Annals Journal of Dental and Medical Assisting
2025, Volume 5, Issue 1, Page No: 120-125
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Available online at: www.tsdp.net

ISSN: 3062-3510

Original Article

Evaluation of Sleep-Disordered Breathing Risk and Associated Factors in Children Undergoing Orthodontic Treatment: A Cross-Sectional Study

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Received: 11 March 2025; **Revised:** 07 June 2025; **Accepted:** 08 June 2025

ABSTRACT

Sleep-disordered breathing (SDB) encompasses conditions that increase the tendency of the upper airway to collapse during sleep, potentially affecting children's health and development. This study aimed to determine how common SDB is in children undergoing orthodontic treatment and to identify factors that may contribute to its occurrence. A cross-sectional analysis was performed on 60 children aged 7–12 years who visited the orthodontic clinics at Aga Khan University Hospital, Karachi, Pakistan. Parents or guardians completed a validated Pediatric Sleep Questionnaire (PSQ) and an additional survey on health history and potential risk factors for SDB. Logistic regression analysis was used to explore associations between SDB risk and relevant factors. Twelve children (20%) were classified as high risk for SDB (PSQ score ≥33%). Children with a history of allergies were nearly four times more likely to be at high risk (odds ratio = 3.96, p = 0.049). Male children showed a higher likelihood of SDB compared to females. SDB affected one in five children in this orthodontic population, with allergies more prevalent among those at high risk. These findings highlight the importance of integrating routine SDB screening in orthodontic care to identify children who might not be detected in standard pediatric settings.

Keywords: Pediatric Sleep Questionnaire, Pediatric, Sleep, Sleep disorders, Sleepiness

How to Cite This Article: Coppola R, Galofaro V, Iacono VJ. Evaluation of Sleep-Disordered Breathing Risk and Associated Factors in Children Undergoing Orthodontic Treatment: A Cross-Sectional Study. Ann J Dent Med Assist. 2025;5(1):120-5. https://doi.org/10.51847/ifa53LoqcH

Introduction

Sleep-disordered breathing (SDB) encompasses a spectrum of conditions that compromise the upper airway, increasing its tendency to collapse during sleep [1]. This disorder can substantially impact quality of life (QoL) in both children and adults [2]. Notably, the manifestation of SDB differs between these populations [3]. In adults, SDB shows a higher prevalence in males, indicating a gender-related susceptibility [4], whereas in children, no clear gender disparity is observed [1]. Etiologically, obesity is the predominant factor in adults, while adenotonsillar hypertrophy is the main contributor in the pediatric population [5, 6]. Routine orthodontic assessments provide a unique opportunity for clinicians to identify these features, highlighting the important role of orthodontists and general practitioners in early detection and referral [7].

Through detailed physical and cephalometric evaluations, several craniofacial and dental risk factors for SDB have been identified, including narrow maxillae, V-shaped arch forms, retrognathic mandibles, enlarged tongues, and bidental arch constriction [8, 9]. Additionally, Topaloglu-Ak *et al.* reported that pediatric sleep disturbances are exacerbated by sleep bruxism, temporomandibular disorders (TMDs), and untreated dental caries [10].

Polysomnography (PSG) remains the gold standard for diagnosing SDB [11]. This comprehensive evaluation

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includes electrooculography, electroencephalography, chin electromyography, airflow measurement, respiratory effort monitoring, oxygen saturation tracking, and electrocardiography recording. In pediatric patients, PSG requires specialized training to accommodate children and guide their families through the monitoring process. While the procedure parallels adult PSG, key differences exist, particularly in electrode placement, sleep stage classification, respiratory assessment, and severity evaluation [12]. Despite its diagnostic value, PSG is limited by its time-intensive nature, high initial costs, and the need for expert sleep physiologists [13]. To address these challenges, predictive screening tools such as the Berlin Questionnaire (BQ), STOP-BANG, STBUR (Snoring, Trouble Breathing, and Un-Refreshed), and the Pediatric Sleep Questionnaire (PSQ) have been developed [14].

