

## Original Article

# Polisomographic Investigation of Sleep Disorders in Patients with Sickle Cell Anemia and Evaluation of the Effect on the Prognosis

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## Abstract

**OBJECTIVE:** The aim of this study is to identify sleep disorders in adults with sickle cell disease and to examine the effects of accompanying sleep disorders on the prognosis of sickle cell disease.

**MATERIAL AND METHODS:** Twenty-eight patients followed up with a diagnosis of sickle cell disease and 22 healthy volunteers were included in our study.

**RESULTS:** Both groups had similar characteristics in terms of age, gender, and body mass index. More obstructive sleep apnea syndrome was detected in the sickle cell group than in healthy volunteers. Statistically, the sickle cell patient group had higher apnea-hypopnea index and lower nighttime oxygen desaturation. As the degree of obstructive sleep apnea syndrome increased in the sickle cell group, it was found that there were more emergency admissions and hospitalization due to painful crises and/or acute chest syndrome in the last 1 year. Also, lower sleep efficiency was found in the sickle cell disease patient group. In the sickle cell group, it was found that the restless leg syndrome severity was statistically significantly more.

**CONCLUSION:** As hypoxia deepens in sickle cell patients, mortality and morbidity due to the disease increase significantly. Comorbid sleep disturbances in sickle cell patients exacerbate nocturnal hypoxia and negatively affect the prognosis of the disease. Therefore, patients with sickle cell disease should be questioned in detail in terms of obstructive sleep apnea syndrome and, if necessary, polysomnographic evaluation should be performed to provide treatment for sleep disorders in the early period.

**KEYWORD:** Sleep apnea syndrome, sickle cell anemia, hypoxia, the restless leg syndrome

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## INTRODUCTION

Sickle cell anemia caused by sickle cell disease (SCD) is one of the most common hemoglobinopathies in the world. The replacement of glutamic acid with valine at the 6th position of the  $\beta$  globin chain results in hemoglobin S (Hb S), an abnormal hemoglobin (Hb). It shows autosomal recessive inheritance.<sup>1</sup> Sickle cell disease is characterized by complications associated with chronic hemolytic anemia and recurrent vaso-occlusion of small vessels. One of the strongest triggers for vaso-occlusion is hemoglobin oxygen (HbO<sub>2</sub>) desaturation. Hemoglobin oxygen desaturation has been associated with various complications in SCD, including increased pain (especially prominent in the extremities), central nervous system events (stroke, etc.), cognitive dysfunction, and acute chest syndrome.<sup>2</sup> Individuals with homozygous variant S alleles or Hb SS (SS) disease develop serious complications such as chronic hemolysis syndrome, pulmonary hypertension, and stroke together with anemia.<sup>3</sup>

Obstructive sleep apnea syndrome (OSAS) is a complete and/or partial airway obstruction that can cause significant physiological discomfort with various clinical effects. Etiology is multifactorial and clinical symptoms are snoring, morning headaches, daytime sleepiness, and impairment in cognitive performance. Some recent international studies show that the prevalence of OSAS is 2%-4% in men and 1%-2% in women.<sup>4</sup> Since HbO<sub>2</sub> desaturation frequently occurs in patients with OSA, recent research has focused on the relationship between SCD and OSA.<sup>1</sup>

The aim of this study is to investigate the prevalence of sleep disturbance and its effect on the prognosis of the disease in SCD patients.

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## MATERIAL AND METHODS

Forty-nine patients over the age of 18 who were followed up by the hematology department for Hb SS disease (SCD), who did not have any active symptoms, and did not describe acute painful crisis or acute chest syndrome were included in the study. Detailed anamnesis of the patients were taken. Demographic data (height, age, weight, medications, duration of illness, etc.) were recorded. Hemoglobin, hematocrit, and ferritin results from the routine blood tests of the patients were recorded. Patients were subjected to polysomnographic examination after a detailed sleep questioning (Epworth Sleepiness Scale (ESS), Stanford Sleepiness Scale, and the Berlin questionnaire). Physical examination findings and Mallampati scores were recorded. Emergency service admissions of SCD patients in the last 1 year and the history of hospitalization due to painful crisis and/or acute chest syndrome in the last 1 year were questioned. Patients under 18 years of age, patients with known sleep problems other than SCD, additional systemic disease, known respiratory disease, and patients who did not consent to polysomnographic evaluation were excluded from the study. A total of 28 SCD patients were included in the study. All patients included in the study underwent polysomnography, regardless of their symptoms. As the control group, 30 healthy volunteers over the age of 18, who had no known disease, and who had similar demographic data to the SCD group were included in the study. Consent was obtained from the volunteer patients. A control group was formed with a total of 22 volunteers, whose consents were obtained and accepted for the polysomnographic examination. Detailed anamnesis was taken and physical examination findings were recorded. Pulmonary function tests were performed in both groups if there were no contraindications (having recently had Myocardial Infarction (MI) known thoracic abdominal or cerebral aneurysm, having recently had eye surgery, etc.) after respiratory system examination, and the results were recorded.

