# Diagnostic Possibilities of Obstructive Sleep Apnea

Doctoral (PhD) Dissertation

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Pécs, 2025

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# List of Abbreviations

AASM - American Academy of Sleep Medicine

AHI - Apnea Hypopnea Index

AveO2 - Average Oxygen Saturation

BMI - Body Mass Index

CPAP - Continuous Positive Airway Pressure

EDS - Excessive Daytime Sleepiness

EEG - Electroencephalography

EMG - Electromyography

EOG - Electrooculography

ESS - Epworth Sleepiness Scale

HSAT - Home Sleep Apnea Test

ICSD-3 - International Classification of Sleep Disorders, 3rd edition

MAD - Mandibular Advancement Device

MinO2 - Minimal Oxygen Saturation

MSLT - Multiple Sleep Latency Test

MWT - Maintenance of Wakefulness Test

ODI - Oxygen Desaturation Index

OSA - Obstructive Sleep Apnea

PSG – Polysomnography

ρc - Lin's Concordance Correlation Coefficient

PWA - Pulse Wave Amplitude

RAAS - Renin-Angiotensin-Aldosterone System

REM - Rapid Eye Movement

SD - Standard Deviation

T90 - Percentage of time spent with oxygen saturation below 90%

TIB - Time In Bed

# 1. Introduction

According to various surveys, 4–15% of the population suffers from some form of sleep disorder. Nevertheless, medical education and clinical practice devote little attention to their recognition and treatment, resulting in these conditions often being underdiagnosed and undertreated. Among sleep disorders, sleep-related breathing disorders are of particular public health importance, with obstructive sleep apnea (OSA) being the most common. This disease is characterized by repeated complete or partial obstruction of the pharynx, and due to its increasing prevalence, cardio- and cerebrovascular consequences, comorbidities, and treatability, it is receiving growing attention.

The prevalence of OSA is high: it occurs in 2–4% of the general population and increases with age. Severe forms affect 6.8% of men and 2.9% of women aged 30–70. The disease is an established risk factor for hypertension, arrhythmias, heart failure, diabetes, coronary artery disease, pulmonary hypertension, and stroke. It is strongly associated with later cognitive dysfunction and plays a role in traffic accidents. Clinical symptoms are divided into nocturnal and daytime manifestations. Cardinal nocturnal complaints include snoring, prolonged breathing pauses often observed by the bed partner, the snoring-apnea-gasping triad, and choking or gasping during sleep. Nighttime rest in those suffering from obstructive sleep apnea is restless, characterized by frequent awakenings, massive thrashing movements, nocturia, and excessive sweating. Daytime symptoms include varying degrees of sleepiness, cognitive deficits (forgetfulness, attention deficits, executive dysfunction), and affective disturbances, including irritability personality and depression. However, cardinal symptoms can occur in individual combinations, independent of AHI, with varying cardiovascular risk and impact on quality of life. Based on these, different OSA phenotypes are distinguished, representing subtypes that encompass geographical and ethnic differences, pathophysiological mechanisms ("endotypes"), clinical and physiological features, identifiable biomarkers, and genetic background. The potential endotypes of OSA are different pathophysiology/pathogenetic mechanisms based on, for example, craniofacial morphology, obesity, upper airway muscle activity, ventilatory control stability and nocturnal rostral fluid shift, different arousal threshold. The clinical phenotype may include several endotypes.

Based on a large pan-European analysis, five main clinical phenotypes can currently be distinguished:

1) Disturbed sleep: insomnia-like complaints and symptoms predominate.
2) Minimal symptoms: the patient is practically asymptomatic or has nonspecific complaints.
3) Upper airway symptoms with sleepiness: typical OSA symptoms, comorbidities, and demonstrable sleepiness.
4) Upper airway symptoms dominant: Observed and experienced apneas, snoring, and other symptoms without sleepiness or comorbidities.
5) Sleepiness-dominant type: Excessive sleepiness is the main complaint; comorbidities may be present, but observed/experienced apneas are absent.