The PSQ is a validated and reliable screening instrument designed to assess SDB risk in children [11]. It consists of 22 items evaluating snoring frequency, observed apneas, breathing difficulties, and behavioral concerns such as inattentiveness and hyperactivity. This tool helps identify children who may require further PSG evaluation for a comprehensive assessment [11]. Early detection of SDB is critical, as untreated cases may contribute to the development of attention-deficit/hyperactivity disorder (ADHD) and cardiovascular complications, including atherosclerosis, ultimately diminishing QoL [15, 16]. Consequently, screening for SDB within the pediatric orthodontic population allows clinicians to intervene early, address associated risk factors, and enhance patient care.

The objective of this study was to evaluate the risk of SDB and its associated factors in the pediatric orthodontic population using the PSQ.

Material and Methods

Following approval from the institutional ethical review committee (ERC) (No. 2022-7818-22971), a questionnaire-based cross-sectional study was conducted at Aga Khan University Hospital, Karachi, Pakistan. The sample size was calculated using OpenEpi® software, version 3.01 (https://www.openepi.com/Menu/OE_Menu.htm), based on the SDB prevalence of 3.3% reported by Sogut *et al.* in Turkish children [17]. Considering an absolute precision of 5% and a 95% confidence interval (CI), a minimum sample of 50 participants was required. To account for potential attrition, the sample size was increased by 20%, resulting in a final target of 60 subjects.

The study included 60 pediatric patients aged 7–12 years who presented for orthodontic consultation and subsequent treatment. The age range was selected by the research team, consisting of a research assistant, two orthodontic residents, and an orthodontist, to ensure appropriate representation of the pediatric orthodontic population. Inclusion criteria encompassed children aged 7–12 years seeking orthodontic care, with parents or guardians providing informed consent and monitoring their children's sleep patterns. Patients with craniofacial or dental anomalies, syndromes, trauma, or prior orthodontic treatment were excluded to maintain sample homogeneity and minimize potential bias.

During the initial visit, parents or guardians completed informed consent forms, and baseline records of the patients were obtained. Subsequently, they filled out the Pediatric Sleep Questionnaire (PSQ), assisted by a member of the orthodontic team. The PSQ, developed and validated by Chervin *et al.*, is a reliable instrument for evaluating pediatric SDB [11]. This questionnaire contains 22 items, with responses scored as 'yes' = 1, 'no' = 0, and 'don't know' = 00. It assesses the frequency of observed apneas, snoring, daytime sleepiness, breathing difficulties, and attentional issues in children [11]. A score of 0.33 (33% positive responses) or higher is considered indicative of a high risk for SDB, with increasing percentages representing greater likelihood of the disorder [1, 11].

Additionally, parents or guardians completed a health history questionnaire to capture environmental and health-related factors contributing to pediatric SDB [1]. This included questions regarding asthma, allergies, presence of indoor pets, preterm birth, nocturnal enuresis, family history of sleep apnea, and exposure to tobacco smoke [1]. Patients identified as high-risk for SDB were provided appropriate follow-up care and referred to relevant specialists as needed.

Table 1. Pediatric Sleep Questionnaire (PSQ) [11]

No.	Questions	Responses
1.	While sleeping, does your child:	
	- Snore more than half the time?	Yes / No / Don't Know
	- Always snore?	Yes / No / Don't Know
	- Snore loudly?	Yes / No / Don't Know
	- Have heavy or loud breathing?	Yes / No / Don't Know

	- Struggle to breathe or have trouble breathing?	Yes / No / Don't Know
2.	Have you ever noticed your child stop breathing during sleep?	Yes / No / Don't Know
3.	Does your child:	
	- Breathe through the mouth during the day?	Yes / No / Don't Know
	- Wake up with a dry mouth in the morning?	Yes / No / Don't Know
	- Sometimes wet the bed?	Yes / No / Don't Know
	Does your child:	
4.	- Feel unrefreshed upon waking in the morning?	Yes / No / Don't Know
	- Experience sleepiness during the day?	Yes / No / Don't Know
5.	Has a teacher or supervisor noted that your child seems sleepy during the day?	Yes / No / Don't Know
6.	Is it difficult to wake your child in the morning?	Yes / No / Don't Know
7.	Does your child wake up with headaches?	Yes / No / Don't Know
8.	Has your child's growth rate slowed since birth?	Yes / No / Don't Know
9.	Is your child overweight?	Yes / No / Don't Know
	Does your child often:	
	- Seem not to listen when spoken to directly?	Yes / No / Don't Know
	- Struggle to organize tasks or activities?	Yes / No / Don't Know
10.	- Get easily distracted by external stimuli?	Yes / No / Don't Know
	- Fidget with hands or feet, or squirm in their seat?	Yes / No / Don't Know
	- Act as if "driven by a motor" or always be on the go?	Yes / No / Don't Know
	- Interrupt or intrude on others (e.g., butt into conversations or games)?	Yes / No / Don't Know

