

# Pediatric sleep questionnaire-based risk of obstructive sleep apnea in children with morbid obesity

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## ABSTRACT

**Objective:** Obstructive sleep apnea (OSA) in children with morbid obesity is an important health problem requiring early diagnosis and intervention due to its high prevalence and multidimensional clinical effects. This study aimed to assess the Pediatric Sleep Questionnaire (PSQ)-based OSA risk in children with morbid obesity and to evaluate associated clinical and laboratory findings.

**Materials and Methods:** This retrospective cross-sectional study included children with morbid obesity who were admitted to a tertiary pediatric pulmonology outpatient clinic between 2021 and 2023 and followed up for at least one year. Morbid obesity was defined as a body mass index (BMI)  $\geq 99^{\text{th}}$  percentile. Patient clinical characteristics were obtained from the electronic medical record system. OSA was evaluated using the PSQ. Patients were divided into two groups according to the PSQ cut-off value: Group 1 included children with PSQ scores  $<0.33$ , and Group 2 included children with PSQ scores  $\geq 0.33$ .

**Results:** This study included 47 children with morbid obesity, with a median age of 15.0 years (Q1–Q3: 12.5–16.5); 21 patients (44.7%) were male. The most common complaint was fatigue with exertion ( $n=41$ , 87.0%). The median PSQ score was 0.42 (Q1–Q3: 0.25–0.59). A negative correlation was found between PSQ score and oxygen saturation ( $r=-0.289$ ,  $p=0.049$ ) and FEF25–75 (L) ( $r=-0.490$ ,  $p=0.011$ ). According to the evaluation of PSQ cut-off values, hypercarbia was more frequently detected in Group 2 than in Group 1 ( $p=0.047$ ). Only four of the 47 patients underwent PSG; three of these patients had an apnea-hypopnea index (AHI)  $>5$ , and a these three patients were in Group 2 based on their PSQ scores.

**Conclusion:** In this study, the risk of OSA in children with morbid obesity, as assessed by the PSQ, was found to be high. Our findings highlight the importance of clinical awareness of OSA in children with morbid obesity. Further PSG-based studies with larger sample sizes are needed to better establish the potential role of the PSQ as a feasible alternative screening tool for early diagnosis.

**Keywords:** Children, obesity, obstructive sleep apnea, polysomnography

## Introduction

Obstructive sleep apnea (OSA) is a condition characterized by recurrent partial or complete airway obstruction, which can result in hypoxia, hypercapnia, and respiratory disorders during sleep. OSA occurs in 1–4% of healthy children, with a prevalence of up to 60% in children with morbid obesity (1). Symptoms indicative of OSA include snoring, paradoxical chest–abdominal movements, apnea attacks, nocturnal enuresis, and abnormal sleep positions. Morning headaches, daytime sleepiness, fatigue, attention deficits, and behavioral problems may be observed while awake. The effects of OSA on children are not merely physical, but can be neurocognitive, behavioral, and psychosocial. Left untreated, OSA could lead to serious long-term consequences such as cardiovascular diseases and metabolic disorders (1–4). Early diagnosis in

patients with morbid obesity at high risk of OSA is beneficial in preventing these associated complications (5–9).

While the gold standard diagnostic method, polysomnography (PSG), objectively confirms OSA, it is not widely used due to high costs, limited equipment, and the need for specialists (1,4). This results in delays in OSA diagnosis, particularly at centers with limited resources. Alternative screening tools are key in this context. The Pediatric Sleep Questionnaire (PSQ) is a valuable screening tool for childhood OSA due to its practical applicability, cost-effectiveness, and high sensitivity (10–12).

The primary aim of this study was to assess PSQ-based OSA risk in children with morbid obesity. The secondary aims were to evaluate patient demographic characteristics and clinical, laboratory, and pulmonary function test findings, and to define accompanying conditions.

