical Research Ethics Committee of Istanbul Faculty of Medicine, Istanbul University (Approval No: 2026/490; Decision No: 06; Date: 26/03/2026). Written informed consent was obtained from all participants and their parents before participation. The study was conducted in accordance with the principles of the Declaration of Helsinki. All methods were performed in accordance with the relevant guidelines and regulations.

All questionnaires were administered face-to-face during outpatient clinic visits under the supervision of the researchers. Participants completed the Rosenberg Self-Esteem Scale (RSES), Child and Adolescent Bullying Scale–9 Short Form (CABS-9), and Social Anxiety Scale for Adolescents (SAS-A) in the presence of their parents. The purpose of the questionnaires was explained before administration, and when participants had difficulty understanding any questions, additional clarification was provided with the assistance of their parents to ensure accurate responses.

Statistical analysis

Statistical analyses were performed using SPSS v.26 (macOS, IBM Corp., Armonk, NY, USA).

The sample size was calculated using G*Power 3.1.9 (Heinrich Heine University, Düsseldorf, Germany) based on RSES scores. With $\alpha = 0.05$, power $(1-\beta) = 0.95$, and an effect size of 0.88, a minimum of 30 participants per group was required. Descriptive statistics were calculated for demographic and clinical variables. Continuous variables were expressed as mean (standard deviation) and categorical variables as number (percentage). The Mann-Whitney U test was used for between-group comparisons of continuous variables, and the Pearson chi-square or Fisher's exact test was used for categorical variables. Current and former brace users were compared with each other and separately with controls; because of the small subgroup sizes, these subgroup analyses were considered exploratory. Within the brace group, Spearman's correlation analysis was used to examine

relationships between age, age at brace initiation, duration of brace use, Cobb angle, daily brace-wear time, and psychosocial scale scores, and CABS-9 scores were compared between Lenke type 1 and other curve types. Correlation strength was interpreted as follows: $r = 0.81–1.00$, excellent; $r = 0.61–0.80$, very good; $r = 0.41–0.60$, good; $r = 0.21–0.40$, fair; and $r = 0.00–0.20$, poor. A sensitivity analysis of the correlation between brace duration and CABS-9 scores was performed in current brace users only. A p value of < 0.05 was considered statistically significant.

Results

Thirty-one participants who used or had used a brace (brace group; 22 girls, 9 boys) and 32 healthy controls (21 girls, 11 boys) were included. At the time of questionnaire administration, 24 participants in the brace group were actively using a brace and 7 were no longer using one. The mean age was 13.1 (3.0) years in the brace group and 12.5 (2.6) years in the control group. The mean age at brace initiation was 11.5 (2.9) years, and mean brace duration was 17.1 (10.2) months. In the brace group, the mean RSES score was 19.3 (4.5), the mean CABS-9 score was 19.6 (5.9), and the mean SAS-A score was 50.8 (11.0) (Table 1). All patients in the brace group were treated with a Chêneau brace. The mean Cobb angle of the major curve was 31.1° (4.4°; range 25°–39°). According to the Lenke classification, 21 curves (67.7%) were type 1 (1 A, $n = 12$; 1B, $n = 7$; 1 C, $n = 2$), 7 (22.6%) were type 5 C, 2 (6.5%) were type 3 C, and 1 (3.2%) was type 6 C. The mean self-reported daily brace-wear time was 21.2 (1.2) hours (range 19–23), and the median treatment duration was 12 months (range 6–45). All patients reported wearing the brace for at least 18 h per day and were therefore classified as having good compliance (Table 1). All

Table 1 Descriptives of the variables for both groups.

	Brace group (n = 31)	Control group (n = 32)	Total (n = 63)	p value
Age (years) (mean(SD))	13.1 (3.0)	12.5 (2.6)	12.8 (2.8)	0.366
Gender (male/female)	9 / 22	11/ 21	20/ 43	0.649†
RSES (mean(SD))	19.3 (4.5)	20.6 (6.2)	20.0 (5.4)	0.238
CABS-9 (mean(SD))	19.6 (5.9)	12.5 (6.3)	16.0 (7.0)	<0.001*
SAS-A (mean(SD))	50.8 (11.0)	51.3 (10.2)	51.1 (10.5)	0.826
Age to start wearing brace (years) (mean(SD))	11.5 (2.9)	–	–	–
Duration of brace use (months) (mean(SD))	17.1 (10.2)	–	–	–
Cobb angle of major curve (°) (mean(SD); range)	31.1 (4.4); 25–39	–	–	–
Lenke curve type, n (%)	1 A 12 (38.7) 1B 7 (22.6) 1 C 2 (6.5) 3 C 2 (6.5) 5 C 7 (22.6) 6 C 1 (3.2)	–	–	–
Brace type, n (%)	Chêneau: 31 (100)	–	–	–
Daily brace-wear time, self-reported (hours) (mean(SD); range)	21.2 (1.2); 19–23	–	–	–
Good compliance (self-reported wear ≥ 18 h/day), n (%)	31 (100)	–	–	–
Brace status: current/former, n	24 / 7	–	–	–
Time since brace discontinuation in former users (months) (median; range)	3; 3–6	–	–	–