Statistical analysis

Analyses were performed using IBM SPSS Statistics (version 23.0, IBM Corp., Armonk, USA) and Stata software (version 12.0, StataCorp, College Station, USA). Data distribution was examined with the Shapiro–Wilk test, which showed that the variables did not follow a normal distribution. Patient age was summarized using median (Me) and interquartile range (IQR). Responses from the Pediatric Sleep Questionnaire (PSQ) were obtained for 60 participants, with scores of 33% or higher classified as high risk for sleep-disordered breathing (SDB). The prevalence of high-risk cases and associated contributing factors were tabulated. All participants also completed additional health history questionnaires to evaluate their overall health status, and results were compared between the high- and low-risk SDB groups. Factors influencing SDB were further examined using logistic regression, adopting a significance threshold of $p \leq 0.05$.

Results

The study cohort consisted of 60 children, evenly split between males and females (30 each) **(Figure 1)**. The median age of participants was 10.04 years, with an interquartile range from 8.00 to 11.33 years **(Table 2)**.

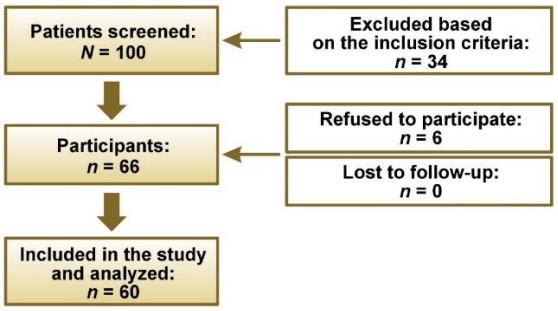

Figure 1. Flow diagram of the study

Table 2. Demographics of the study group (N = 60)

Gender	Age [years]
Male (n = 30)	9.33 (8.00–11.08)
Female (n = 30)	10.30 (8.00–11.66)
Total (N = 60)	10.04 (8.00–11.33)

Data presented as median (interquartile range) (Me (IQR)).

Out of the sixty participants, 12 (20%) were identified as being at high risk for sleep-disordered breathing (SDB), defined by a PSQ score of ≥33%. Analysis of the supplementary health history questionnaire revealed that 36.7 percent of the study population suffered from environmental allergies (such as dust), 13.3 percent were exposed to tobacco smoke, and 8.3 percent had indoor pets **(Table 3)**. Within the high-risk SDB group, 8 were male and 4 were female. Among these high-risk individuals, 7 reported environmental allergies, compared to 15 patients with environmental allergies in the low-risk SDB group **(Table 4)**.

Table 3. Risk of sleep-disordered breathing (SDB) and its associated factors (N = 60)

Variable	n (%)
SDB	12 (20.0)
Bed wetting	2 (3.3)
Allergy	22 (36.7)
ADHD	4 (6.7)
Indoor pets	5 (8.3)
Smoke exposure	8 (13.3)

ADHD – attention-deficit/hyperactivity disorder.

Table 4. Associated environmental and health factors in the high-risk vs. low-risk sleep-disordered breathing (SDB) groups (N = 60) (Fisher's exact test)

Variable	High-risk SDB group n = 12 M: n = 8 F: n = 4	Low-risk SDB group n = 48 M: n = 22 F: n = 26	p-value
Bed wetting	1 (8.3)	1 (2.1)	0.363
Allergy	7 (58.3)	15 (31.3)	0.102
ADHD	2 (16.7)	2 (4.2)	0.175
Indoor pets	1 (8.3)	4 (8.3)	1.000
Smoke exposure	1 (8.3)	7 (14.6)	1.000

Data presented as number (percentage) (n (%)).
M – male; F – female.

Logistic regression was conducted to identify factors linked to sleep-disordered breathing (SDB). The analysis revealed that a history of allergies was significantly associated with SDB, with affected patients being 3.96 times more likely to develop the condition (p = 0.049). Patients diagnosed with ADHD exhibited a 5.22-fold higher likelihood of having SDB compared to those without ADHD, although this association did not reach statistical significance (p = 0.120). Similarly, children who experienced bedwetting showed a 4.80 times greater risk of SDB than those who did not, but this finding was also not statistically significant (p = 0.281) **(Table 5)**.

