Chronic Diseases Journal

DOI: 10.22122/cdj.v12i2.736 Published by Vesnu Publications

# Evaluation of sleep structure in children of 2 to 12 years of age with obstructive sleep apnea proven by polysomnography

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Original Article

## Abstract

**BACKGROUND:** Identifying children with sleep-disordered breathing (SDB) and treating them early is essential. This study was conducted to determine the structure of sleep in children with obstructive sleep apnea (OSA).

**METHODS:** This cross-sectional, retrospective-descriptive study was performed in the sleep center of Qods Hospital, Qazvin City, Iran, from April 2017 to June 2021. Using simple random sampling, 46 children and adolescents aged 2-12 years, who underwent polysomnography, were selected. Electroencephalography (EEG), chin and limbs electrooculography (EOG) and electromyography (EMG), and electrocardiogram (ECG) electrodes were implanted. The information recorded using polysomnography were interpreted manually according to the standards of the American Academy of Sleep Medicine (AASM). Due to the quality of the data, frequency distribution tables were used to analyze the data.

**RESULTS:** Among the 33 patients with OSA included in the study, 24 (72.72%) patients had severe OSA and 9 (27.3%) patients had moderate OSA. The mean of respiratory disorders in each patient included: 6.73% central apnea, 58.92% obstructive apnea, 3.87% mixed apnea, and 30.45% hypopnea. The average total sleep time (TST) was 6 hours and 47 minutes. Furthermore, the mean hypopnea apnea index (AHI) was 30.86 per hour. Sleep structure consisted of 9.03% stage N1, 51.33% stage N2, 23.18% stage N3, and 14.39% rapid eye movement sleep (REM). Sleep efficiency was estimated to be 79.57%

**CONCLUSION:** Sleep apnea-disordered breathing including severe OSA, moderate apnea, central apnea, obstructive apnea, and mixed apnea-hypopnea were observed in the studied children.

**KEYWORDS:** Sleep Structure; Children; Obstructive Sleep Apnea; Polysomnography

***Date of submission:*** 05 Jan. 2023, ***Date of acceptance:*** 20 Mar. 2023

**Citation:** Jalilalghadr S, Taher Ahmadi H, Nozari H, Taghiloo M. **Evaluation of sleep structure in children of 2 to 12 years of age with obstructive sleep apnea proven by polysomnography.** Chron Dis J 2024; 12(2): 86-92.

## Introduction

Sleep disorders are conditions that affect the ability to sleep well regularly. These disorders are becoming more common day by day due to health problems or due to excessive stress. Sleep disorders, sleep structure disorders, and too much or too little sleep or skipping sleep, and not reaching the deep and difficult sleep stage. Another cause of sleep disorders is stress and anxiety. Usually stress and anxiety have a negative and bad effect on the sleep process and make it difficult to sleep. Nightmares of seeing, talking, or walking in sleep are among the negative effects of stress on the sleep process. Good sleep is a basic need of children as well as adolescents and has a great impact on physical and mental health, and its role begins at birth.[1,2] However, adequate sleep duration varies for infants,