Phenotypes can also be categorized based on differences observed in diagnostic studies (polysomnography, polygraphy), such as the nocturnal pattern of apneas/hypopneas (e.g., supine-dependent, REM-predominant). Patients with REM-predominant OSA are usually younger women with reduced sleep time and sleep efficiency and more REM phase time. Musculus genioglossus muscle activity is lowest during REM phase, with longer REM phase duration resulting in more severe hypoxia and increased sympathetic activity. Individuals with position-dependent (supine dominant) OSA tend to be younger, have a lower body mass index (BMI), lower AHI, which are mostly manifested in the supine position.

The pathomechanism of obstructive sleep apnea is complex and consists of several components, but the basic mechanisms are based on the Starling resistor model and Bernoulli's law. According to these, the muscles that dilate the upper airways cannot resist the negative forces generated during inspiration, resulting in narrowing and obstruction at the level of the pharynx (mainly the oro- and mesopharynx). Physiologically, the muscles that keep the upper airways open contract in coordination with inspiration, counteracting the suction force and negative pressure generated during inspiration. Factors that disrupt this equilibrium result in narrowing and complete obstruction.

Structural factors encompass anatomical features of the upper airways, inherited and acquired pathological abnormalities and, together with the functional causes that build on them, play a role in the development of the different endotypes of OSA. Three main factors are distinguished in the development of the disease: upper airway muscles

function, changes in ventilation control and the arousal threshold. The pathophysiological consequences of OSA-chronic intermittent nocturnal hypoxia-reoxygenation, severe oxidative stress, intermittent thoracic pressure changes, and sleep fragmentation-induced sympathetic activation-contribute to the development of cardio- and cerebrovascular diseases and other comorbidities.

In the diagnosis of the disease, questionnaire methods and sleep study procedures are available. Questionnaire methods and sleep testing procedures are available for the diagnosis of obstructive sleep apnea. Questionnaires can help in the detection and screening of OSA: symptoms and complaints specific to the disease are assessed, together with physiological features and comorbidities. The best known international questionnaires available in Hungarian are the Berlin questionnaire, the STOP-BANG questionnaire. Daytime sleepiness, a main symptom of sleep apnea, is assessed using the Epworth Sleepiness Scale (ESS).

Validated cardiorespiratory polygraphy is a widely used method for simultaneous recording of cardiorespiratory parameters, suitable for both home and institutional use in OSA diagnosis. The examination must record, for at least 6 hours and with adequate quality, the following parameters: airflow, respiratory effort, blood oxygen saturation (SpO2), heart rate, body position, snoring, and sleep events. The diagnosis can be established based on these. The method should not be used in pulmonary diseases with severe and moderate respiratory insufficiency, neuromuscular diseases, heart failure, suspected other sleep disorders, psychiatric diseases. Both the AASM and Hungarian guidelines emphasize that for proper diagnosis, home polygraphic studies must be performed and evaluated in accredited laboratories with the involvement of sleep medicine specialists. Manual scoring is also emphasized over automated analysis. Home-based polygraphy is simpler, more acceptable to patients, more accessible, cost-effective. Its disadvantage is the lack of an EEG sensor, which prevents the assessment of hypopnea and RERA-induced arousal, which often under-detects the severity of OSA. In negative or questionable cases, polysomnography is the gold standard diagnostic method.

Nocturnal polysomnography, performed using a standardized technique with a qualified somnologist technologist, is the gold standard test for obstructive sleep apnea syndrome. It provides information on sleep stages, arousal reactions, cardiorespiratory abnormalities, movement phenomena and their relationships. The polysomnograph records at least the following physiological parameters: sleep quality and structure (EEG,

EOG, chin EMG) respiratory effort (thoracic and abdominal), airflow (nasal or oro-nasal, as well as thermistor and pressure-based) blood oxygen level (SpO2) pulse, ECG, body position snoring, infrared video monitoring.