Table 5. Factors associated with sleep-disordered breathing (SDB) (logistic regression analysis)

Variable	OR	95% CI	p-value
Bed wetting	4.80	0.276–83.340	0.281
Allergy	3.96	1.007–15.618	0.049*
ADHD	5.22	0.649–42.039	0.120
Indoor pets	1.12	0.113–11.175	0.920
Smoke exposure	0.60	0.066–5.447	0.650

OR – odds ratio; CI – confidence interval; * statistically significant ($p \leq 0.05$).

Discussion

This study aimed to explore the prevalence of sleep-disordered breathing (SDB) and its related factors in an Asian pediatric orthodontic population. Within our tertiary care hospital sample, 20% of children were identified as being at high risk for SDB. Comparing these findings with international literature, a recent study from Alberta, Canada, reported a prevalence of 10.8% in their orthodontic cohort [1]. Other investigations focusing on orthodontic populations have documented prevalence rates of 7.3% in site-specific samples [13] and 18% in university-based cohorts [18]. When applying the same PSQ tool, German preschool children showed a lower prevalence of 3.3% [19]. According to Graf *et al.*, 53% of children included in their study were reported by parents to snore [20]. A meta-analysis by Lumeng and Chervin summarized parent-reported nocturnal childhood snoring prevalence between 1.5% and 12%, with a pooled average of 7.45% [21]. Ancoli-Israel *et al.* compared SDB risk among Caucasian and African-American children, finding that African-Americans had a substantially higher risk of severe SDB, with a relative risk approximately double that of Caucasians (RR = 2.13) [22]. Additional research has also highlighted a higher SDB risk among African-American children relative to Asian, Hispanic, and European populations [23].

At the regional level, studies report a 21% prevalence of SDB among Saudi children [24]. In Japan, Kobayashi *et al.* found the incidence of pediatric obstructive sleep apnea (OSA) to be 7.9% [25]. In India, researchers using a modified STOP-BANG questionnaire estimated a 14% prevalence of OSA in adolescents [26].

Accurate prediction of disease risk is a critical skill for clinicians. Prior investigations have identified several craniofacial and physiological factors that may predispose children to SDB, including a convex facial profile, mandibular retrusion, tonsillar enlargement, and early-onset mouth breathing [27]. Additional predictive markers include body adiposity and distal molar occlusion between ages 6 and 8 years [27]. Unlike adults, in whom SDB is primarily linked to obesity, pediatric SDB is often associated with adenotonsillar hypertrophy, allergic conditions, recurrent colds, and habitual mouth breathing [28]. Our findings align with previous research, indicating higher SDB susceptibility in males with environmental allergies. Allergic reactions can disrupt breathing patterns through multiple mechanisms, including: (1) inflammatory mediators such as histamine, which alter sleep-wake cycles; (2) nasal obstruction, contributing to snoring and impaired sleep quality; and (3) dysfunction of autonomic reflexes, including the

trigeminocardiac and nasotrigeminal reflexes, which play essential roles in sleep regulation [29].

Nocturnal enuresis (NE) has also been identified as a relevant predictive factor for SDB. A study from Taiwan reported a positive correlation among environmental allergies, SDB, and childhood NE [30]. Similarly, a prospective study involving 4,318 children found that 33.1% of those with SDB experienced NE [18]. These observations are consistent with our findings, which showed a 4.8-fold increased likelihood of SDB among children with NE. Furthermore, Lai *et al.* confirmed that children with allergic rhinitis, particularly males, have a higher incidence and risk of NE [31].

Body mass index (BMI) has been highlighted as another contributing factor for OSA. Barone *et al.* investigated the relationship between overweight status, NE, and SDB, reporting no statistically significant association [32]. Nonetheless, when considered individually, both overweight and NE were frequently observed among children with OSA [32]. In our study, we similarly found these factors to have no significant association with SDB risk.