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children, and adolescents, and sleep patterns change as one grows older. Lack of sleep and sleep-wake disorders are among the most common problems in the world today. Obstructive sleep apnea (OSA) in children is a loss of thermal or pressure signal of more than 90%, lasting 2 normal respiratory cycles, before the event and simultaneous with it, movements are seen in the signals sent from the abdominal belts as well as the respiratory muscles. More than 90% of the signal height for at least 2 normal respiratory cycles before the event along with the movements of the respiratory muscles.[3] One of the most common causes of OSA is enlarged tonsils or tonsillitis. Being overweight or obese can also cause this type of sleep disorder. OSA is a sleep disorder in which the walls of the throat become relaxed and narrow during sleep. This condition causes a stop in breathing. People with OSA can be very tired during the day or even fall asleep. This situation can be dangerous. In children, sleep apnea can cause problems at school or make them hyperactive. The prevalence of OSA in children is reported to be 3%. OSA is estimated to affect 2-5.3% of children.[4] Various studies have shown the development of OSA and its disorders in children and adolescents; in a study conducted in Iran by Rezaeitalab et al., the presence of depressive symptoms and suicide attempts following severe obesity and adenoid hypertrophy in an 18-year-old adolescent with OSA was confirmed.[5] Polysomnography with an apnea-hypopnea index of 58.5 per hour confirmed the diagnosis of severe sleep apnea syndrome in this adolescent.[5] In another study conducted by Sadegh Niyat Haghighi et al. in Iran, insomnia was a common complaint in patients with sleep apnea, and among 126 patients diagnosed with sleep apnea, 81.7% suffered from insomnia.[6] In polysomnographic studies by Zhan et al. in China, all 511 patients with OSA [mean apnea-hypopnea duration (MAD)] were significantly associated with the apnea-hypopnea index (AHI), but no significant relationship was observed with the patient's age, body weight, and height.[7] In 206 patients with long-term MAD with severe OSA, blood oxygen levels and sleep parameters were significantly worse.[7] Lack of timely diagnosis and treatment of OSA also have side effects such as hyperactivity, lack of concentration, decreased ability to learn, developmental retardation, and stunted growth.[8]

Given that adequate and appropriate sleep is an important mechanism to combat pathogens and plays an important role in maintaining the health of the body and optimal cognitive function, especially in children and adolescents, the study, identification, and treatment of sleep disorders in children and adolescents need to be fast and timely. Therefore, this study was conducted to evaluate the sleep structure in patients aged 2 to 12 years old with OSA using polysomnography in the sleepward of Qods Children's Hospital, Iran.

## Methods

This study was conducted with a cross-sectional, retrospective-descriptive design. Using simple random sampling, 46 children and adolescents (aged: 2-12 years) were selected as the study sample. They were referred to the sleep center of Qods Children's Hospital in Qazvin (April 2017 to June 2021). Polysomnography was used to study sleep disorders. Only individuals with pure obstructive apnea/hypopnea were included in the study. Individuals with pure central apnea, and obstructive and central apnea were excluded from the test. Moreover, individuals who had other abnormalities in their history or examination or sleep test results that interfered with sleep structure were excluded from the study. Based on the inclusion and exclusion criteria, out of 46 patients, 33 patients with OSA were included in the study. Parents

of children with "attention deficit hyperactivity disorder (ADHD), seizures, neuromuscular diseases, previous tonsillectomy, cardiopulmonary disease, depression, and other psychiatric disorders, down syndrome and other genetic syndromes, metabolic diseases, taking drugs that affect the structure of sleep, cystic fibrosis, patients with hypoxemia due to non-obstructive sleep apnea and hypoventilation (also known as respiratory depression) syndromes" were recommended to bathe their children before presenting in the sleep center. The parents were also recommended to adjust their children's sleep and wake time. According to this program, children can sleep very well the night before the polysomnography. Parents were advised not to allow the children to sleep during the day. They could eat a light dinner, 4 hours before the test in the hospital's sleeping ward. Before performing polysomnography, parents completed an information checklist about the child, including the main problem during sleep (such as snoring), history of previous medical treatment, family history of sleeping problems, type of nutrition, diagnosis and treatment measures, history of referring physician, reasons for referral and also clinical examination findings, weight, height, body mass index (BMI), and the child's growth (normal or abnormal growth). A questionnaire was also completed by parents regarding the children's sleep history such as normal child sleep time, average 24-hour sleep duration, average daily nap time, sleep disorders, and sleep habits. After completing the checklist, we gave parents the necessary preparations and provided sufficient explanations on how to perform the test and prepare the test room. The room had a suitable bed according to the children's age. It also had a standard space with access to the bathroom and toilet. We tried to set up and decorate the test room similar to the child's bedroom at home. The test room temperature was adjusted, and silence was established during sleep. After all of these, polysomnography was performed. First, gold electrodes and sensors including electroencephalography (EEG) electrodes (of at least 8 strands), electrooculography (EOG) and electromyography (EMG) (of the chin and limbs of at least 6 strands), electrocardiogram (ECG), and respiratory airflow sensors (including thermal and compression sensors), arterial blood oxygen saturation sensors, abdominal and chest motion sensors (to monitor respiratory effort), audio-visual snoring recording, and body position sensors were connected by a specialist nurse, based on the American Academy of Sleep Medicine (AASM) structure. Then, the patients went to bed according to their normal sleeping hours. Finally, the light was turned off and the test started. The test was continued for each child for 400 minutes (6-67 hours) and it ended in the morning. The light was turned on after the end of the test.[9,10] The fellowship physician analyzed the information on the polysomnograph according to AASM standards. According to the results, the fellowship physician surveyed respiratory disease severity, apnea-hypopnea (index during sleep; number per hour), obstructive apnea, central apnea, mixed apnea, and hypopnea. Apnea is when a 90% or more reduction occurs in the nasopharyngeal airflow. Obstructive apnea is diagnosed by respiratory effort in the chest and abdominal muscles. There is no respiratory effort in central apnea. Mixed apnea has two parts, the first part includes central respiratory arrest and the second part includes respiratory obstruction.[17]