RSES: Rosenberg Self-Esteem Scale; CABS-9: Child-Adolescent Bullying Scale-9 Short Form; SAS-A: Social Anxiety Scale for Adolescents; brace group: participants who currently use or previously used a brace. p values were calculated using the Mann-Whitney U test for continuous variables. †Pearson chi-square test was used for sex distribution. *$p < 0.05$ was considered statistically significant. Clinical characteristics apply to the brace group only; Cobb angle was measured on the most recent radiograph at the time of questionnaire administration.

Table 2 Correlation analysis of the variables in brace group.

	Age	RSES	CABS-9	SAS-A
Age				
r	1.000	−0.266	0.120	−0.396*
p	–	0.147	0.521	0.027
Age to start wearing brace				
r	0.917*	−0.310	−0.040	−0.351
p	<0.001	0.090	0.830	0.053
Duration of brace use				
r	−0.314	0.025	0.397*	0.167
p	0.085	0.894	0.027	0.369
RSES				
r	−0.266	1.000	0.144	0.050
p	0.147	–	0.439	0.790
CABS-9				
r	0.120	0.144	1.000	−0.204
p	0.521	0.439	–	0.272
SAS-A				
r	−0.396*	0.050	−0.204	1.000
p	0.027	0.790	0.272	–

RSES: Rosenberg Self Esteem Scale, CABS-9: Child-Adolescent Bullying Scale-9 Short Form, SAS-A: Social anxiety scale for adolescents,
r: correlation coefficient,
*$p<0.05$ is statistically significant for Spearman's Correlation Analysis. Correlations of CABS-9 scores with Cobb angle (r=-0.149, $p=0.424$) and daily brace-wear time (r=-0.080, $p=0.667$) are reported in the Results.

Table 3 Categorization of the scale scores and inter-group analysis of the variables for both groups.

	Brace group (n=31)	Control group (n=32)	*p*
RSES	19.3 (4.5)	20.6 (6.2)	p^1=0.238
Normal (≥15)	25 (80.6%)	28 (87.5%)	
Low self-esteem (<15)	6 (19.4%)	4 (12.5%)	p^2=0.509
CABS-9	19.6 (5.9)	12.5 (6.3)	p^1<0.001*
No-to-minimal exposure (9–17)	9 (29%)	28 (87.5%)	p^2<0.001*
Exposure (18–26)	19 (61.3%)	2 (6.3%)	
High exposure (27–36)	3 (9.7%)	2 (6.3%)	
SAS-A	50.8 (11.0)	51.3 (10.2)	p^1 =0.826
Non-socially anxious (≤44)	8 (25.8%)	8 (25%)	p^2=0.941
Socially anxious (>44)	23 (74.2%)	24 (75%)	

RSES: Rosenberg Self Esteem Scale, CABS-9: Child-Adolescent Bullying Scale-9 Short Form, SAS-A: Social anxiety scale for adolescents, brace group: participants who currently use or previously used a brace, *$p<0.05$ is statistically significant, p^1 for Mann-Whitney-U test, p^2 for Pearson chi-square test (Fisher's exact test for RSES categories).

seven former users had discontinued bracing because treatment was completed, 3–6 months (median 3 months) before questionnaire administration.

When examining the correlation of variables within the brace group, a negative fair correlation was found between age and SAS-A scores (r=-0.396, $p=0.027$); a positive fair correlation was found between the duration of brace use and CABS-9 ($r=0.397$, $p=0.027$). There was no correlation between other variables (Table 2). CABS-9 scores were not significantly correlated with Cobb angle (r=-0.149, $p=0.424$) or daily brace-wear time (r=-0.080, $p=0.667$) and did not differ between Lenke type 1 curves and other curve types (20.6 (5.6) vs. 17.4 (6.3), $p=0.211$). In current brace users only, the correlation between brace duration and CABS-9 scores was weaker and not statistically significant ($r=0.298$, $p=0.158$).