Confirmation of the Local Ethics Committee was obtained. Our study was approved by Hatay Mustafa Kemal University, Ethics Committee with the date and number of 2018/36. The purpose of our study was explained to the participants in detail, and informed by Helsinki rules, and a consent form was obtained. The patients were informed about what procedures would be applied, and they completed filling out the informed consent forms. Each patient was interviewed after the polysomnography test, and demographic data of the patients, height, and weight measurements were recorded. Similar numbers of patients were included in both groups.

### MAIN POINTS

- Obstructive sleep apnea syndrome (OSAS) is a disease that causes serious mortality and morbidity.
- The presence of concomitant OSAS in sickle cell patients has negative effects on the prognosis of the disease.
- Therefore, OSAS symptoms should be questioned in sickle cell patients, suspicious patients should be evaluated with polysomnography, and patients with OSAS should be treated.

Patients were questioned with regards to age, gender, associated additional diseases, existing symptoms and risk factors, smoking habits, and alcohol use. Age, gender, height, and weight values of the patients were noted, and body mass indices (BMI) were calculated ( $BMI = \text{weight/height}^2$ ) ( $\text{kg/m}^2$ ).

Epworth Sleepiness Scale was completed for each patient. The ESS is a test used to demonstrate daytime sleepiness. It consists of 8 questions in total. Each question is filled by the patient himself/herself to give 0-3 points. In this survey, the possibility of falling asleep in certain situations is questioned on an ordinary day when the patient is not overly tired. Total scores of the patients were recorded. If the total score is 10 or more, it indicates the presence of excessive daytime sleepiness. The validity and reliability of the ESS in terms of excessive daytime sleepiness have been demonstrated by domestic and international studies.

In addition, patients were evaluated in terms of restless leg syndrome (RLS). The diagnosis of RLS was made using the criteria of the International Restless Legs Syndrome Study Group (IRLSSG). The patients were asked 4 questions to identify RLS and those who answered yes were accepted as having RLS.<sup>5</sup> For the severity of RLS, the IRLS Rating Scale was used. The IRLS Rating Scale is a scale on typical symptoms of the disease, each of which is graded from 0 to 4. The evaluation is made with this scale as follows: 0-10 points were evaluated as mild, 11-20 points as moderate, 21-30 points as severe, and 31-40 points as very severe RLS.<sup>6</sup>

Two subjective scales and polysomnographic objective evaluation are used to measure RLS severity. Another subjective scale is the Johns Hopkins RLS severity scale (JHRLSS) and it was developed to evaluate the current status of patients before treatment. Patients are graded according to the time of onset of symptoms with this scale. It is scored between 0 and 3 (Table 1).<sup>7</sup> In addition to patients with RLS symptoms, we applied the JHRLSS.

### Polysomnography

Standard polysomnography was performed for all patients overnight. Philips Respironics, ALIS 6 LDXN, 68 channel polysomnography, Sleepware G3 (USA) device was used for polysomnographic evaluation. Measurements performed during polysomnography (PSG) testing were 4 channel electroencephalography (C3-A2, C4-A1, O1-A2, and O2-A1), 2 channel electrooculogram, electrocardiogram, electromyogram monitoring (submental and tibialis anterior muscle), oronasal airflow and nasal airflow, thoracoabdominal movements, and oxygen saturation with fingertip pulse oximeter. Video and audio recordings as well as body position were obtained. Sleep scoring was conducted according to the criteria of Rechtschaffen and Kales.<sup>8</sup>

All respiratory events were scored simultaneously by 2 physicians with experience and certification in sleep medicine, according to the guidelines of the American Academy of Sleep Medicine.<sup>9</sup> A decrease of more than 90% in airflow for at least 10 seconds was considered as apnea. If respiratory effort is recorded throughout the event, it was evaluated as obstructive apnea. If respiratory effort is absent throughout the

**Table 1.** John Hopkins Scale

Score	Hours of RLS Symptoms Beginning
0 (Never)	No symptoms
1 (Mild)	At bedtime and/or during the sleep period (symptoms may occur within 60 minutes before the usual bed or simply at the time of going to bed or during the night after bed).
2 (Moderate)	At Night (6 PM and after)
3 (Severe)	In the afternoon (before 6 PM). Symptoms may begin in the afternoon or last all day.

event, it was evaluated as central apnea. If there is absence of respiratory effort at the beginning of the event followed by increasing respiratory effort during the second half, it was evaluated as mixed apnea. Thoracic and abdominal movements were accepted as respiratory efforts. A 50% decrease in air flow for at least 10 seconds and a decrease in saturation of at least 3% were accepted as hypopnea.