The Pediatric Sleep Questionnaire (PSQ) employed in this study is among the most widely recognized tools for assessing the risk of sleep-disordered breathing (SDB) in children and adolescents, suitable for use in individuals aged 2–18 years. This comprehensive instrument demonstrates a sensitivity of 0.87 and a specificity of 0.85 [11]. Although some researchers consider the PSQ time-intensive, Kadmon *et al.* developed a shorter version called I'M SLEEPY, which includes eight items and has a sensitivity and specificity of 82 percent and 50 percent, respectively [33]. A systematic review and meta-analysis published in 2020 reported that the PSQ exhibited the highest sensitivity (74 percent) for detecting moderate pediatric obstructive sleep apnea syndrome (OSAS) [34]. For mild and severe pediatric OSAS, the PSQ and pulse oximetry (PO) were shown to have comparable sensitivity, suggesting that PO, alongside the PSQ, can serve as an effective screening tool when polysomnography (PSG) is not feasible [34].

Structural features of the craniofacial complex may influence SDB risk. Dastan *et al.* observed a significantly reduced upper airway volume in individuals with a dolichofacial pattern [35]. Orthodontic interventions during growth, such as functional appliances, as well as surgical procedures in adults, can help mitigate this reduction, improving both sleep quality and overall quality of life [36]. Management of SDB depends on the patient's age and the severity of the condition. Treatment options range from non-surgical approaches, such as mandibular advancement devices and continuous positive airway pressure, to surgical interventions like adenoidectomy and maxillomandibular advancement [37, 38]. Maxillary expansion, through methods such as mini-screw-assisted rapid maxillary expansion (MARPE) in adolescents and surgically assisted rapid maxillary expansion (SARPE) in adults, is another established modality [38]. A newer technique, endoscopically assisted surgical expansion (EASE), has been proposed for obstructive sleep apnea (OSA). This procedure is less invasive and reportedly yields more consistent outcomes compared to traditional maxillary expansion techniques. EASE is performed under general anesthesia using nasal endoscopy to guide midpalatal osteotomy and separation of the pterygomaxillary suture with a piezoelectric blade, followed by transpalatal distractor expansion of the nasal floor until symptoms improve or 7 mm of expansion is achieved. Appliance removal is recommended under local anesthesia after two months [39].

The American Association of Orthodontists (AAO) white paper on OSA emphasizes the orthodontist's role in screening, diagnosing, and appropriately referring patients [40]. Orthodontists intending to manage SDB should acquire updated knowledge, training, and skills in this domain. Encouragingly, current evidence suggests that orthodontic treatment does not cause or exacerbate OSA; instead, certain orthodontic interventions may confer benefits. Nonetheless, an interdisciplinary approach remains optimal for patient care.

As with most observational studies, including ours, potential biases and confounding variables must be considered. This study's limitations include a relatively small sample size, a single-center design, and the inability to generalize findings across the broader Asian population. Another limitation is the lack of objective SDB evaluation using PSG. However, our focus was on assessing SDB risk, and the PSQ served as a cost-effective and practical alternative, particularly for patients not deemed high-risk, where the initial installation costs of PSG may be prohibitive. Despite these constraints, we took careful steps to mitigate potential biases, applying rigorous statistical controls and using a validated, reliable instrument to measure SDB symptoms accurately within the orthodontic population.

The literature indicates that adults who exhibit sleep bruxism may experience impaired sleep quality, which could contribute to the development of temporomandibular disorders (TMDs) [41, 42]. Future research should explore the relationship between sleep

bruxism and its potential links to both SDB and TMDs. Additional recommendations include expanding the sample size and incorporating other non-invasive, cost-effective measures that could serve as predictors of SDB.

The observed differences in health profiles between children attending general pediatric clinics and those visiting orthodontic clinics suggest that orthodontists may encounter a subgroup of patients at higher risk for SDB—individuals who might otherwise remain undetected in other healthcare settings. Therefore, proactive SDB screening by orthodontic practitioners can be crucial for early identification and management, enabling a multidisciplinary approach to diagnosis and treatment.

Conclusions

In this study, the prevalence of SDB within the pediatric orthodontic population was 20%. Allergic conditions were more frequently observed among children in the high-risk SDB group.

These findings highlight the importance for orthodontic clinicians to implement routine SDB screening in their practice, as they may encounter a subset of at-risk patients who could be overlooked in general pediatric care.

Acknowledgments: None

Conflict of Interest: None

Financial Support: None

Ethics Statement: None

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