The severity of sleep apnea is evaluated based on the apnea/hypopnea index. The apnea/hypopnea index includes the number of apneas and hypopneas that occur in each hour during sleep (less than 1 apnea/ hypopnea per hour is normal, 1-4 apneas/hypopneas per hour is mild, 5-10 and

more than 10 apneas/hypopneas per hour is classified as severe AHI).[18] Sleep structure also means total sleep time (TST) is the percentage of effective sleep (sleep efficiency) and the percentage of each of the stages of N1, N2, N3, and REM. Finally, sleep structure was evaluated in 2 to 12-year-old patients with OSA proven by polysomnography. The final results were analyzed by severity of apnea (mild, moderate, and severe).[11] Frequency distribution tables were used to analyze the qualitative data (Code of Ethics: IR.QUMS.REC.1399.075).

## Results

The mean age of the participants was 6.42 years. The participants included 19 (57.57%) boys and 14 (42.42%) girls. Of the 33 patients, 24 (72.72%) had severe OSA, and 9 (27.27%) had moderate apnea. Mild OSA was not found in any of the children. The average of respiratory disorders in all patients includes: 12.57 times (6.73%) central apnea, 110 times (58.92%) obstructive apnea, 7.24 times (3.87%) mixed apnea, and 56.84 times (45)/30%) hypopnea (Table 1).

The TST in patients was 6 hours and 47 minutes [(407.69 minutes, average sleep time per patient) 33 patients/13454 minutes, TST of all patients]. Moreover, the AHI (total number of apneas and hypopneas per hour of sleep, number of respiratory events/total sleep time per hour) was 30.86 per hour. The three stages of non-rapid eye movement (NREM) sleep in our 33 patients included the following: 298.30 minutes (9.03%) stage N1, 1694.50 minutes (51.33%) stage N2, and 765.10 minutes (23.18%) stage N3. Furthermore, 475.50 minutes (14.39%) of REM was observed in the children. Sleep efficiency of patients was estimated to be 79.57% (Table 2).

## Discussion

This study evaluated the sleep structure of 2 to 12-year-old children with OSA proven using polysomnography. The results of our research showed OSA in children. OSA is a sleep disorder in which your baby's breathing is partially or completely interrupted repeatedly during sleep. This disease is due to narrowing or blockage of the upper airway during sleep.[12] The structure of sleep in patients aged 2 to 12 years with OSA was examined in this study. Undiagnosed and untreated OSA can predispose children to neurobehavioral consequences. However, there is a lack of information on the extent of and risk factors for OSA in children. Therefore, it is necessary to determine the extent of OSA and identify risk factors related to the presence and severity of OSA.[8,13] Selvadurai et al. in Canada in 2019 performed polysomnography on healthy children between 1 and 3 years old and found that 113 children (58%) had OSA.[14] Moreover, 20% had mild apnea. This was contradictory to our study findings, as mild OSA was not found in the children in our study. In addition, in their study, 80% of children had moderate to severe OSA, which was higher than our results.