Obstructive sleep apnea syndrome was diagnosed based on the International Classification of Sleep Disorders-3 classification and defined as the presence of 1 or more of the criteria including snoring, witnessed apnea or daytime sleepiness, and >5 apneahypopnea index (AHI) score identified on PSG. Obstructive sleep apnea syndrome severity based on AHI was mild for AHI = 5-15, moderate for AHI = 15-30, and severe for AHI >30.<sup>10</sup>

**Statistical Analysis**

Shapiro–Wilk test was used for suitability with normal distribution. Student’s *t*-test was used to compare normally distributed features in 2 independent groups. Mann–Whitney *U*-test was used to compare non-normally distributed properties. Relationships between numerical variables were tested with Pearson’s correlation coefficient. Mean ± standard deviation values were given for numerical variables as descriptive statistics. Number and percent values were given for categorical variables. Statistical Package for the Social Sciences software Windows version 23.0 package program was used for statistical analysis and *P* < .05 was considered statistically significant.

**RESULTS**

Of the 49 SCD patients evaluated for our study, 28 patients who gave consent to participate in the study, who were not in a painful crisis attack, and who had sufficient sleep efficiency

as a result of polysomnographic evaluation were included in the study. Of the 30 healthy volunteers who were evaluated in the control group, 22 individuals who had no comorbidity and gave consent to participate in the study were included in the study. There were a total of 28 patients in the SCD group including 16 males (57.1%) and 12 females (42.9%). In the control group, there were a total of 22 patients, 13 men (59.1%) and 9 women (40.9%). Both groups were similar in terms of gender (*P* = .890). Both groups were similar in terms of mean age (32.96 ± 8.31 in SCD patients and 35.23 ± 9.40 for the control group) and BMI (22.31 ± 3.57 in SCD patients and 23.94 ± 2.79 in the control group, respectively; *P* = .371, *P* = .084, respectively) (Table 2).

The total ESS score was statistically higher in the SCD patient group than in the control group (ESS was 5.71 ± 3.48 in SCD patients and 3.00 ± 3.27 in the control patient group, *P* = .001). When the Berlin Sleep Questionnaire and Stanford Sleepiness Scale results were compared between the control group and the SCD patient group, the results of both scales were found to be significantly higher in the SCD patient group (*P*-values: .008-.002, respectively).

The polysomnographic evaluation results of both groups are given in Table 3. While sleep efficiency was 72.94 ± 11.32 in the SCD group, it was 88.94 ± 8.12 in the control group and sleep efficiency was significantly lower in SCD patients (*P* < .001). While the minimum oxygen saturation during sleep was 84.14 ± 5.1 in the SCD patient group, it was 91.32 ± 5.59 in the control group. Hence, the minimum saturation at night was significantly lower in the SCD group than in the control group (*P* < .001). Stage 3 sleep percentage was found to be significantly lower in the SCD patient group compared to the control group (*P* = .023). However,

**Table 2.** Comparison of Age, Gender, and BMI of groups

	Sickle Cell Disease Patient Group (n = 28)	Control Group (n = 22)	<i>P</i>
Age (mean ± SD)	32.96 ± 8.31	35.23 ± 9.40	.371
BMI (mean ± SD)	22.31 ± 3.57	23.94 ± 2.79	.084
Gender (n, %)	12 (42.9%)	9 (40.9%)	.890
Female	16 (57.1%)	13(59.1%)	
Male			

BMI, body mass index; SD, standard deviation.

