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Original Article

Sleep Quality and Associated Respiratory Problems in Mucopolysaccharidosis: A Cross-sectional Study based on Parent Reports

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ABSTRACT

Aim: Mucopolysaccharidoses (MPS) are a group of lysosomal storage disorders characterized by the accumulation of glycosaminoglycans (GAGs) in various tissues. Particularly, the accumulation of GAGs in the soft tissues of the head and neck region contributes to obstructive respiratory problems and sleep disturbances. This study aimed to evaluate sleep-related respiratory symptoms in patients with different subtypes of MPS.

Materials and Methods: This study included 25 patients diagnosed with MPS. The patients were evaluated in terms of their MPS subtypes, age, gender, duration of enzyme replacement therapy (ERT), and sleep questionnaire scores. Sleep-related respiratory problems were assessed using the "Pediatric Sleep Questionnaire: Sleep-Disordered Breathing (SDB) Subscale." A mean score above 0.33 on the 22-item questionnaire was considered indicative of SDB.

Results: This study included 25 patients diagnosed with MPS I (n=8), MPS II (n=1), MPS IIIA (n=2), MPS IIIB (n=2), MPS IVA (n=3), and MPS VI (n=9). Six patients were not receiving ERT. The median score on the Pediatric Sleep Questionnaire: SDB Subscale was 0.27 (range: 0.15-0.56). Eleven patients (44%) had SDB. No significant differences were found in the sleep questionnaire scores based on the patients' MPS subtype ($p>0.05$). There was no correlation between ERT duration, age, and the sleep questionnaire scores. Polysomnography (PSG) was planned for those patients with SDB.

Conclusion: In our study, we found that approximately half of the patients diagnosed with MPS had SDB. MPS patients should be routinely evaluated for sleep-related respiratory problems during follow-up visits, and those with symptoms of SDB should undergo PSG.

Keywords: Mucopolysaccharidosis, sleep disorders, apnea, polysomnography

Introduction

Mucopolysaccharidoses (MPS) are a group of lysosomal storage disorders characterized by deficiencies in the specific enzymes responsible for the degradation of glycosaminoglycans (GAGs). The accumulation of GAGs leads to progressive dysfunction at the cellular, tissue, and organ levels. To date, eleven distinct enzyme deficiencies have been identified, giving rise to seven recognized MPS subtypes (I, II, III, IV, VI, VII, and IX), with additional subtypes described for MPS III and MPS IV (1-4). Except for MPS type

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II (Hunter syndrome), which is inherited in an X-linked recessive manner, all other MPS types follow autosomal recessive inheritance patterns. Most MPS disorders are characterized by multisystem involvement, including short stature, musculoskeletal abnormalities, visual impairment, hearing loss, hepatosplenomegaly, cardiovascular disease, and/or respiratory complications. The specific manifestations and severity vary among the different MPS types. The accumulation of GAGs in tissues, resulting from enzyme deficiency, is primarily responsible for the clinical phenotype (2-4).

The two mainstays of treatment for MPS are enzyme replacement therapy (ERT) and supportive care. ERT is available for patients with MPS types I, II, IVA, VI, and VII. Except for MPS VII, where ERT is given every two weeks, it is usually given by weekly parenteral infusions. Hematopoietic stem cell transplantation, especially if carried out before the age of two, may be an option for certain MPS I patients. Additionally, the development of therapeutic approaches based on genes and enzymes is the focus of current research efforts (5-9).

GAG deposition in the head and neck region and upper airway can lead to airway obstruction through mechanisms such as corneal clouding, periodontal disease, conductive hearing loss, postural abnormalities related to vertebral involvement, and soft tissue enlargement (including macroglossia, adenotonsillar hypertrophy, and tracheomalacia). Additionally, GAG accumulation within the lower respiratory tract may result in both restrictive and obstructive lung diseases. These upper and lower airway abnormalities contribute significantly to the respiratory complications observed in MPS (10,11).

Sleep disturbances are also frequently reported clinical features in patients with MPS (12-15). Sleep disorders represent an important cause of impaired quality of life in this population. Disrupted night-time sleep can interfere with daily functioning, negatively affecting both patients and their families. If not diagnosed and managed early, sleep-related hypoventilation and recurrent hypoxia may lead to irreversible impacts on daytime alertness, fatigue levels, cardiovascular health, and neurocognitive functions (16,17).