## Materials and Methods

### Study design and participants

This retrospective cross-sectional study included children with morbid obesity who were admitted to the Pediatric Pulmonology Outpatient Clinic of Ankara Bilkent City Hospital between 2021 and 2023 and followed up for at least one year. The PSQ was administered during outpatient clinic visits as part of the routine clinical assessment of children with obesity. Patient clinical characteristics and medical records were retrospectively reviewed using the electronic health record system. Patient demographic characteristics (date of birth, gender, body mass index (BMI) percentile) were recorded. Anthropometric values were calculated using the BMI kg/m<sup>2</sup> formula. According to age and gender, a BMI  $\geq$  the 99<sup>th</sup> percentile was considered morbidly obese. BMI percentiles and standard deviation scores (z-scores) were calculated using reference values developed by Neyzi and colleagues (13). Questions regarding OSA symptoms (cough with exertion, cough at night, fatigue on mild exertion, difficulty waking up in the morning, morning headaches, daytime sleepiness, mouth breathing during sleep, snoring, apnea, frequent waking up at night, and nocturnal urinary incontinence) were routinely asked and recorded. Comorbidities (hypertension, diabetes mellitus, etc.) and regularly used medications were also noted. Following systemic physical examination, oxygen saturation was measured by pulse oximetry in room air. Pulmonary function tests with spirometry were administered to cooperative patients. Daytime arterial blood gas analysis was performed during the outpatient clinic evaluation, and hypercarbia was defined as arterial partial pressure of carbon dioxide (PaCO<sub>2</sub>)  $\geq$  45 mmHg (14). Echocardiography and PSG results were recorded where these were performed. The PSQ was administered to all patients.

Symptom assessment, PSQ administration, oxygen saturation measurement, blood gas analysis, and spirometry were performed during the same outpatient clinic visit. Echocardiography results obtained within three months before or after this visit were recorded. PSG results were recorded if available during the minimum one-year follow-up period.

### Procedures

#### *Spirometry*

Spirometry was performed by a single technician according to the American Thoracic Society and European Respiratory Society requirements (15). The same spirometer (winspiroPRO, CareFusion) was used for each participant and calibrated daily with a single 3-L discharge syringe. Patients were seated in an upright position and a nose clip applied during measurement. Spirometry was determined complete when three technically acceptable tests were obtained. Respiratory function test parameters, including forced vital capacity (FVC), forced expiratory volume in 1 second (FEV<sub>1</sub>), the ratio of FEV<sub>1</sub> to FVC (FEV<sub>1</sub>/FVC), and forced expiratory flow at 25% to 75% (FEF<sub>25–75</sub>) were collected. Percent predicted values and z-scores were calculated using the Global Lung Function Initiative's full age prediction equations for spirometry (16).

#### *PSQ*

The PSQ consists of 22 closed-ended questions divided into three sections. Section A includes questions on snoring,

nocturnal cessation of breathing, and mouth breathing; Section B addresses daytime sleepiness, feeling unrefreshed in the morning, difficulty waking, morning headaches, delayed growth, and obesity; and Section C assesses problems with inattention, hyperactivity, and impulsivity. A "yes" response is considered 1; a "no" response is considered 0; a "don't know" response is considered missing. The resulting score is calculated by dividing the number of "yes" responses by the total number of "yes" and "no" responses. A score of 0.33 is used as a cut-off value for OSA screening (11,17). The validated Turkish version of the PSQ was used (18). The questionnaire was provided to the parents/caregivers as a written form during the outpatient clinic visit and was completed by them. In this study, patients were divided into two groups according to this cut-off value: Group 1 included children with PSQ scores <0.33, and Group 2 included children with PSQ scores  $\geq$ 0.33. Group 2 was considered at risk for OSA.

### Statistical analyses

Statistical analyses were performed using SPSS version 28.0 (IBM, SPSS, Chicago, IL, USA). Findings from descriptive analyses were reported as relative and absolute frequencies for categorical variables and as medians (Q1–Q3) for quantitative variables. In all statistical tests,  $p < 0.050$  was considered statistically significant. The Chi-square test ( $\chi^2$ ) was used to analyze the differences between the two groups for categorical data. Where the expected frequency in any cell of the contingency table was less than 5, the  $p$ -value corresponding to the Fisher's exact test was used. The Mann–Whitney U test was used to compare the two groups for quantitative variables. A Spearman's rho correlation was performed.