The clinical severity of OSA is shown by the results of overnight sleep monitoring, characterized by the apnea-hypopnea index (AHI) per hour of sleep: mild (>= 5/h and <15/h), moderate (>= 15/h and <30/h) and severe (>= 30/h) categories.

The correct evaluation of questionnaire methods, polygraphic and polysomnographic elements and the reliability of examination procedures are fundamental requirements for the proper diagnosis of sleep disorders and thus for therapy. In our study, we investigated the reliability of these testing procedures using different methods.

Excessive daytime sleepiness (EDS) significantly affects everyday life. Many treatable conditions may be behind it, and the underlying diseases can have serious consequences. Increased daytime sleepiness is associated with workplace and traffic accidents, as well as increased mortality. The Epworth Sleepiness Scale (ESS), developed by Murray W. Johns, MD in 1991, is the most widely used validated questionnaire for measuring sleepiness, but there is limited and contradictory data about its reliability.

The severity of obstructive sleep apnea can be influenced by several factors, such as gender, obesity, nocturnal changes in sleep structure, and sleeping position. Sleep is an adaptive process whose structure is not stable, and its quality can vary from day to day. This daily variation can cause changes in the severity of respiratory disorders. Time spent in different positions and different breathing pathology patterns can change from night to night, which can affect the severity of the respiratory disorder and therapy.

The traditional diagnostic procedure is mostly based on a single night examination, during which the so-called "first night effect" must also be considered, which results in reduced sleep time and lower sleep efficiency, further reducing the reliability of overnight sleep studies. The gold standard for the diagnosis of OSA is overnight polysomnography, but its availability is limited, and its personnel requirements are high. According to AASM guidelines, polygraphy performed at the patient's home can be a useful tool in diagnosing sleep apnea. Several studies have analyzed its reliability compared to polysomnography performed in a sleep laboratory, reporting 68-95% reliability depending on risk groups and diagnostic conditions.

# 2. Objectives

Proper evaluation of questionnaire methods, polygraphic and polysomnographic studies, and the reliability of these procedures are fundamental requirements for correct diagnosis and adequate therapy in sleep disorders. In our research, we examined the reliability of these diagnostic procedures using various methods.

## 2.1. First study objectives:

1) To examine the reliability of the Epworth Sleepiness Scale questionnaire using a test-retest method performed within a short (within 1 hour) time interval.
2) To explore what differences can be observed between two consecutive tests when subjective or objective changes affecting patients are minimized.
3) To investigate whether we find differences in the reliability of the ESS test when analyzing our data using different (old and new) statistical methods.

## 2.2. Second study objectives:

1) To determine the daily variability of the severity of sleep-related breathing disorders by comparing characteristic parameters (AHI, ODI, T90, TIB) during two consecutive night examinations.
2) To examine whether the severity of sleep-related breathing disorders changes over two consecutive nights, and if so, to what extent.
3) To determine the variability of polygraphic patterns during two consecutive night studies, and to explore how this affects the severity and therapy of OSA.
4) To answer how daily changes in sleep-related breathing disorders affects OSA severity and whether this affects therapeutic decision.

# 3. Methods

## 3.1. Epworth Sleepiness Scale Test-Retest Study

For our study, we recruited 100 unselected patients referred to our sleep laboratory with various sleep complaints (insomnia, snoring, nocturnal respiratory arrest, restless legs, increased sleepiness, etc.) between June 1, 2016, and September 15, 2016. At the time of completing the test, the participants had no known diagnosis of sleep disorder. We used the validated Hungarian translation of the eight-item standard Epworth Sleepiness Scale.

The study was conducted using a test-retest method, with a short 1-hour interval between the two testing occasions. All 100 patients completed the Epworth Sleepiness

Scale on their own, without supervision, on both occasions during the morning period between 9:00 and 11:00 AM. A "blind" protocol was employed: patients were informed of the primary aim (assessment of sleepiness by questionnaire) but were unaware of the test repetition.