**Table 3.** Comparison of Polysomographic Data

	Sickle Cell Disease Patient Group (n = 28) (Mean ± SD)	Control Group (n = 22) (Mean ± SD)	P
Sleep efficiency	72.94 ± 11.32	88.94 ± 8.12	<.001*
Stage 1 %	8.37 ± 6.09	5.04 ± 3.9	.036*
Stage 2 %	54.24 ± 13.93	60.7 ± 10.82	.080
Stage 3 %	11.07 ± 6.62	16.63 ± 10.1	.023*
REM%	10.27 ± 7.3	13.75 ± 7.13	.080
AHI	17.47 ± 17.84	3.44 ± 3.67	<.001*
Supin AHI	21.42 ± 25.4	3.21 ± 4.28	<.001*
Nonsupin AHI	10.29 ± 13.41	2.88 ± 3.98	.014*
Rem AHI	19.74 ± 28.35	4.33 ± 5.53	.029*
Non-REM AHI	15.24 ± 18.01	3.22 ± 3.73	<.001*
Minimum saturation	84.14 ± 5.1	91.32 ± 5.59	<.001*
Mean saturation	93.95 ± 2.81	92.61 ± 18.72	.001*
ODI	11.34 ± 13.68	0.83 ± 1.18	<.001*
PLMI	2.35 ± 3.08	0.6 ± 1.48	.002*
Minimum heart rate	51.96 ± 6.14	47.86 ± 4.82	.013*
Mean heart rate	65.89 ± 7.35	62.82 ± 5.78	.114
Maximum heart rate	97.18 ± 10.78	100.85 ± 2.31	.014*
OSAS (n, %)	8 (28.6%)	5 (22.7%)	.001*
Mild	9 (36.1%)	0 (0%)	
Moderate	4 (14.3%)	0 (0%)	
Severe			
IRLS-RS (n, %)	12 (44%)	0 (0%)	.001*
Mild	7 (25%)	1 (3%)	
Moderate	7 (25%)	0 (0%)	
Severe	1 (3%)	0 (0%)	
Very severe			
Johns Hopkins RLS (n, %)	13 (48%)	1 (3%)	.001*
Mild	9 (9%)	0 (0%)	
Moderate	5 (18%)	0 (0%)	
Severe			

AHI, apnea-hypopnea index; ODI, oxygen desaturation index; PLMI, periodic leg movement index; IRLS-RS, International Restless Leg Syndrome Rating Scale; RLS, restless leg syndrome.  
\*P < .05 was considered statistically significant

the percentage of sleep stage 1, supine/non-supine AHI, and rapid eye movement (REM)/non-REM AHI were found to be significantly higher in the SCD group than in the control group.

When the apnea-hypopnea index was examined, it was found to be 17.47 ± 17.84 in the SCD group and 3.44 ± 3.67 in the control group. The AHI level in the SCD group was found to be statistically significantly higher than the control group (P < .001). Oxygen desaturation index (ODI) was significantly higher in the SCD group (11.34 ± 13.68) compared to the control group (0.83 ± 1.18) (P < .001).

In the SCD patient group, OSAS was detected in a total of 19 patients. Of these, 8 patients (28%) had mild OSAS, 7 patients (25%) had moderate OSAS, and 4 patients had severe OSAS. In the control group, OSAS was detected in 5 patients (22%), and all patients had mild OSAS.

In the SCD group, restrictive type respiratory dysfunction was found in 11 patients (39%) and mixed (obstructive+restrictive) type respiratory dysfunction was detected in 1 patient (3%). The mean forced expiratory volume in 1 second (FEV1%) and forced vital capacity (FVC%) values were significantly lower in the SCD group than in the control group (P = .004, P = .007, respectively) (Table 4). When the correlation between pulmonary function tests and ODI and AHI was examined, it was found that there was a weak negative correlation between AHI and ODI as the FEV1 level decreased in patients (r = -0.314; r = -0.276, respectively), but no significant correlation was found with FVC. A moderate positive correlation was found between FEV1 and FVC values and minimum saturation (r values were 0.437 and 0.413, respectively).

When the periodic leg movement index (PLMI) of the groups were compared, PLMI was found to be 2.35 ± 3.08 in the SCD patient group and 0.6 ± 1.48 in the control group, and it was significantly higher in the SCD patient group (P = .002).

When the groups were compared in terms of RLS, 27 patients in the SCD group and 1 patient in the control group were accepted as RLS according to the IRLSSG criteria. According to IRLSSG Severity Scale (IRLSSG-SS), in the SCD group, 12 patients (44%) had mild, 7 patients (25%) had moderate, 7 patients (25%) had severe, and 1 patient (3%) had very severe RLS. In the control group, moderate RLS was detected in 1 patient. When the JHRLSS was evaluated, of the 27 patients with RLS, 13 (48%) had mild RLS, 9 patients (9%) had moderate severity, and 5 patients (18%) had severe RLS. One patient in the control group with RLS symptoms had mild RLS symptoms.