According to the intergroup analysis, CABS-9 scores differed significantly between the groups ($p<0.001$). Bullying exposure (CABS-9≥18) was present in 22 of 31 participants in the brace group (71.0%) and in 4 of 32 controls (12.5%) ($p<0.001$) (Table 3).

In the exploratory subgroup analysis (Table 4), former brace users ($n=7$) were older than current users ($n=24$) (17.3 (0.8) vs. 11.9 (2.1) years, $p<0.001$) and had started brace treatment at an older age (15.6 (1.0) vs. 10.3 (2.1)

Table 4 Exploratory comparison of current and former brace users with each other and with healthy controls.

	Current brace users (n = 24)	Former brace users (n = 7)	p (current vs. former)	Controls (n = 32)	p (current vs. controls)	p (former vs. controls)
Age (years)	11.9 (2.1)	17.3 (0.8)	< 0.001*	12.5 (2.6)	0.529	< 0.001*
Sex (male/female)	7 / 17	2 / 5	1.000†	11 / 21	0.777†	1.000†
Age to start wearing brace (years)	10.3 (2.1)	15.6 (1.0)	< 0.001*	–	–	–
Duration of brace use (months) [median]	17.8 (9.1)[12]	14.9 (14.1)[9]	0.039*	–	–	–
Cobb angle (°)	31.7 (4.6)	29.1 (2.7)	0.236	–	–	–
Daily brace-wear time (hours)	21.1 (1.3)	21.3 (0.8)	0.769	–	–	–
Time since brace discontinuation (months), median (range)	–	3 (3–6)	–	–	–	–
RSES	20.0 (4.5)	17.0 (4.3)	0.162	20.6 (6.2)	0.506	0.098
Low self-esteem (< 15), n (%)	4 (16.7)	2 (28.6)	0.596†	4 (12.5)	0.713†	0.290†
CABS-9	19.4 (5.9)	20.3 (6.6)	0.981	12.5 (6.3)	< 0.001*	0.009*
Bullying exposure (CABS-9 ≥ 18), n (%)	17 (70.8)	5 (71.4)	1.000†	4 (12.5)	< 0.001*†	0.004*†
SAS-A	52.2 (8.7)	46.0 (16.6)	0.149	51.3 (10.2)	0.316	0.107
Socially anxious (> 44), n (%)	21 (87.5)	2 (28.6)	0.006*†	24 (75.0)	0.319†	0.030*†

Values are mean (SD) unless otherwise indicated. RSES: Rosenberg Self-Esteem Scale; CABS-9: Child-Adolescent Bullying Scale-9 Short Form; SAS-A: Social Anxiety Scale for Adolescents. p values were calculated using the Mann-Whitney U test; †Fisher's exact test. *$p < 0.05$. Subgroup analyses are exploratory because of the small number of former brace users.

years, $p < 0.001$). CABS-9 scores were similar in current and former users (19.4 (5.9) vs. 20.3 (6.6), $p = 0.981$), and the proportion with bullying exposure was nearly identical (17/24, 70.8% vs. 5/7, 71.4%; $p = 1.000$). Compared with controls, CABS-9 scores were significantly higher in both current ($p < 0.001$) and former users ($p = 0.009$). RSES and SAS-A total scores did not differ significantly between current and former users ($p = 0.162$ and $p = 0.149$, respectively), although fewer former users were classified as socially anxious (2/7 vs. 21/24, $p = 0.006$).

Discussion

The principal finding of this case-control study was that adolescents with AIS treated with bracing had significantly greater exposure to peer bullying than age- and sex-matched healthy controls, as reflected by both CABS-9 scores and bullying-exposure categories; this difference was present in both current and former brace users. In contrast, self-esteem and social anxiety did not differ significantly between groups. In exploratory analyses within the brace group, longer brace duration was associated with greater bullying exposure, and younger age was associated with higher social anxiety scores. These findings suggest that the main psychosocial difference identified in our cohort was related to peer bullying rather than a generalized deterioration across all psychosocial domains.