## Results

A total of 47 children with morbid obesity were included in the study; 26 patients (55.3%) were female. The median age was 15.0 years (12.5–16.5). The median BMI percentile was 99.98% (99.95–99.98), and the median BMI z-score was 3.4 (2.7–4.1). The most frequently reported OSA-related symptoms were fatigue with exertion (87.0%), mouth breathing during sleep (76.6%), daytime sleepiness (70.2%), and snoring (70.2%). Patient demographic characteristics and clinical findings are presented in Table I, and spirometry and blood gas results are presented in Table II.

The median PSQ score was 0.42 (0.25–0.59). According to the PSQ cut-off value of 0.33, 16 patients (34.0%) were classified as Group 1 and 31 patients (66.0%) as Group 2. Therefore, approximately two-thirds of the study population were considered to be at risk for OSA based on PSQ scores.

PSQ scores showed a positive trend with increasing BMI percentiles and BMI z-scores; however, these correlations did not reach statistical significance ( $r = 0.099$ ,  $p = 0.509$  and  $r = 0.080$ ,  $p = 0.591$ , respectively). A significant negative correlation was found between PSQ score and peripheral oxygen saturation (SpO<sub>2</sub>) ( $r = -0.289$ ,  $p = 0.049$ ). Similarly, PSQ score was negatively correlated with FEF<sub>25–75</sub> L ( $r = -0.490$ ,  $p = 0.011$ ). No significant correlations were observed between PSQ score and FEV<sub>1</sub> L ( $r = -0.380$ ,  $p = 0.056$ ) or FVC L ( $r = -0.314$ ,  $p = 0.118$ ) (Table III).

**Table I: Patient demographic characteristics and clinical findings**

| Variables                               | Values              |
|-----------------------------------------|---------------------|
| Age*                                    | 15.0 (12.5-16.5)    |
| Female†                                 | 26 (55.3)           |
| BMI percentile*                         | 99.98 (99.95-99.98) |
| BMI z-score*                            | 3.4 (2.7-4.1)       |
| SpO <sub>2</sub> *                      | 98.0 (97.0-98.0)    |
| Symptoms†                               |                     |
| Rapid fatigue during exertion           | 41 (87.2)           |
| Mouth breathing during sleep            | 36 (76.6)           |
| Excessive daytime sleepiness            | 33 (70.2)           |
| Habitual snoring                        | 33 (70.2)           |
| Morning headaches                       | 21 (44.7)           |
| Difficulty waking in the morning        | 19 (40.4)           |
| Exertional cough                        | 14 (29.8)           |
| Nocturnal cough                         | 9 (19.1)            |
| Witnessed apnea during sleep            | 9 (19.1)            |
| Frequent nocturnal awakenings           | 7 (14.9)            |
| Echocardiography†                       |                     |
| Normal                                  | 39 (86.7)           |
| Concentric left ventricular hypertrophy | 6 (13.3)            |
| Comorbidities†                          |                     |
| Diabetes mellitus                       | 12 (25.5)           |
| Hypertension                            | 7 (14.9)            |

\*: median (Q1–Q3), †: n(%), **BMI**: Body mass index, **SpO<sub>2</sub>**: Peripheral oxygen saturation

**Table II: Patient spirometry and blood gas results**

| Variables                     | Values             |
|-------------------------------|--------------------|
| Spirometry* (n= 30)           |                    |
| FEV <sub>1</sub> %            | 97.5 (90.0-107.5)  |
| FEV <sub>1</sub> lt           | 3.3 (2.7-3.8)      |
| FEV <sub>1</sub> z-score      | -0.63 (-0.9-0.4)   |
| FVC %                         | 95.0 (87.0 -102.0) |
| FVC lt                        | 3.7 (2.9- 4.4)     |
| FVC z-score                   | -1.1 (-1.5--0.1))  |
| FEV <sub>1</sub> /FVC         | 102.5 (96.0-106.5) |
| FEV <sub>1</sub> /FVC z-score | 0.7 (-0.3-1.6)     |
| FEF25–75 %                    | 102.0 (89.0-114.0) |
| FEF25–75 lt                   | 4.3 (3.2-4.6)      |
| FEF25–75 z-score              | 0.2 (-0.4-0.9)     |
| Blood gas* (n= 44)            |                    |
| PCO <sub>2</sub>              | 42.7 (37.4-45.6)   |

