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Current aspects and future perspectives on polysomnography. Applicability in rehabilitation patients diagnosed with sleep related breathing disorders -A narrative review

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Abstract: Background: Polysomnography is continually advancing technically, with its applicability expanding across various fields. This narrative review aims to highlight its recent developments, current applications, and future perspectives from a clinical point of view. **Methods:** Relevant articles written in English published from 2015 to 2024 were searched in PubMed and Google Scholar. **Results:** Polysomnography remains the gold standard test in sleep disorders but in certain categories of patients it is not very accesible. Some of the home sleep tests (HSAT) perform closely to PSG testing. Identifying REM movement disorders early is important because it is a predictor factor for developing neurodegenerative diseases. Artificial intelligence (AI) can be used for diagnosis by integrating AI in wearable devices for remote monitoring, using it for faster and a more accurate scoring, as well as using it to offer personalized treatment for each individual. Polysomnography can play a pivotal role in diagnosing sleep related breathing disorders in rehabilitation patients to offer treatment, help in the improvement of sleep quality and consequently, offer better rehabilitation outcomes. **Conclusions:** Polysomnography opens up numerous possibilities for investigating sleep disorders, providing a comprehensive understanding of an individual's sleep health, and improving the management of sleep-related disorders

Keywords: polysomnography (PSG); obstructive sleep apnea (OSA); Artificial intelligence (AI); sleep relat-ed breathing disorders (SRBD); rehabilitation

1. Introduction

Sleep is a complex cyclical and organized physiological state where neurological, hormonal and enviromental factors intricate and synergize in order to maintain its regularity and homeostasis. Disruption of sleep patterns result in alteration of the physiological processes leading to a wide range of conditions, widely known as sleep breathing disorders (SBD). As our understanding of the physiological processes of sleep deepens, the role of polysomnography emerges, playing a pivotal role in the precise diagnosis of sleep disorders and its applicability widens in various fields.

By definition, polysomnography is a diagnostic tool used in the evaluation of sleep quality and sleep disorders. Its capacity to record and monitor multiple physiological parameters during sleep has proven to be essential to the comprehension of sleep disorders and their physical and mental health consequences, as well as the development of sleep medicine as a science [1].

The genesis of polysomnography can be traced back to the early 1970s when researchers began using the term "polysomnography" to describe a diagnostic methodology evaluating sleep. At its inception, PSG primarily relied on the electroencephalogram (EEG), marking a pivotal moment in sleep medicine. Over subsequent decades, PSG underwent transformative enhancements, expanding its scope by correlating EEG findings with parameters from other physiological systems, including respiratory and cardiovascular systems [2].

The cornerstone in the development of polysomnography (PSG) was descovering rapid eye movement sleep (REM sleep) in the early 1950s when researchers introduced eye movement electrodes during the recording of sleep EEG. Shortly after, it was discovered that REM sleep with non REM(non rapid eye movement) sleep alternated in approximately 90 minutes-cycles. Following closely, electromyography (EMG) electrodes were introduced but the main and the most innovative revelation happened in the 1960s when respiratory and cardiac monitoring was added to the previously rudimentary version of PSG. After a few decades of advancement in the recording area, the digitalization that started in the 1990s allowed more parameters to be evaluated and correlated [2,3].

As a consequence of the rapid development and refinement of PSG, the American Academy of Sleep Medicine (AASM) has developed the AASM Manual for Scoring of Sleep and Associated Events to define universally accepted criteria for standard recording and guidelines for scoring (AASM Scoring Manual version 3)[4,5].

In recent years, the field of sleep medicine has witnessed rapid advancements in technology and understanding, propelling polysomnography to the forefront as an indispensable tool for diagnosing and managing a diverse array of sleep disorders.

In the context of rehabilitation medicine, especially stroke rehabilitation and recovery, concomitant sleep disorders may have a greater impact than previously considered. Motor learning, which is the main mechanism of recovery after stroke seems to be considerably influenced by sleep, motor skills practice being consolidated during sleep time. Patients with disordered sleep perform newly learned motor skills with more error compared to patients without sleep disturbances. Other solid processes important in neurorehabilitation include memory, attention, cognition are affected by sleep disturbances and make the recovery process more challanging with worse rehabilitation outcomes. Abnormal sleep seems to play an important negative role in rehabilitation after stroke thus identifying sleep disturbances and improving sleep quality in these patients should be part of the rehabilitation process [6].

Sleep disturbances in COPD are associated with more frequent exacerbations, greater severity of disease and higher mortality [7,8]. There have been shown that patients suffering from chronic respiratory diseases often present symptoms such as - sleep fragmentation, frequent awakenings and insomnia, often accompanied by coughing and nocturnal dyspnea. As a result of the pathologically progressive respiratory failure accompanying patients with severe COPD, they often present a worsening of nocturnal oxygen levels as the disease progresses. The overlap syndrome, associating COPD and obstructive sleep apnnea, has been proven to have higher morbidity and mortality. Cardiopulmonary rehabilitation has important health benefits for patients associating COPD and heart failure, such as improved disease symptoms, higher exercise tolerance, and improved quality of life.