In the SCD patient group, it was reported that the patients were admitted to the emergency department on an average of 3.03 ± 2.5 times in the last year due to an attack (venoocclusive crisis or acute chest syndrome) (min: 0; max: 10). It was also determined that the patients had an average of 1.2 ± 1.2 (min: 0; max: 4) hospitalizations in the last 1 year. When the SCD patient group was evaluated within itself, it was found that as AHI increased, sleep efficiency decreased in moderate and statistically significant (r = -0.401, P < .05). A very strong

**Table 4.** Pulmonary function test results

	Sickle Cell Disease Patient Group (n = 28) (mean ± SD)	Control Group (n = 22) (mean ± SD)	P
FEV1%	74.54 ± 13	88.82 ± 20.08	.004*
FVC%	75.61 ± 13.53	89.5 ± 21.14	.007*
FEV1/FVC	84.2 ± 4.5	84.17 ± 5.28	.984

FEV1, forced expiratory volume in 1 second; FVC, forced vital capacity.  
\*P < .05 was considered statistically significant



positive correlation was found between the AHI level and the patients' admission to the emergency service due to vasoocclusive crisis and/or acute chest syndrome in the last 1 year ( $r = 0.805, P < .01$ ). In other words, as the AHI increased, the emergency admissions of the patients increased significantly. A statistically significant positive correlation was found between the AHI and the number of hospitalizations of the patients in the last 1 year ( $r = 0.657, P < .01$ ). The correlation between sleep parameters in the SCD patient group and attacks and hospitalizations in the last 1 year is shown in Table 5. The scatter plots graph of the correlation between AHI and the number of admissions to the emergency department and the number of hospitalizations due to an attack in the last 1 year are shown in Figures 1A and 1B.

As AHI increased in SCD patients, the patients had more severe RLS symptoms. A positive moderate statistically significant correlation was found between AHI and IRLSSG-SS ( $r = 0.469, P < .01$ ). Restless leg syndrome symptoms were more severe in patients with higher AHI values.

A moderate statistically significant negative correlation was found between the minimum oxygen saturation during night sleep and the number of emergency admissions within the last 1 year ( $r = -0.496, P < .05$ ). However, a weak negative correlation was found between minimum saturation and the number of hospitalizations in the last 1 year ( $r = -0.354$ ).

**DISCUSSION**

In this study, the frequency of OSAS in SCD patients and SCD prognosis in patients with OSAS were evaluated. In our study, OSAS was detected in 19 patients (67%) after polysomnographic evaluation in the SCD patient group. This number was significantly higher than the control patient group. Similar to our study, Wallen et al<sup>11</sup> evaluated the Pittsburgh Sleep Quality Index questionnaire in terms of accompanying sleep disorders in 328 adult SCD patients, patients with a score of 5 and above were defined as having sleep disorders, and they found sleep disturbances in more than 70% of adults with SCD. Sharma et al<sup>12</sup> performed a comprehensive sleep assessment and polysomnography at an accredited sleep center on 32 adult SCD patients with irregular sleep or patients with ESS score of  $\geq 10$  and found that the prevalence of sleep breathing disorder in these patients was 44%. They found that the severity of the disease was generally mild and moderate (mean AHI = 17/h (95% CI: 10-24/h)) and they also

found that 57% of the patients were accompanied by sleep disorders such as insomnia and delayed sleep phase syndrome.<sup>12</sup> In our study, 8 (28%) of the patients with OSAS in the SCD patient group had mild OSAS, 7 (25%) had moderate OSAS, and 4 had severe OSAS.

In another study, Berlin Sleep Questionnaire was applied to 47 patients who were followed up with a diagnosis of SCD and they performed polysomnographic evaluations in 13 patients who were considered to be high risk for OSAS, and they found OSAS in 23% of the patients.<sup>13</sup> In our study, 6 patients who underwent the Berlin Sleep Questionnaire were found to be at high risk for OSAS, and 4 of these 6 patients had severe OSAS and 2 of them had moderate OSAS. In 10 patients included in the study, at least 2 categories were evaluated as positive in the Berlin Sleep Questionnaire, and moderate OSAS was found in 7 of these patients and mild in 3 of them.

In many studies of patients with SCD, hypoxia was observed during the day, while sleeping or after exercising. The results of this hypoxia occurring in children and adult patients with SCD are not clear. In some studies, hypoxia is accepted as a high risk for cognitive impairment, especially in children, while it is considered a risk for more pain attacks and secondary pulmonary complications (such as pulmonary hypertension) in adults.<sup>14</sup> In our study, in the SCD patient group, the minimum oxygen saturation values observed at night and the average oxygen saturation values detected during sleep were found to be significantly lower than the control group. In a study conducted by Rosen et al<sup>15</sup>, in which 243 SCD children (mean age 10) were evaluated, they found that children with SCD experienced more nighttime desaturation and, beyond this, the prevalence of sleep breathing disorders compatibility with OSAS was higher.<sup>15</sup> When Kaleyias et al<sup>16</sup> compared children with SCD to healthy controls, they found that the oxygen saturation rate below 85% was 4 times higher in children with SCD. They also found more severe nocturnal desaturation and hypercapnia in children with SCD with suspected OSAS compared to children with OSAS without complications.<sup>16</sup> In another similar study, night desaturation was found more frequently in the SCD group than in the control group, and the median SpO<sub>2</sub> and minimal SpO<sub>2</sub> were significantly lower in the SCD group.<sup>17</sup>