\*: median (Q1–Q3), **FVC**: Forced vital capacity, **FEV<sub>1</sub>**: Forced expiratory volume in 1 second, **FEF25–75**: Forced expiratory flow at 25% to 75%, **PCO<sub>2</sub>**: Partial carbon dioxide pressure

When patients were compared according to PSQ risk groups, there were no significant differences between Group 1 and Group 2 in terms of age, BMI z-score, or SpO<sub>2</sub>. Spirometry results, available in 30 patients (n=11 in Group 1 and n=19 in Group 2), showed no statistically significant differences between the groups across FEV<sub>1</sub> (L, %, z-scores), FVC (L, %, z-scores), FEV<sub>1</sub>/FVC ratio (% , z-scores), and FEF25–75 (L, %, z-scores) measures. Median values for these parameters were comparable between groups (Table IV).

PCO<sub>2</sub> was available for 44 patients (n=14 in Group 1 and n=30 in Group 2). Although PCO<sub>2</sub> values tended to be higher in Group 2 [median 43.5 mmHg (37.0–47.0)] than in Group 1 [median 38.9 mmHg (37.7–43.4)], the difference did not achieve statistical significance (p=0.154) (Table IV). Patients were categorized into two groups according to

**Table III: Correlation of Pediatric Sleep Questionnaire (PSQ) scores with patient demographic characteristics, spirometry parameters, and clinical findings**

| Variables                     | rho    | p     |
|-------------------------------|--------|-------|
| Age                           | 0.008  | 0.958 |
| Gender                        | 0.002  | 0.992 |
| BMI percentile                | 0.099  | 0.509 |
| BMI z-score                   | 0.080  | 0.591 |
| SpO <sub>2</sub>              | -0.289 | 0.049 |
| FEV <sub>1</sub> %            | -0.057 | 0.763 |
| FEV <sub>1</sub> lt           | -0.380 | 0.056 |
| FEV <sub>1</sub> z-score      | 0.014  | 0.946 |
| FVC %                         | 0.063  | 0.747 |
| FVC lt                        | -0.314 | 0.118 |
| FVC z-score                   | 0.285  | 0.157 |
| FEV <sub>1</sub> /FVC         | -0.253 | 0.177 |
| FEV <sub>1</sub> /FVC z-score | -0.059 | 0.776 |
| FEF25–75 %                    | -0.259 | 0.175 |
| FEF25–75 lt                   | -0.490 | 0.011 |
| FEF25–75 z-score              | -0.250 | 0.218 |
| PCO <sub>2</sub>              | 0.172  | 0.263 |

**BMI**: Body mass index, **FVC**: Forced vital capacity, **FEV<sub>1</sub>**: Forced expiratory volume in 1 second, **FEF25–75**: Forced expiratory flow at 25% to 75%, **SpO<sub>2</sub>**: Peripheral oxygen saturation, **PCO<sub>2</sub>**: Partial carbon dioxide pressure

**Table IV: Patient demographic characteristics, spirometry parameters, and clinical findings according to Pediatric Sleep Questionnaire (PSQ) score group**