The primary aim of this study was to facilitate the early identification of sleep-disordered breathing (SDB) in patients with MPS, a complication known to contribute to impaired quality of life and cognitive decline. By recognizing SDB at an early stage, we seek to prevent potential physical and psychological complications during childhood and to support timely interventions. Ultimately, our goal is to promote a multidisciplinary approach which enables the implementation of appropriate management strategies tailored to the needs of this vulnerable patient population.

Materials and Methods

Study Design and Participants

This descriptive, cross-sectional study was conducted between January and April 2025 in our institution. A total of 25 patients diagnosed with MPS and followed in the pediatric metabolism and pediatric pulmonology outpatient clinics were included. Face-to-face interviews were conducted with the parents of all of the participating patients, and a survey form was completed by the researchers. The sleep quality and respiratory problems of the patients were evaluated through parental reports using the aforementioned questionnaire. Informed consent was obtained from the parents of all of the patients. To detect sleep-related breathing disorders in the patients, the "Pediatric Sleep Questionnaire: Sleep-Related Breathing Disorder Subscale" was administered. Associations between MPS subtypes, patient age, gender, duration of ERT, and the sleep questionnaire scores were analysed. A mean score greater than 0.33 on the 22-item questionnaire indicated the presence of SDB.

The inclusion criteria were: a confirmed diagnosis of MPS by genetic testing, regular follow-up at our clinic, literacy of the parents, and parental consent by signing the voluntary participation form. Those patients who did not meet these criteria were excluded.

Ethical approval for this study was obtained from the University of Health Sciences Türkiye, Van Training and Research Hospital Non-Interventional Clinical Research Ethics Committee (approval number: GOKAEK/2025-05-08, date: 04.07.2025).

Statistical Analysis

All collected data were analysed using SPSS version 22.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics are presented as frequency, percentage, median, and interquartile range. As the assumptions for parametric testing were not met, the Mann-Whitney U test was used for continuous variables, and the chi-square test was applied for nominal variables. Spearman correlation analysis was conducted to evaluate associations between the variables and other parameters. A p value <0.05 was considered statistically significant.

Results

This study included 25 patients with the following MPS subtypes: MPS I (n=8), MPS II (n=1), MPS IIIA (n=2), MPS IIIB (n=2), MPS IVA (n=3), and MPS VI (n=9). Twelve patients (48%) were female. The median age of the patients was 13 years (range: 6-16 years). Six patients were not receiving ERT. The nineteen patients receiving enzyme therapy had been receiving ERT treatment continuously since their diagnosis. Among these 19 patients, four had previously undergone adenotonsillectomy, all of whom had been diagnosed with MPS type I. Four of the eight patients with MPS type I had previously undergone adenotonsillectomy. These four patients had Pediatric Sleep Questionnaire (PSQ) Scores of 0.18, 0.18, 0.22, and 0.59, respectively, with a median score of 0.20 (range: 0.18-0.59). Only one of these patients (25%) had a PSQ score above the diagnostic threshold of 0.33. Although the sample size was small, this result suggests that adenotonsillectomy may be beneficial. The demographic and clinical characteristics of all of the patients are presented in Table I. A classification of the patients based on the median values of their sex, age, duration of ERT and PSQ Scores are presented in Table II.

The median PSQ: Sleep-Related Breathing Disorder Subscale score of the patients was 0.27 (0.15-0.56). A mean score greater than 0.33 on the 22-item questionnaire indicated the presence of SDB. The distribution of PSQ

Table I. Demographic and clinical characteristics of patients with MPS (reordered)

Patient number	Age (years)	Gender	MPS type	Duration of ERT (years)	PSQ score
P1	13	Female	MPS I	8	0.09
P2	6	Male	MPS I	3	0.18
P3	6	Male	MPS I	3	0.18
P4	15	Female	MPS I	10	0.09
P5	7	Male	MPS I	4	0.18
P6	5	Male	MPS I	4	0.63
P7	13	Female	MPS I	12	0.59
P8	14	Female	MPS I	12	0.22
P9	17	Male	MPS II	5	0.59
P10	5	Female	MPS IIIA	None	0.22
P11	4	Male	MPS IIIA	None	0.63
P12	16	Male	MPS IIIB	None	0.22
P13	16	Male	MPS IIIB	None	0.59
P14	6	Male	MPS IVA	3	0.31
P15	4	Male	MPS IVA	None	0.4
P16	23	Male	MPS IV A	9	0.36
P17	5	Male	MPS VI	2	0.0
P18	20	Male	MPS VI	19	0.72
P19	14	Female	MPS VI	12	0.27
P20	9	Male	MPS VI	9	0.0
P21	9	Female	MPS VI	None	0.4
P22	16	Female	MPS VI	12	0.54
P23	14	Female	MPS VI	10	0.04
P24	12	Male	MPS VI	10	0.13
P25	16	Female	MPS VI	12	0.45