Spivey et al<sup>18</sup> showed that SCD children with a daytime saturation SpO<sub>2</sub>  $\leq 94\%$  are a reasonable threshold for screening for sleep breathing disorders. They found abnormal

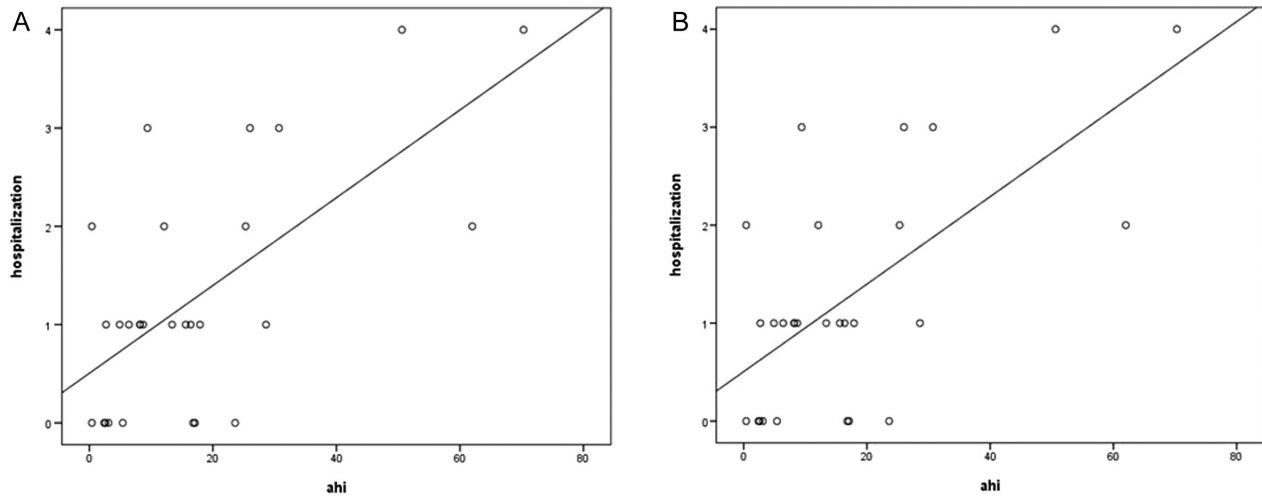
**Table 5.** Correlation Analysis Between Sleep Data and Attacks and Hospitalizations in Sickle Cell Disease Patients (r values)

	AHI	Minimum Saturation	Mean Saturation	Attack	Hospitalization
ODI	0.961**	-0.525**	-0.028	0.733**	0.584**
AHI		-0.546**	-0.019	0.805**	0.657**
Minimum saturation			-0.001	-0.496**	-0.354
Mean saturation				-0.252	0.005
Attack					0.834**

\*\*Correlation is significant at the 0.01

\*Correlation is significant at the 0.05

ODI, oxygen desaturation index; AHI, apnea-hypopnea index.



**Figure 1.** A. Scatter plots graph of the correlation between AHI and hospitalizations. B. Scatter plots graph of the correlation between AHI and the number of admissions to the hospital in the last 1 year due to attack. AHI, apnea-hypopnea index.

sleep patterns in all 12 SCD children with a daytime SpO<sub>2</sub> 94%. They also found OSAS in 35% of these children. Many studies have found that as the depth of hypoxemia increases, complications associated with SCD increase. Patients presented with more pain and more frequent acute chest syndrome clinic. Especially in children, neurocognitive functions were impaired. In our study, as the degree of OSAS increased and the minimum oxygen saturation during sleep decreased, the emergency admissions of the patients in the last 1 year increased significantly, and a significant increase was found in hospitalizations due to vasoocclusive crisis and/or acute chest syndrome in the last 1 year. In SCD patients, hypoxia that deepens more at night contributes to the polymerization of Hb S, which has been found to lead to more vaso-occlusion and other complications.<sup>19</sup> Also, Katz et al<sup>20</sup> in their study found higher rates of pneumonia, cardiovascular, and neurological complications in children with OSAS and SCD compared to children with SCD without OSAS.

In a study by Narang et al<sup>21</sup>, it was evaluated whether the use of hydroxyurea (HU) was associated with a decrease in the frequency of OSA and high nocturnal and awake oxygen saturation (SaO<sub>2</sub>) in children with SCD. Hydroxyurea use was associated with an increase in alertness and nocturnal SaO<sub>2</sub>, although there was no difference in the severity of obstructive apnea-hypopnea index. It has been emphasized that improving night SaO<sub>2</sub> can be an important mechanism of action of HU treatment.<sup>21</sup> Because all of our patients used HU, the efficiency of HU could not be evaluated.