| Variables                      | Group 1*           | Group 2*           | p     |
|--------------------------------|--------------------|--------------------|-------|
| Age (16 /31)†                  | 14.8 (12.1-16.0)   | 15.0 (12.5-16.5)   | 0.937 |
| BMI z-score (16 /31)†          | 3.4 (2.6-3.9)      | 3.4 (2.9-4.3)      | 0.323 |
| SpO <sub>2</sub> (16 /31) †    | 98 (98-98)         | 98 (97-98)         | 0.093 |
| Spirometry parameters (11/19)† |                    |                    |       |
| FEV <sub>1</sub> %             | 100.0 (92.0-107.0) | 94 .0 (90.0-109.0) | 0.328 |
| FEV <sub>1</sub> lt            | 3.5 (2.9-3.9)      | 3.2 (2.7-3.7)      | 0.363 |
| FEV <sub>1</sub> z-score       | -0.3 (-1.0-0.1)    | -0.8 (-0.9-0.4)    | 0.623 |
| FVC %                          | 95.0 (83.0-103.0)  | 94.5 (87.5-98.5)   | 0.877 |
| FVC lt                         | 3.8 (3.2-4.4)      | 3.5 (2.8-4.4)      | 0.660 |
| FVC z-score                    | -0.9 (-2.1--0.4)   | -1.1 (-1.5-0.1)    | 0.660 |
| FEV <sub>1</sub> /FVC          | 105.0 (97.0-109.0) | 101.0 (96.0-106.0) | 0.307 |
| FEV <sub>1</sub> /FVC z-score  | 0.8 (-0.1-2.0)     | 0.69 (-0.3-1.6)    | 0.856 |
| FEF25–75 %                     | 111.0 (98.0-125.0) | 97.5 (88-112.5)    | 0.122 |
| FEF25–75 lt                    | 4.4 (3.9-4.9)      | 4.1 (2.9-4.5)      | 0.165 |
| FEF25–75 z-score               | 0.5 (-0.1-1.1)     | 0.1 (-0.6-0.6)     | 0.201 |
| PCO <sub>2</sub> (14/30)†      | 38.9 (37.7-43.4)   | 43.5 (37-47)       | 0.154 |

\*: median (Q1–Q3), †: n (Group 1/Group 2), **BMI**: Body mass index, **FVC**: Forced vital capacity, **FEV<sub>1</sub>**: Forced expiratory volume in 1 second, **FEF25–75**: Forced expiratory flow at 25% to 75%, **SpO<sub>2</sub>**: Peripheral oxygen saturation, **PCO<sub>2</sub>**: Partial carbon dioxide pressure

PCO<sub>2</sub> levels: <45 mmHg and ≥45 mmHg. These groups were subsequently compared between Group 1 and Group 2. Hypercarbia was significantly more common in Group 2 than in Group 1 (p=0.047).

All patients with OSA symptoms were referred for PSG; however, after at least one year of follow-up, only four of the 47 patients underwent PSG at the reference center. Three of these patients had apnea–hypopnea indices (AHIs) >5, and these three patients were in Group 2 based on their PSQ

scores, whereas the remaining patient had an AHI <1 and was in Group 1 based on the PSQ score.

Nine patients (19.1%) had witnessed apnea, and all were in Group 2 based on their PSQ scores; however, none of these patients underwent PSG during the minimum one-year follow-up period.

## Discussion

In this study, children with morbid obesity were found to have a high risk of OSA based on PSQ assessment. In addition, hypercarbia was more frequently observed among children classified as being at higher risk for sleep-disordered breathing according to PSQ scores.

PSG is accepted as the gold standard in OSA diagnosis but cannot be routinely used at every center due to its high cost and limited accessibility (12,17). Therefore, valid and reliable screening tools which can be easily applied in outpatient settings are needed. In the present study, the risk of sleep-disordered breathing was found to be high among children with morbid obesity based on PSQ findings. Although the absence of PSG confirmation precluded evaluation of the diagnostic performance of the PSQ, these findings suggest that the questionnaire may help identify children who warrant further assessment, particularly where access to PSG is limited.

Clinical studies have shown a positive relationship between BMI and OSA severity, with OSA being more pronounced in children classified as overweight or obese (4). Reductions in BMI have also been associated with significant improvements in the obstructive apnea-hypopnea index (4). In the present study, PSQ scores tended to increase with increasing BMI percentiles and BMI z-scores, although these correlations were weak and did not reach statistical significance. Obesity and OSA may interact in a bidirectional manner. Poor sleep quality and sleep fragmentation due to OSA may contribute to further increases in BMI through daytime fatigue, reduced physical activity, and metabolic dysregulation, while increasing BMI may worsen upper airway obstruction and OSA severity (19). Therefore, early diagnosis and management of OSA in children with morbid obesity are important not only for sleep-related breathing outcomes but also for preventing further obesity-related respiratory complications.