When designing the study, we tried to minimize the effect of the answers given during the first test (the so-called "carry back" effect). Participants were asked to answer questions unrelated to the purpose and topic of the study (such as quality of life, depression, and anxiety questionnaires) between the first and second Epworth Sleepiness Scale tests, thus distracting their attention and reducing the carry back effect.

Data were analyzed using SPSS v.22, calculating both Lin's concordance coefficient (ρc) and Pearson's correlation. Lin's concordance correlation coefficient is now considered the gold standard for comparing two variables; values below 0.90 are considered low, 0.90–0.95 moderate, 0.95–0.99 substantial, and above 0.99 near-perfect reliability.

### 3.2. Comparison of two consecutive night polygraphy studies

We included 100 unselected patients referred to our laboratory with sleep-related complaints between July 1, 2020, and September 15, 2021. The severity and day-to-day variability of sleep-related breathing disorders were studied in all subjects using cardiorespiratory polygraphy on two consecutive nights. The minimum study duration was six hours.

Inclusion required technically adequate polygraphy recordings on both nights; participants with recordings shorter than six hours or of inadequate quality were excluded (23 excluded). All studies were performed using the Alice PDx polygraph (Philips Inc., Amsterdam, Netherlands). Recorded channels included: oronasal airflow (pressure cannula), respiratory effort (thoracic and abdominal belts), peripheral oxygen saturation and pulse (pulse oximetry). Snoring, sleep position, and events were detected by sensors on the thoracic belt.

The following parameters were studied: time in bed, apnea-hypopnea index, severity classification of obstructive sleep apnea (negative, mild, moderate, and severe), percentage of time with oxygen saturation below 90%, oxygen desaturation index, and the nocturnal pattern of breathing disorder.

Based on the appearance of obstructive breathing disorders, the following polygraphic patterns were defined:

- Phasic position-dependent (supine dependent)
- Supine dominant
- Phasic, not position-dependent
- Continuous pattern
- Continuous pattern with phasic deterioration
- Sporadic

Recordings were evaluated according to AASM rules, with manual validation in all cases (version 6, 2020). In all cases, the participants' first examination was compared with the results of the second examination. Pearson correlation coefficients were used to compare characteristic polygraphic parameters (AHI, ODI, MinO2, AveO2, TIB, etc.), while the severity grades of the two examinations and the patterns of pathological respiratory events were compared using Spearman and Wilcoxon tests.

The studies were approved by the local ethics committee (5332/2014, Regional and Institutional Research Ethics Committee, University of Pécs, Hungary).

# 4. Results

## 4.1. Results of the Epworth Sleepiness Scale test-retest study

### 4.1.1. Demographic data

Our study included 100 participants (63 men, 37 women). The age of the male patients ranged from 22 to 77 years (mean 49.21 years; SD: 13.35 years), and the female patients were between 35 and 79 years old (mean: 55.98 years; SD: 10.63 years).

### 4.1.2. ESS Test and Retest Values

During the first administration of the Epworth Sleepiness Scale (ESS 1), the mean score for all patients was 7.62 (SD: 4.48), with a median value of 7. For males, the mean value was 7.24 (SD: 4.51), and for females, it was 8.27 (SD: 4.29).

One hour later, at the second administration of the Epworth Sleepiness Scale, the mean score was 8.49 (standard deviation 5.00), with a median of 8. For men, the mean was 8.40 (SD 4.77), and for women, 8.65 (SD 5.30).

The mean difference between the test and retest was 2.44 (SD: 2.40), with a median of 2. The ESS values obtained during the second testing decreased in 34 cases, increased in 43 cases, and remained unchanged in 23 cases. The difference between the ESS values of the two examinations was greater than two in 42 cases.

When examining the test-retest reliability, the value of Lin's concordance coefficient (ρc) was 0.748, which indicates a low correlation (correlation is considered weak if the value is less than 0.9). The value of Pearson's correlation was 0.76, which is considered a good correlation (correlation is considered good if the value is between 0.5 and 1).