In studies, restrictive type respiratory dysfunction has been found especially in adults with SCD, while obstructive type disorders have been detected in children and adolescents.<sup>22,23</sup> Possible factors associated with restrictive respiratory dysfunction in SCD patients are acute or chronic inflammation and resulting fibrosis, recurrent episodes of acute chest syndrome, small vessel vascular volume on computed tomography sections, cardiomegaly, and pulmonary hypertension.<sup>24</sup> In our study, restrictive type respiratory dysfunction was common in the SCD patient group, and as the

FEV1 level decreased in these patients, ODI and AHI levels increased significantly. However, secondary causes of restrictive pathology were not investigated in our patients. Since higher AHI levels are detected in patients with restrictive respiratory dysfunction, we think that OSAS symptoms should be questioned, especially in these patients, and PSG should be performed if necessary, regardless of the presence of symptoms.

Another condition that can affect the sleep quality of SCD patients is RLS, which affects 8.4% of the general population. Wali et al<sup>25</sup> in their study in which they evaluated 44 patients with SCD and 45 patients with non-SCD anemia found higher RLS rates and lower sleep quality in patients with SCD.<sup>25</sup> Rogers et al<sup>26</sup> evaluated the frequency and rates of PLM in 64 children with sickle cells aged 2-18 years. They found the average PLM index in children to be 3.7. They found RLS in 12.5% of the children. And in these children, accompanying sleep disorders were found to be more frequent and sleep efficiency was lower. In another study, 36% of adolescent SCD patients had sleep breathing disorders and 23% of these patients had PLM. Again, in the same study, 21%- 41% of adolescent with SCD reported a behavioral sleep disorder characterized by insomnia, difficulty in falling asleep, and maintaining sleep.<sup>27</sup> Similarly in our study, very high levels of RLS were found in the SCD group compared to the control group according to the criteria of the IRLSSG. Restless leg syndrome symptoms were especially detected in moderate and severe levels. Again, significantly lower sleep efficiency and more disturbances in sleep quality were found in the SCD group than in the control group.

## CONCLUSION

Obstructive sleep apnea syndrome is a treatable condition that can have adverse health consequences, and studies have found that it is more common in patients with SCD. Therefore, in this high-risk SCD patient population, we think that performing and evaluating procedures for screening, diagnosis, and treatment of OSAS will improve the patient's quality of life in preventing complications and improving sleep quality. Therefore, all SCD patients should be evaluated for OSAS.

Also, we think that PSG should be performed on patients with OSAS symptoms, frequent attacks, frequent hospitalization rates, and restrictive respiratory dysfunction.

**Ethics Committee Approval:** This study was approved by Ethics committee of Hatay Mustafa Kemal University, (Approval No: 2018/36).