**Table 1. Respiratory disorders in patients aged 2 to 12 years with obstructive sleep apnea**

| Respiratory disorders in 33 patients | Number (n) of respiratory disorders in 33 patients | Mean number (n) of respiratory disorders/33 patients | Percentage of frequency (n) of respiratory disorders / total number of respiratory disorders × 100 (%) |
|---|---|---|---|
| Central apnea | 415 | 415/33 = 0.5712 | 415/6160 × 100 (6.73) |
| Obstructive apnea | 3630 | 3630/33 = 110 | 3630/6160 × 100 (58.92) |
| Mixed apnea | 239 | 239/33 = 0.247 | 239/6160 × 100 (3.87) |
| Hypopnea | 1876 | 1876/33 = 0.8456 | 1867/6160 × 100 (30.45) |
| Total number of respiratory disorders | 6160 | 6160/33 = 0.66186 | 100% |

**Table 2. Sleep stages in patients aged 2 to 12 years with obstructive sleep apnea**

| Calculations | N1 | N2 | N3 | REM | SE |
|---|---|---|---|---|---|
| Total amount of each sleep phase for total patients/total number of patients (Average total amount of each sleep stage for each patient) | 298.30/33 (2.98) | 1694.50/33 (16.94) | 765.10/33 (7.65) | 475.50/33 (4.75) | 2626.80/33 (26.26) |
| The average total amount of each sleep phase for each patient / total number of patients × 100 (%) | 2.98/33 × 100 (9.03) | 16.94/33 × 100 (51.33) | 7.65/33 × 100 (23.18) | 4.75/33 × 100 (14.39) | 26.26/33 × 100 (79.57) |

REM: Rapid eye movement; SE: Sleep efficiency

In the present study, 72.72% had severe OSA and 27.27% had moderate apnea. High rates of OSA have also been observed in children of 3 years of age and younger. Therefore, the age difference of children in different studies can be a reason for the difference in results. On the other hand, children referred by an ear, nose, and throat (ENT) specialist are more likely to be diagnosed with moderate to severe OSA. In our study, the mean age of children was 6.42 years. Children 3 years of age and younger with OSA symptoms should be considered at risk for OSA and prioritized for early PSG and management. Moreover, in the study by Selvadurai et al., nasal congestion, adenoid hypertrophy, and tonsillar hypertrophy at the time of pediatric referral were more common in the OSA group than in the non-OSA group, and referral from an ENT specialist was associated with moderate to severe OSA.[13] In a 2021 study in the United States, DelRosso et al. assessed OSA and hypopnea during REM and NREM on pediatric polysomnography with a mean age of 8.7 years.[14] The duration of apnea during NREM at all ages was over 8 seconds, and in the older age groups, 10 seconds. During REM sleep, a gradual increase was reported from 6 seconds in the youngest children to 10 seconds in the oldest children. AHI in the present study was 30.86 per hour and REM was 14.39%. Time differences can be seen between this study and the study by DelRosso et al.[14] Research has shown that respiration is an essential function that requires metabolic and voluntary control when awake, but depends on metabolic control through peripheral and central chemical receptors during sleep. Breathing during sleep also depends on the maturity of the nerve centers and the strength of the respiratory muscles. Therefore, sleep duration at different stages in children with apnea depends on the age and body structure of children and varies in different groups of children. The duration of apnea/hypopnea increases with age in children and adolescents regardless of gender or severity of OSA.[14]