ERT: Enzyme replacement therapy, PSQ: Pediatric Sleep Questionnaire Scores, MPS: Mucopolysaccharidoses

Scores according to MPS subtypes are listed in Table III. Eleven patients (44%) had scores above the limit, and that meant that they had sleep-related breathing disorders. Figure 1 illustrates the relationship between MPS subtypes, age, and PSQ scores in the eleven patients with PSQ values above the diagnostic threshold. Elevated PSQ scores were observed across all MPS subtypes, and no clear correlation between age and PSQ scores was evident from the graphical distribution.

Two patients, diagnosed with obstructive sleep apnea (OSA) syndrome by polysomnography (PSG), were receiving positive airway pressure (PAP) therapy. Patient 21 (P21) was a 9-year-old female diagnosed with MPS type VI who was not receiving ERT. This patient exhibited severe respiratory symptoms, prompting further evaluation with PSG and the initiation of PAP treatment. In contrast, Patient 22 (P22) was a 16-year-old female with MPS type VI who had been receiving ERT for 12 years. Despite ongoing ERT, this patient demonstrated clinically significant SDB requiring PAP therapy. No significant differences in sleep questionnaire scores were found based on gender or diagnosis ($p>0.05$ and $p>0.05$, respectively). No correlations were observed between the duration of ERT, age, and the sleep questionnaire scores. The correlation results are presented in Table IV.

Table II. Classification of patients based on the median values of sex, age, duration of enzyme replacement therapy, and Paediatric Sleep Questionnaire scores

Variable	**n (%)**	**Median (interquartile range)**
Gender		
Female	12 (48)	
Male	13 (52)	
Age (years)		13 (6-16)
Patients receiving enzyme replacement therapy (ERT)	19 (76)	
Duration of ERT (years)		5 (1-11)
Pediatric Sleep Questionnaire Score		0.27 (0.15-0.56)

Table III. PSQ scores categorized by MPS subtypes

MPS subtype	**n (Patients)**	**Mean PSQ Score**	**Minimum**	**Maximum**
MPS I	8	0.27	0.09	0.63
MPS II	1	0.59	–	–
MPS IIIA	2	0.42	0.22	0.59
MPS IIIB	2	0.40	0.22	0.59
MPS IVA	3	0.35	0.31	0.40
MPS VI	9	0.36	0.00	0.72

PSQ: Pediatric Sleep Questionnaire Scores, MPS: Mucopolysaccharidoses

Table IV. Correlation results

Variable	**Pediatric Sleep Questionnaire score (r)**	**p value**
Age (years)	0.18	0.326
Duration of ERT (years)	0.23	0.912

ERT: Enzyme replacement therapy

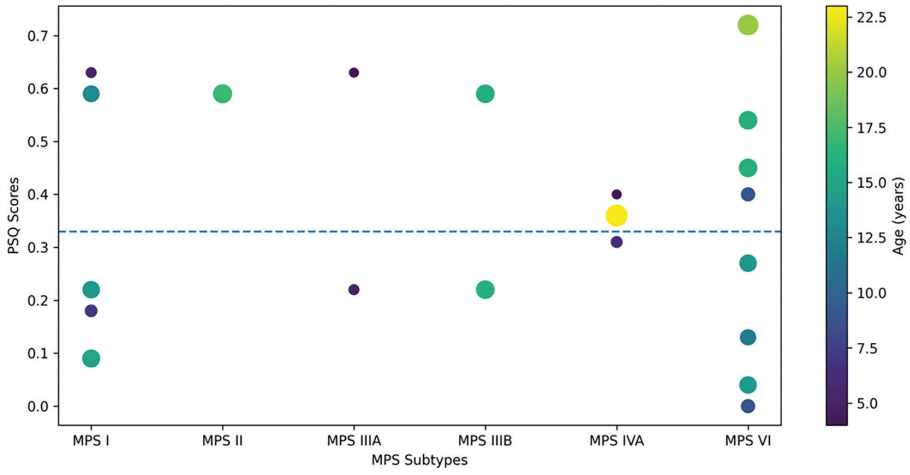

Figure 1. Stratified distribution of sleep-disordered breathing risk in patients with MPS (corrected)
MPS: Mucopolysaccharidoses, PSQ: Pediatric Sleep Questionnaire Scores

Discussion

This study investigated sleep-related breathing disturbances in a diverse cohort of pediatric patients with various subtypes of MPS. Using the PSQ, we identified that nearly half of the patients (44%) exhibited symptoms suggestive of SDB, despite the absence of significant associations with age, gender, MPS subtype, or duration of ERT. These findings underscore the high prevalence of SDB in MPS patients and highlight the importance of systematic screening, regardless of clinical classification or treatment status, in order to facilitate early detection and intervention.