## 4.2. Comparative Results of Polygraphic Examination

### 4.2.1. Demographic Data

Of the 100 participants, 85 were men and 15 were women. The age of the male patients ranged from 23 to 75 years (mean: 48.61 years, SD: 12.16 years), and the female patients were between 37 and 73 years old (mean: 55.4 years, SD: 10.05 years).

### 4.2.2. Correlation Results

When comparing the first and second polygraphic examinations, the Pearson coefficients for AHI, ODI, T90, and TIB were: 0.9199, 0.9282, 0.8126, and 0.4993, respectively. These results indicate good correlation between the AHI, ODI, and T90 obtained during the two examinations, but only moderate correlation for TIB.

For AHI, there was good correlation in the severe OSA group, moderate in the mild group, and low in the moderate OSA and negative groups. For ODI, we found good correlation in severe, mild, and negative OSA and moderate correlation in the moderate severity group. For T90, the correlation was high in the severe and mild groups, and low in the moderate and negative groups.

When examining the moderate and severe OSA groups together, which are important from a therapeutic perspective, we measured good correlation for AHI and ODI, while for T90, the correlation was only moderate (0.6983).

### 4.2.3. Changes in OSA Severity and Patterns

Based on the Wilcoxon test, we found no significant differences in OSA severity grades and pattern changes. When comparing the severity grades and nocturnal patterns of the two polygraphic examinations, the Spearman correlation showed a strong association both for all participants and for patients in the moderate-severe OSA group.

Among the 100 cases, we found changes in OSA severity in 25 cases based on the second examination. The severity decreased in 11 cases and increased in 14 cases. Regarding changes in polygraphic patterns, out of 100 consecutive examinations, we detected changes in the nocturnal pattern of apneas/hypopneas in 15 cases.

### 4.2.4. Therapeutic Consequences

We identified six cases where more severe OSA was detected based on the results of the second examination, and this modified the treatment. In three of these cases, the first examination was negative, but mild OSA was diagnosed in the second examination, and in three examinations, mild OSA changed to moderate severity in the second examination.

## 5. Summary

Excessive daytime sleepiness is one of the cardinal symptoms of OSA. Assessing its extent is an important factor in diagnostics and subsequent therapeutic monitoring, including the assessment of driving licenses. Sleepiness can be measured using subjective (questionnaire) and objective tools. The Epworth Sleepiness Scale is a widely used, validated questionnaire, but there is still limited and contradictory data about its reliability.

In our study, we repeated the ESS questionnaire within an extremely short time (after 1 hour), thus minimizing the influence of factors affecting sleepiness. Analyzing the data with two different statistical methods, Lin's concordance coefficient proved to be low ($\rho c = 0.748$), which suggests low reliability of the ESS. This questions its routine use and suggests caution, especially in OSA diagnosis and therapeutic follow-up.

Polygraphy is a widely used method in the home diagnosis of obstructive sleep apnea under defined clinical conditions. Due to its simplicity and cost-effectiveness, it is important to study the usefulness of this method. In our study, we found good reliability of the polygraphic examination in moderate and severe OSA categories, which supports the applicability of the tool both from diagnostic and therapeutic perspectives.

In our research, night-to-night changes in disease severity were observed in 25% of cases, but this led to therapy modification in only 6%. Both increases and decreases in severity occurred. This nearly equal, bidirectional change may be due to physiological daily variability in sleep rather than the "first night effect".

In other severity categories, the decision to repeat polygraphy or perform polysomnography should be based on clinical characteristics. Changes in breathing disorder patterns found in repeated polygraphy may provide new information about OSA pathophysiology.

Our findings on the reliability of the ESS and home polygraphy may contribute new perspectives to OSA diagnosis and management.

# 6. Summary of New Results

To our knowledge, this is the first study to apply the Epworth Sleepiness Scale for test-retest validation within an extremely short time interval (within 1 hour), minimizing changes in environmental and internal conditions. This may provide more accurate reliability results compared to previous studies.