Schaefer et al. in Australia in 2021, among 17 children (mean age: 11.6 years), identified 15 different sleep-disordered breathing (SDBs) disorders including central sleep apnea (18%), OSA (24%), obstructive and central sleep apnea (29%), and hypoventilation without obstructive or central sleep apnea (18%).[15] In 2022, Jalilolghadr et al. conducted a study in Iran on children with respiratory disorders and those with sleep disorders using polysomnography.[11] They reported that, among 112 children and adolescents aged 0 to 18 years, the most common sleep disorder was restless sleep (60.71%), and 85.92% had sleep apnea. Furthermore, 58.92% were diagnosed with severe OSA, 16.96% with moderate OSA, and 12.5% with mild OSA.[11] Our results showed that the mean of respiratory disorders in patients was 6.73% for central apnea, 58.92% for obstructive apnea, 3.87% for mixed apnea, and 30.45% for hypopnea. SDB and its types differ in different groups of children, for example, children with underlying disorders and other diseases, and children with growth

hormone (GH) deficiency are more likely to develop these types of disorders. AHI, age, and sex are also affected by sleep-related symptoms and disorders in children. Long-term monitoring and polysomnography in children and the diagnosis of apnea and measurement of partial pressure of carbon dioxide (pCO2) should be performed continuously in children with suspected sleep disorders. Adenotonsillectomy, drug therapy for OSA, and noninvasive ventilation (NIV) are recommended for the recovery of children with sleep disorders.[16,11] Studies have shown that the severity of OSA is related to structural changes in sleep in children. Frequent electroencephalogram stimuli indicate that intermittent nocturnal hypoxia, apnea/hypopnea, and sleep may lead to significant sleep disturbances.[16] Studies have shown that the quality or quantity of sleep in children depends on a group of problems, including academic, behavioral, developmental, and social difficulties, weight disorders, and other health problems. Children's sleep problems not only affect their health, but can also hurt their social and academic behavior. In addition, the developmental aspects of childhood and healthy sleep are directly related to each other. Therefore, it is necessary to study and treat sleep disorders in children.[17,18] Therapeutic approaches to OSA in children have evolved dramatically in the last 2 decades. Removal of enlarged upper airway lymphadenoid tissue or adenotonsillectomy is the first-line treatment recommended for pediatric OSA. Children who are likely to develop stable OSA after adenotonsillar hypertrophy and adenotonsillectomy (T&A) include those with severe OSA, obese or older children, and those with concomitant asthma or allergic rhinitis. Children who are prone to oropharyngeal or maxillofacial factors (lower and upper jaw disorders have a major impact on the development of OSA) are more susceptible, and patients with underlying medical conditions are more likely to develop persistent types of sleep disorders. Anti-inflammatory treatment or orthodontic interventions may be preferred in milder cases.[19]

Respiratory disorders in children were diagnosed in this study. Respiratory sleep disorders cause the child to be unable to perform daily tasks. OSA is a serious sleep disorder. This blockage causes frequent interruption in breathing during sleep. OSA treatments are available, and since complete and healthy sleep affects the growth and health of the child, children with SDB should be followed up and treated. It is suggested that future studies select larger samples and to examine several centers. In addition, the psychological conditions of children and parents should be measured in this regard using a questionnaire. It is suggested that treatment processes and effective drugs in the treatment of children be investigated and compared in future studies.

## Conclusion

Severe and moderate OSA, as well as central respiratory apnea, mixed apnea, and hypopnea were diagnosed in the studied children. The AHI and their sleep structure indicated that the children in question needed treatment and management of sleep disorders. SDB causes the child to have trouble sleeping at night and during uninterrupted sleep.

## Conflict of Interests

Authors have no conflict of interests.

## Acknowledgments

The authors would like to thank all participants in this study for their collaboration and the Children Growth Research Center, Research Institute for Prevention of Non-Communicable Diseases, Qazvin University of Medical Sciences, Qazvin, Iran.

## Financials support and sponsorship

The authors of the article declare that they have not received any financial support.

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