Upper airway obstructions and associated complications are commonly seen in MPS patients. The accumulation of GAGs in tissues, resulting from enzyme deficiency, is primarily responsible for the clinical phenotype (2-4). Supraglottic manifestations are common in MPS and develop due to cranial and spinal abnormalities (e.g., flattened nasal bridge, short neck, high epiglottis, mandibular abnormalities, abnormal cervical vertebrae) and GAG deposition in the mouth, nose, and throat (18). Oral manifestations include gingival hyperplasia, mucosal edema, mucoid secretions, and impaired opening of the mouth. Tonsillar hypertrophy is one of the clinical manifestations, and tonsillectomy may be required for the treatment of OSA. A systematic meta-analysis conducted in 2024 identified MPS I and II as the most frequently operated on MPS subtypes. That study reported improvements in polysomnographic parameters during the postoperative period (2). Postoperatively, these patients demonstrated low PSQ scores, suggesting a potential benefit of surgical intervention in alleviating SDB symptoms in this subgroup.

Among the19 patients receiving ERT in our study, four had previously undergone adenotonsillectomy, all of whom had been diagnosed with MPS type I. These four patients had PSQ scores of 0.18, 0.18, 0.22, and 0.59, respectively, with a median score of 0.20 (range: 0.18-0.59). When evaluated on an individual patient basis, two patients (P2 and P3), both aged 6 years and diagnosed with MPS type I, demonstrated low PSQ scores of 0.18 following adenotonsillectomy, suggesting minimal parent-reported symptoms of SDB. Another patient (P8), a 14-year-old female with MPS type I, also showed a low PSQ score of 0.22, indicating a favourable sleep-related symptom profile after surgical intervention. In contrast, patient P7, a 13-year-old female with the same MPS subtype, exhibited a markedly higher PSQ Score of 0.59 despite a history of adenotonsillectomy, reflecting persistent sleep-related breathing symptoms. Clinically, this patient had a markedly short neck as an anatomical disadvantage and presented with prominent nocturnal symptoms, including loud snoring and habitual mouth breathing during sleep. In comparison, the remaining three patients did not exhibit apparent anatomical airway disadvantages. This anatomical and clinical disparity may partially explain the observed differences in PSQ scores among patients with the same MPS subtype. Collectively, these patient-level observations highlight the heterogeneous nature of airway involvement in MPS type I SDB -disordered breathing when additional anatomical risk factors are present. These findings underscore the importance of individualized airway assessment and continued follow-up in patients with MPS type I.

Respiration physiologically requires the coordinated activity of the diaphragm, chest wall, and upper airway

muscles, all of which are controlled by the brain. Feedback from blood gases (pCO_2 and pO_2) and mechanical reflexes from the chest wall, airways, and lungs regulate and balance this system. In patients with MPS, impaired central ventilation responses may occur due to central nervous system involvement, but the most common respiratory abnormalities are upper and lower airway obstructions and changes in respiratory mechanics, leading to restrictive lung disease. Progressive upper airway compromise is extremely frequent in MPS I, II, and VI, but it is least pronounced in MPS III (5,19). Most patients with severe MPS I develop snoring and obstructive upper airway disease by 2 or 3 years of age. OSA typically occurs first during rapid eye movement sleep and can be diagnosed via sleep studies (20). Our findings are consistent with previous studies demonstrating a high prevalence of SDB and abnormal sleep architecture in patients with mucopolysaccharidosis. Wooten et al. (21) investigated sleep and pulmonary characteristics in a cohort of 30 enzyme-naive MPS II patients, revealing OSA in 90% of cases, reduced rapid eye movement and slow-wave sleep, and frequent episodes of oxygen desaturation and hypoventilation. Importantly, their study identified a significant inverse correlation between pulmonary function, measured by FEV_1, and the severity of sleep-related respiratory abnormalities, including apnea-hypopnea index and elevated end-tidal CO_2 levels (21). Although our cohort included patients with MPS types I, II, and III, and we primarily relied on parent-reported outcomes, the elevated PSQ scores observed in certain individuals may reflect similar underlying disturbances. The overlap between poor sleep quality and impaired respiratory status in both studies highlights the importance of incorporating comprehensive respiratory assessments, including PSG and pulmonary function testing, into the routine clinical care for MPS patients. These findings underscore that even in the absence of overt clinical symptoms, subclinical SDB may be present and clinically significant. Pal et al. (22) conducted a study on children with MPS type I and reported that PSQ-SDB scores showed strong concordance with PSG findings. Elevated scores were significantly associated with moderate-to-severe OSA, supporting the PSQ's validity as a screening tool in this population. It should be emphasised that early recognition of sleep-related breathing problems using PSQ can allow for timely therapeutic interventions such as continuous PAP (CPAP) or adenotonsillectomy. In our study, the median PSQ-SDB scores of those patients with MPS type I were within the normal range, and all patients were receiving ERT. Notably, half of the patients with MPS type I had a history of adenotonsillectomy, suggesting that the favourable sleep-related outcomes in this group may be partially attributable to their prior surgical interventions. The questionnaire used in this study can offer guidance in assessing SDB in those patients who have challenges in accessing or adhering to PSG due to the scarcity of clinics in our country and prolonged appointment waiting times.