Bullying in childhood is recognized as an important public health problem and is associated with adverse health, social, and educational outcomes[20]. Bullying involves repeated victimization in the context of a power imbalance and may include verbal, physical, social, and cyber forms. Carrillo et al. reported that approximately 39% of pediatric orthopedic patients experienced moderate-to-severe bullying and identified visible orthopedic devices as an important risk factor[21]. A recent case-control study also reported greater peer victimization among adolescents with AIS than among healthy controls, although brace-treated patients were not evaluated as a distinct treatment-specific cohort[13]. Our findings extend this literature by specifically demonstrating higher bullying exposure in adolescents treated with a scoliosis brace.

The categorical results are also clinically relevant. 71% of brace-treated adolescents scored in the exposure or high-exposure range, compared with 12.5% of controls. In the CABS-9 framework, these categories indicate bullying experiences beyond isolated incidents[15], and such repeated victimization has been associated with depression, anxiety, low self-esteem, school avoidance, and poorer academic performance[8,9,20]. A CABS-9 score of 18 or higher may therefore serve as a practical threshold for identifying brace-treated adolescents who warrant

further psychosocial assessment or referral. However, the categories are based on self-report and should be used as a screening aid rather than as a diagnosis.

Yapar et al. examined stigma in adolescents with AIS and reported relationships between stigma and psychosocial variables in patients receiving brace or surgical treatment[22]. In the present study, however, self-esteem did not differ significantly between the brace and control groups. This finding is consistent with the possibility that the psychosocial effects of brace treatment are not uniform across all domains and that self-esteem may be influenced by adaptation, family support, clinical support, body image, and other individual factors not directly measured in this study.

Danielsson et al. reported that patients treated with a brace for AIS had self-esteem, depression, and life-satisfaction outcomes comparable with the general population at long-term follow-up[23]. Similarly, we found no significant difference in RSES scores between brace-treated adolescents and healthy controls.

Although the mean SAS-A score in the brace group was within a range suggestive of clinically relevant social anxiety, a comparable mean score was observed in the control group, and no significant between-group difference was found (50.8 ± 11.0 vs. 51.3 ± 10.2, $p = 0.826$). Therefore, our findings do not support increased social anxiety in brace-treated adolescents compared with healthy controls. Previous studies have described brace-related stress, restrictions in social participation, and psychological concerns among adolescents with AIS[24,25]. However, CABS-9 and SAS-A scores were not significantly correlated within the brace group (r=-0.204, $p = 0.272$), indicating that greater bullying exposure was not accompanied by higher social anxiety scores in this sample. This lack of association should not be interpreted as evidence that bullying has no psychological effect. Social anxiety is multifactorial and may be influenced by age, coping mechanisms, family and peer support, personality characteristics, and other factors not assessed in this study. The modest sample size may also have limited our ability to detect weaker associations. Notably, younger age was associated with higher SAS-A scores within the brace group, suggesting that developmental vulnerability may be relevant to social anxiety independently of bullying exposure.

Our findings indicate increased bullying exposure among adolescents treated with a brace for AIS. Previous literature suggests that children and adolescents with visible physical conditions, physical differences, or medical devices may be particularly vulnerable to peer bullying[26]. Brace treatment may similarly increase social visibility by altering body contour, clothing choices, and movement and may contribute to a perception of being different from peers. This interpretation is consistent with the qualitative experiences reported by brace-treated adolescents in school settings[12]. Nevertheless, because the present study was observational, these findings should not be interpreted as establishing a causal effect of brace use on bullying. The higher CABS-9 scores in the brace group are also consistent with broader evidence linking appearance-related victimization with adverse psychosocial outcomes in adolescents[27].

Our study focuses on a specific treatment context: adolescents with AIS who are currently using or have previously used a scoliosis brace. Brace duration was positively correlated with CABS-9 scores ($r=0.397$, $p=0.027$); however, this correlation was weaker and not statistically significant when the analysis was restricted to current brace users. It should therefore be interpreted cautiously, particularly because the cross-sectional design does not establish temporality or causality.

Bullying exposure was not associated with curve severity, curve type, or daily brace-wear time in this cohort. However, the brace group was clinically homogeneous: all patients wore the same brace type, Cobb angles ranged within a narrow interval (25°–39°), and all reported good compliance with 19–23 h of daily wear. Limited variability and the small sample size may have reduced our ability to detect these associations; the null findings should not be taken as evidence that disease severity or brace prescription is unrelated to bullying. Conversely, this homogeneity makes it less likely that the between-group difference was driven by a subgroup with markedly more severe deformity or a different brace regimen.