Symptoms such as fatigue with exertion, mouth breathing during sleep, daytime sleepiness, and morning headaches are among the typical clinical findings of OSA. The high prevalence of these OSA-associated symptoms in our study suggests that they should be taken seriously in children with morbid obesity, and that careful clinical evaluation is key to the diagnosis of OSA.

Hypercarbia is a marker of alveolar hypoventilation in children with obesity-related OSA and may be associated with OSA-related respiratory pauses (20,21). The finding that PCO<sub>2</sub> levels increased with increasing PSQ scores in this study suggests that blood gas monitoring is important for the early detection and management of respiratory complications in children with obesity.

Several studies in adults have shown that individuals with obesity have low FEV<sub>1</sub> and FVC but normal FEV<sub>1</sub>/FVC, indicating a restrictive respiratory pattern. Although the relationship between obesity and respiratory function in children and adolescents is not well established, several studies have shown that obesity is associated with reduced FEV<sub>1</sub>/FVC, indicating an obstructive respiratory pattern (6,22,23). Similar to previous research, this study found a negative correlation between BMI and FEF<sub>25-75</sub>, as well as between PSQ score and FEF<sub>25-75</sub>, suggesting that airway resistance is increased in patients with obesity-related sleep apnea, leading to restricted airflow (24).

## Limitations

The main limitation of this study is that, although all patients were referred for PSG, only four underwent the test. This limited the evaluation of diagnostic accuracy and reduced the generalizability of the findings, as the PSQ results could not be compared against the gold standard method. Additionally, since all patients included in the study were classified as having morbid obesity, the study population was relatively homogeneous. Changes in body weight during follow-up and repeated PSQ assessments after possible weight loss were not systematically evaluated, which may be considered another limitation. A further limitation relates to the retrospective nature of blood gas data collection: although arterial blood gas samples were obtained during daytime outpatient evaluations, the exact sampling time, the order of sampling relative to spirometry, and other standardized sampling conditions could not be fully verified from the medical records. Potential confounding factors for pediatric OSA—including adenotonsillar hypertrophy, allergic rhinitis, asthma, craniofacial abnormalities, neuromuscular disease, hypothyroidism, previous adenotonsillectomy, pubertal status, relevant medication use, and environmental smoke exposure—were not systematically evaluated because of the retrospective design. Nevertheless, these limitations underscore an important clinical reality: even today, many symptomatic children lack access to the gold standard diagnostic test. These findings therefore highlight the value of easily applicable tools such as the PSQ for identifying high-risk patients in settings where PSG is not readily available.

## Conclusion

In conclusion, this study found a high PSQ-based risk of OSA in children with morbid obesity. Hypercarbia was more frequently detected in children with higher PSQ scores, suggesting that blood gas analysis may be considered as part of further clinical evaluation in patients with high PSQ scores, particularly when symptoms of sleep-disordered breathing are present. Although the lack of polysomnographic confirmation precluded assessment of the diagnostic performance of the PSQ, the findings underscore the importance of clinical awareness of OSA in this patient group. The PSQ may help prioritize referral for the identification of sleep-disordered breathing in children with morbid obesity in settings with limited PSG access; however, it cannot replace PSG for diagnosis. Larger PSG-

based studies are needed to better define the role of the PSQ in risk stratification.

#### Ethics committee approval

This study was conducted in accordance with the Helsinki Declaration Principles. The study was approved by Ankara Bilkent City Hospital (2024-07-10, reference number: TABED 2-24-344).

#### Contribution of the authors

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by MKÇ and colleagues. The first draft of the manuscript was written by MKÇ, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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#### Conflict of interest

The authors declare that there is no conflict of interest

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