The Lin correlation, which is a better accepted gold standard in the statistics applied during the ESS test-retest, indicates low reliability ($\rho c = 0.748$), which questions the routine use of the test.

To evaluate the reliability of the polygraphic examination, we performed repeated examinations on two consecutive nights, comparing the stability of the severity of respiratory disorders and changes in nocturnal patterns based on characteristic parameters. We found good reliability in moderate and severe OSA categories (AHI: 0.9199, ODI: 0.9282), which emphasizes the usefulness of this method both from diagnostic and therapeutic perspectives.

In our research, a change in disease severity from night to night was detectable in 25% of cases, but this led to therapy modification in only 6%. Both an increase and a decrease in severity were observed in the second examination. This nearly equal and bidirectional change may be based on the physiological daily variability of sleep.

Our study provided new perspectives on the daily variability of nocturnal respiratory disorder patterns and their consequences, which may provide further important information in understanding the pathophysiology of OSA.

# 7. Publications

MTMT identifier: 10078858

## 7.1. Publications underlying the PhD dissertation

Rozgonyi R, Dombi I, Janszky J, Kovács N, Faludi B. Low test-retest reliability of the Epworth Sleepiness Scale within a substantial short time frame. Journal of Sleep Research 2021; Jan 25: e 13277
Journal classification: Q1, impact factor: 5.296

Rozgonyi Renáta, Janszky József, Kovács Norbert, Faludi Béla Reliability of the Polygraphic Home Sleep Test for OSA Determined by the Severity and Pattern Changes of Two Consecutive Examinations. APPLIED SCIENCES-BASEL 2023 (13); 1 Paper: 667, 11 p
Journal classification: Q1 (Engineering, Multidisciplinary) /CiteScore – Q1 (General Engineering): impact factor: 2.5

Total impact factor: 7.796

## 7.2. Presentations and posters related to the PhD dissertation

Rozgonyi Renáta, Janszky József, Kovács Norbert, Faludi Béla Renáta Rozgonyi, József Janszky, Norbert Kovács, Béla Faludi. Examination of the reliability of the Epworth Sleepiness Scale in a short-interval test-retest paradigm
XI Congress of the Hungarian Society for Sleep Diagnostics and Therapy, Lajosmizse, 2017.

Renáta Rozgonyi, Béla Faludi: The significance of sleep studies in thalamic and brainstem stroke
XX Conference of the Hungarian Stroke Society 2017, 1st place

Renáta Rozgonyi. Epworth Sleepiness Scale: Usable? Arguments for and against Annual Conference of the Hungarian Society of Neurologists and the 50th International Danube Neurology Symposium, Debrecen, 2018 June 7–10.

Renáta Rozgonyi. The significance of repeated polygraphic examinations in assessing the severity of obstructive sleep apnea syndrome
XII Congress of the Hungarian Society for Sleep Diagnostics, Siófok, 2019 November 15–16.

Renáta Rozgonyi MD, Norbert Kovács MD PhD DSc, Béla Faludi MD PhD, Hungary. Comparison of night-to-night variation of the home sleep polygraphic examination
25th Congress of European Sleep Research Society 2020 (Abstract reference number: A-1126-0022-00555)

## 7.3. Other publications not related to the PhD dissertation

Béla Faludi, Renáta Rozgonyi. Pharmacological and nonpharmacological treatment of insomnias with regard to sleep medicine. Ideggyógyászati Szemle 2018; May 30: 71 (5–06): 149–159. Journal classification: Q4, impact factor: 0.09

Renáta Rozgonyi, Dalma Dorottya Csatlós, Csenge Hargittay, András Mohos, Péter Torzsa. Screening and treatment of restless leg syndrome in primary care. Háziorvos Továbbképző Szemle 2019; 24: 372–379

Béla Faludi, Renáta Rozgonyi. The significance and role of sleep disorders in certain neurological diseases. Neurológiai Praxis; 2020; III/2: 44–46