Upper-airway obstruction and decreased pulmonary reserve often lead to OSA. Clinical features include mouth-breathing, snoring, apnea, and/or restless sleep. Less frequently, daytime somnolence, failure to thrive, pulmonary hypertension, and cor pulmonale may be noticed. Behavioural and learning problems may also occur secondary to disrupted sleep (23). In a study by Ademhan Tural et al. (15), which investigated sleep-related breathing disorders and associated respiratory problems and exercise capacity in patients diagnosed with MPS IVA and MPS VI, the prevalence of OSA was found to be high in these patients. Due to the high prevalence of OSA in MPS IVA and MPS IV patients, they emphasized the importance of PSG screening for sleep disorders in these individuals (15). Similarly, in our study, we planned to perform PSG for those patients diagnosed with sleep-related breathing disorders.

Sleep disturbances are also frequently reported clinical features in patients with MPS (12-15). Sleep disorders represent an important cause of impaired quality of life in this population. Nashed et al. (24) reported a similarly high prevalence of OSA and gas exchange abnormalities in a pediatric cohort with multiple types of mucopolysaccharidosis, using full overnight PSG. Their findings of frequent oxygen desaturation and CO_2 retention, as well as the anatomical factors contributing to upper airway obstruction, mirror the sleep disturbances observed in our study, especially among those patients with elevated PSQ Scores (24). The success of treatment strategies, including CPAP and adenotonsillectomy in Nashed's cohort, further suggests that early and targeted intervention may ameliorate sleep-related respiratory complications.

Together with Wooten et al. (21), who demonstrated that pulmonary function decline correlates with SDB severity, Nashed's data reinforce the need for a dual approach in MPS patient management. Specifically, our results highlight the potential value of integrating objective sleep studies and anatomical airway assessments into routine clinical monitoring, particularly when subjective questionnaires suggest moderate or severe sleep-related symptoms (21,24). This study also emphasized the importance of identifying sleep disturbances in MPS patients and the role of PSG in guiding appropriate therapeutic strategies.

Study Limitations

The primary limitation of this study was its relatively small sample size, which is an inherent challenge in research involving rare diseases such as mucopolysaccharidosis. The limited number of participants may reduce the generalizability of our findings and restrict the statistical power to detect more subtle associations. The small number of patients within each MPS subtype limited the statistical power of subtype-based correlation analyses, and therefore these results should be interpreted cautiously. Our work aimed to contribute to the growing body of evidence by drawing attention to the need for the early recognition and systematic evaluation of sleep-related symptoms in this vulnerable population.

Conclusion

In our study, we found that approximately half of those patients diagnosed with MPS had SDB. We emphasize the need for routine follow-up evaluation of MPS patients for sleep-related breathing problems and the need for PSG in those with symptoms of SDB.

Ethics

Ethics Committee Approval: Approval for this study was obtained from the University of Health Sciences Türkiye, Van Training and Research Hospital Non-Interventional Clinical Research Ethics Committee (approval number: GOKAEK/2025-05-08, date: 04.07.2025) according to the guidelines of the Helsinki Declaration of Human Rights.

Informed Consent: Informed consent was provided by all of the patients.

Footnotes

Authorship Contributions

Surgical and Medical Practices: G.U., F.E.K., Concept: F.E.K., Design: G.U., Data Collection or Processing: G.U., F.E.K., N.G., Analysis or Interpretation: N.G., T.R.G., Literature Search: G.U., T.R.G., Writing: G.U., T.R.G.

Conflict of Interest: The authors have no conflict of interests to declare.

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