**Informed Consent:** Written informed consent was obtained from the patients who agreed to take part in the study.

**Peer-review:** Externally peer-reviewed.

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## REFERENCES

1. Thein MS, Igbineweka NE, Thein SL. Sickle cell disease in the older adult . *Pathology*. 2017;49(1):1-9. [\[CrossRef\]](#)
2. Finch P, Stocks RM, Smeltzer MP, Kimble A, Schoumacher R, Hankins JS. Effects of adenotonsillectomy on polysomnographic parameters in children with sickle cell disease. *Pediatr Blood Cancer*. 2013;60(7):E26-E28. [\[CrossRef\]](#)
3. Wanek J, Gaynes B, Lim JI, Molokie R, Shahidi M. Human bulbar conjunctival hemodynamics in hemoglobin SS and SC disease. *Am J Hematol*. 2013;88(8):661-664. [\[CrossRef\]](#)
4. Maspero C, Giannini L, Galbiati G, Rosso G, Farronato G . Obstructive sleep apnea syndrome: a literature review. *Minerva Stomatol*. 2015;64(2):97-109.
5. Allen RP, Picchietti D, Hening WA, Trenkwalder C, Walters AS, Montplaisi J. Restless legs syndrome diagnosis and epidemiology workshop at the National Institutes of Health, International Restless Legs Syndrome Study Group. *Sleep Med*. 2003;4(2):101-119. [\[CrossRef\]](#)
6. Walters AS, LeBrocq C, Dhar A, et al. Validation of the International Restless Legs Syndrome Study Group rating scale for restless legs syndrome. *Sleep Med*. 2003;4(2):121-132. [\[CrossRef\]](#)
7. Allen RP, Earley CJ. Validation of the Johns Hopkins restless legs severity scale (JHRLSS). *Sleep Med*. 2001;2(3):239-242. [\[CrossRef\]](#)
8. Rechtschaffen A, Kales A. *A Manual of Standardized Terminology, Techniques and Scoring System and Sleep Stages of Human Subjects*. Los Angeles: University of California Brain Information Service; 1968.
9. American Academy of Sleep Medicine. *ICSD-3:the International Classification of Sleep Disorders. Diagnostic and Coding Manual*. Westchester: AASM; 2014.
10. Sateia MJ. International classification of sleep disorders-third edition, highlights and modifications. *Chest*. 2014;146(5):1387-1394 . [\[CrossRef\]](#)
11. Wallen GR, Minniti CP, Krumlauf M, et al. Sleep disturbance, depression and pain in adults with sickle cell disease. *BMC Psychiatry*. 2014;14:207. [\[CrossRef\]](#)
12. Sharma S, Efird JT, Knupp C, et al. Sleep disorders in adult sickle cell patients. *J Clin Sleep Med*. 2015;11(3):219-223. [\[CrossRef\]](#)
13. Al-Saqqaf R, Merdad R, Wali SO, et al. The prevalence of obstructive sleep apnea in adult patient with sickle cell disease. *J Applied Hematol* 2017;8(1):16-22. [\[CrossRef\]](#)
14. Halphen I, Elie C, Brousse V, et al. Severe nocturnal and post-exercise hypoxia in children and adolescents with sickle cell disease. *PLoS ONE*. 2014;9(5):e97462. [\[CrossRef\]](#)
15. Rosen CL, Debaun MR, Strunk RC, et al. Obstructive sleep apnea and sickle cell anemia. *Pediatrics*. 2014;134(2):273-281. [\[CrossRef\]](#)
16. Kaleyias J, Mostofi N, Grant M, et al. Severity of obstructive sleep apnea in children with sickle cell disease. *J Pediatr Hematol Oncol*. 2008;30(9):659-665. [\[CrossRef\]](#)
17. Mascarenhas MI, Loureiro HC, Ferreira T, et al. Sleep pathology characterization in sickle cell disease: Case-control study. *Pediatric Pulmonology*. 2015;50:396-401. [\[CrossRef\]](#)
18. Spivey JF, Uong EC, Strunk R, Boslaugh SE, DeBaun MR. Low daytime pulse oximetry reading is associated with nocturnal desaturation and obstructive sleep apnea in children with sickle cell anemia. *Pediatr Blood Cancer*. 2008;50(2):359-362. [\[CrossRef\]](#)
19. Whitesell PL, Owoyemi O, Oneal P, et al. Sleep disordered breathing and nocturnal hypoxemia in young adults with sickle cell disease. *Sleep Med*. 2016;22:47-49. [\[CrossRef\]](#)
20. Katz T, Schatz J, Roberts CW. Comorbid obstructive sleep apnea and increased risk for sickle cell disease morbidity. *Sleep Breath*. 2018;22(3):797-804. [\[CrossRef\]](#)
21. Narang I, Kadmon G, Lai D, et al. Higher nocturnal and awake oxygen saturations in children with sickle cell disease receiving hydroxyurea therapy. *Ann Am Thorac Soc*. 2015;12(7):1044-1049. [\[CrossRef\]](#)
22. Klings ES, Wyszynski DF, Nolan VG, Steinberg MH. Abnormal pulmonary function in adults with sickle cell anemia. *Am J Respir Crit Care Med*. 2006;173(11):1264-1269. [\[CrossRef\]](#)
23. Intzes S, Kalpathi RV, Short R, Imran H. Pulmonary function abnormalities and asthma are prevalent in children with sickle cell disease and are associated with acute chest syndrome. *Pediatr Hematol Oncol*. 2013;30(8):726-732. [\[CrossRef\]](#)
24. Şen N. Erişkin orak hücre anemili hastalarda pulmoner komplikasyonlar. *Cukurova Med J*. 2018;43(3):1-1. [\[CrossRef\]](#)
25. Wali SO, AlQassas I, Merdad R, Alsaggaf R, Al-Sayes F. Restless legs syndrome and sleep quality among adult sickle cell disease patients. *Sleep Breath*. 2018;22(2):495-501. [\[CrossRef\]](#)
26. Rogers VE, Marcus CL, Jawad AF, et al. Periodic limb movements and disrupted sleep in children with sickle cell disease. *Sleep*. 2011;34(7):899-908. . [\[CrossRef\]](#)
27. Valrie CR, Trout KL, Bond KE, et al. Sleep problem risk for adolescents with sickle cell disease: sociodemographic, physical, and disease-related correlates. *J Pediatr Hematol Oncol*. 2018;40(2):116-121. [\[CrossRef\]](#)