Current and former brace users were combined in the main analysis because both shared the exposure of interest, brace treatment during adolescence, and because the subgroup analysis showed nearly identical bullying scores and exposure rates in the two groups, with each subgroup scoring higher than controls. Former users

were, however, older and had started bracing later. Because all had completed treatment only 3–6 months before questionnaire administration, the recall period was short, but recall bias cannot be fully excluded. The lower proportion of former users classified as socially anxious may reflect their older age, given the negative correlation between age and SAS-A scores, rather than an effect of brace discontinuation. Given the small number of former users, these comparisons should be regarded as exploratory.

Several unmeasured factors may also influence the interpretation of these results. Socioeconomic status and school environment, including school type, class size, the anti-bullying climate, and teachers' awareness of the child's treatment, may affect both the likelihood of victimization and how it is reported. Peer support, psychological resilience, and coping strategies may buffer the psychological effects of bullying[7,8] and may partly explain why greater bullying exposure in the brace group was not accompanied by lower self-esteem or higher social anxiety. Body-image perception may act as a mediator, because a visible brace or trunk asymmetry may alter self-image and make adolescents more conspicuous to peers[5]; it may also influence how adolescents perceive and report peer behavior. Because these factors were not measured, residual confounding cannot be excluded, and the observed difference should be interpreted as an association rather than as an effect of brace treatment.

Several limitations should be considered. First, all psychosocial data were based on self-report and are therefore susceptible to social desirability and reporting bias; in addition, questionnaires were completed in the presence of parents, which may have influenced responses. Second, seven participants were no longer using a brace at the time of questionnaire administration; although all had completed treatment only 3–6 months earlier, retrospective reporting of bullying experiences during the brace-treatment period may still have been affected by recall bias. Third, brace compliance was based on patient and parent report rather than objective monitoring; all patients reported good compliance, which may overestimate actual wear time and precluded analysis of the relationship between compliance and bullying. Fourth, the study did not include adolescents with AIS who were not treated with a brace (for example, those under observation or receiving exercise-based treatment). Consequently, it cannot be determined whether the higher bullying exposure is associated with scoliosis itself, with the visibility and restrictions of brace treatment, with body-image concerns, or with other disease-related factors; the findings indicate an association with brace-treated AIS rather than an effect of bracing per se. Fifth, the sample was small (31 brace-treated adolescents and 32 controls). The limited sample size may have prevented the detection of smaller but potentially clinically relevant differences in self-esteem or social anxiety. The subgroup analyses, particularly those involving only seven former brace users, were underpowered, and the correlations, which were not adjusted for multiple comparisons, should be considered hypothesis-generating. Sixth, controls were matched to the brace group only at the group level for age and sex and were recruited from routine health check-up visits; differences in socioeconomic status, school environment, and other characteristics therefore cannot be excluded. Finally, participants were recruited from a single tertiary center in Türkiye, and cultural attitudes, school environments, and perceptions of brace treatment may differ across settings, which limits generalizability. Future multicenter studies with larger cohorts should include adolescents with AIS managed with observation or exercise-based treatment alone, as well as those undergoing surgical treatment, to determine whether bullying exposure and other psychosocial outcomes differ according to treatment modality.

Conclusion

This case-control study demonstrated that adolescents with AIS treated with bracing were exposed to significantly higher levels of peer bullying than age- and sex-matched healthy controls. In contrast, no significant between-group differences were observed in social anxiety or self-esteem. Higher bullying exposure was observed in both current and former brace users. Because non-braced adolescents with AIS were not included, the study cannot determine whether this association reflects brace treatment, scoliosis itself, or related factors. Within the brace group, longer brace duration was associated with greater bullying exposure in exploratory analyses, while

younger age was associated with higher social anxiety scores. These findings highlight the importance of specifically addressing peer bullying during routine follow-up of adolescents undergoing brace treatment for AIS.

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Author contributions Y.F.A. conceived and designed the study. Y.F.A., M.K., and B.D. collected the data and performed the clinical evaluations. Y.F.A. and T.Y. performed the statistical analyses and interpreted the data. M.D.K. contributed to the psychosocial assessment and interpretation of patient-reported outcome measures. T.A. supervised the study design and critically revised the manuscript for important intellectual content. Y.F.A. drafted the main manuscript text. All authors reviewed, edited, and approved the final version of the manuscript.

Data availability The de-identified dataset supporting the findings of this study is provided as Supplementary Data with this article.

Declarations

Competing interests The authors declare no competing interests.

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