Mingchen He, Gréta Kis-Jakab, Hedvig Komáromy, Gábor Perlaki, Gergely Orsi, Edit Bosnyák, Renáta Rozgonyi, Flóra John, Anita Trauninger, Kata Eklics. The volume of the thalamus and hippocampus in a right-handed female episodic migraine group. Frontiers in Neurology 2023; 14 Paper: 1254628, 10 pages. Journal classification: Q2, impact factor: 2.79

Ágnes Patzkó, Anita Csutak, Noémi Tóth, Zsófia Kölkedi, Zsuzsanna Pfund, Gréta Kis-Jakab, Edit Bosnyák, Renáta Rozgonyi, Edit Szalai. Analysis of the ocular surface functional unit in episodic migraine. Graefes Archive for Clinical and Experimental Ophthalmology. 2024 May; 262(5):1591–1598. Journal classification: Q1, impact factor: 2.4

Veronika Gaál, Renáta Rozgonyi, Béla Faludi. Obstructive sleep apnea – a “known unknown”. Orvostovábbképző Szemle; 2024; 21: 3 pages

Ágnes Patzkó, Zsuzsanna Pfund, Anita Csutak, Noémi Tóth, Zsófia Kölkedi, Gréta Kis-Jakab, Edit Bosnyák, Renáta Rozgonyi, Edit Szalai. Neurovascular changes of the retina and optic nerve head in episodic migraine. Scientific Reports. 2024; 14(1):20243. Journal classification: Q1, impact factor: 3.88

Mingchen He, Gréta Kis-Jakab, Hedvig Komáromy, Gábor Perlaki, Gergely Orsi, Edit Bosnyák, Renáta Rozgonyi, Flóra John, Anita Trauninger, Kata Eklics, Zsuzsanna Pfund. Volumetric alteration of brainstem in female migraineurs with and without aura. Clinical Neurology and Neurosurgery. 2024; 236:108089. Journal classification: Q2, impact factor: 1.83

Flóra John, Gréta Kis-Jakab, Hedvig Komáromy, Gábor Perlaki, Gergely Orsi, Edit Bosnyák, Renáta Rozgonyi, Anita Trauninger, Kata Eklics, Daniel O. Kamson, Zsuzsanna Pfund. Differentiation of hemispheric white matter lesions in migraine and multiple sclerosis with similar radiological features using advanced MRI. Frontiers in Neuroscience. 2024 May 9; 18:1384073. Journal classification: Q2, impact factor: 3.19

### 7.4. Book chapter:

Renáta Rozgonyi, Béla Faludi: 2.7. Reliability aspects of sleep study analysis: automatic or manual scoring?

The total impact factor of scientific publications underlying the dissertation: 7.796

Total impact factor of all scientific publications: 21.97

# 8. Acknowledgements

I would like to express my heartfelt gratitude to my mentor, Béla Faludi, MD, Associate Professor, whose physiological perspective and expertise in sleep medicine impressed me during my university years. Thanks to his influence, I chose and learned this profession; I thank him for teaching me everything step by step and always providing me with tasks that expanded my knowledge. I thank him for his help and support in preparing this dissertation.

I thank the current and former directors of the Department of Neurology, Prof. József Janszky, MD and Prof. Sámuel Komoly, MD, who gave me the opportunity to learn about the world of neurology and supported me in clinical work and professional and research development. I thank Prof. Dr. Norbert Kovács for our collaborative work, his helpful comments, and ideas during the development of the studies.

Special thanks go to Prof. László Szapáry, MD for the time spent in the Stroke Department and for showing me how important it is to treat stroke patients and screen for obstructive sleep apnea in these cases, and for supporting me in this work throughout.

I would like to express my sincere gratitude to all the staff of the Department of Neurology for the many forms of help I received from them over the years, especially the assistants of the Sleep Laboratory, without whom these studies could not have been realized. I also thank my friends who read and helped with their suggestions in creating this work.

Last but not least, I would like to thank my husband and children for their never-ending support and patience, and for standing by me throughout my career.