While associating sleep disturbances aspects with rehabilitation programs outcomes is a relatively new concept, literature shows a strong connection between the two.

In this comprehensive review, we center our attention on delineating the recent advancements in polysomnography (PSG) as a paramount diagnostic instrument for discerning sleep disorders. Our primary objective is to elucidate the insights garnered in

the past few years, shedding light on PSG's pivotal role in circadian rhythm and neurophysiology. Moreover, we endeavor to explore the interplay between rehabilitation strategies and individuals afflicted with sleep disorders, thereby providing a perspective on the multifaceted challenges and opportunities in contemporary sleep medicine.

2. Results

Polysomnography (PSG) plays a pivotal role in the diagnosis and evaluation of sleep-related breathing disorders (**SRBD**s), a category of sleep disorders characterized by abnormalities in breathing during sleep. It helps assess sleep onset, maintenance, and early morning awakening, contributing to the diagnosis of **insomnia.** The study can reveal rapid eye movement (REM) sleep abnormalities and the presence of REM sleep occurring at inappropriate times, aiding in the diagnosis of **narcolepsy**. Polysomnography can detect abnormal behaviors during sleep, such as sleepwalking, night terrors, and REM sleep behavior disorder **(parasomnias**). It can be useful in assessing leg movements during sleep, aiding in the diagnosis of **restless leg syndrome** [4].

2.1. Indications for polysomnography

2.1.1. Polysomnography in Sleep Apnea

2.1.1.1. Obstructive sleep apnea

A number of signs from the patient's history indicate sleep-related breathing disorders (SRBD), including apneas usually witnessed by partners, snoring, weight gain, daytime somnolence, morning headaches, or dry mouth, as well as physical examination findings such as an elevated body mass index (BMI), diagnosis of high blood pressure, and signs of upper airway obstruction [5,9].

Patients' probability of suffering from obstructive sleep apnea syndrome(OSA) can be stratified with screening questionnaires. STOP-BANG is of the most accepted screening tools for obstructive sleep apnea (OSA)[10]. It consists of eight yes-or-no questions that are based on the most common signs and symptoms of OSA (i.e. snoring, witnessed apneas, daytime sleepiness, hypertension, BMI, age, neck circumference, gender). If the score is higher than 3 it indicates a high risk of OSA.[10,11] The sensitivity of the STOP-BANG questionnaire has been repeteadly proven to be greater than 85%. A higher specificity was found in obese men [11].

If the clinical suspicion is high, a further sleep study is required. In spite of polysomnography being the gold standard in the diagnosis of OSA, studies over the years have shown that a home sleep apnea test (HSAT) is noninferior in certain cases [12].

A patient's medical comorbidities, as well as logistical and financial considerations, play an important role in the decision to proceed with PSG rather than HSAT. It is recommended that patients with cardiorespiratory disease, neuromuscular conditions that may lead to respiratory muscle weakness, hypoventilation or suspicion of sleep-related hypoventilation, chronic opioid medication use, and stroke history obtain a PSG since HSAT may underestimate or fail to diagnose sleep disorders in these populations. A PSG is also required in patients where HSAT is non concludent, in patients where suspicion of central sleep apnea is high, suspicion of parasomnia, hypersomnolence and evaluation of restless legs syndrome [13,14].

The main indicator of the presence and the severity of OSA is the apnea-hypopnea index (AHI). The apnea-hypopnea index (AHI) represents the average number of apneas and hypopneas experienced per hour of sleep. According to the American Academy of Sleep Medicine (AASM), OSA severity is stratified into the following: mild (5-15 events/hour), moderate (15-30 events/hr), and severe (> 30 events/hr). Another important marker for the cardiovascular health is the oxygen desaturation index (ODI) as it reflects the severity and the duration of apneas [4,5].

In adults, studies showed that there was no significant difference in the AHI acquired through HSAT compared with the one acquired through polysomnography. Hung et al.

showed in their study that the AHI resulted from HSAT was correlated with the one obtained from PSG and that the sensitivity and specificity were similar between the two tests [14].

However, in young children (younger than 6 years old), HSAT does not perform as well as PSG. This was observed in a study perfomed by Scalzitti et al. where they noticed the differences shown in AHI, lowest oxygen saturation during sleep and the accuracy of diagnosing OSA between in laboratory PSG and HSAT in children. They described a statistically significant difference between the AHI acquired through in lab PSG and home sleep apnea testing ($p<0,005$). However, in children older than 6 years old, the comparison of AHI and lowest oxygen saturation was similar between the HSAT and PSG [15].

2.1.1.1. Central sleep apnea

Central sleep apnea (CSA) is caused by cessation of breathing during sleep as a consequence of the absence of respiratory muscle contraction. It can manifest in a cyclical (periods of hypopnea or apnea alternating with periods of hyperpnea) or intermittent manner.

It is less common than OSA (occasionally both conditions can coexist) with a prevalence of approximately 1% in the general population. It is more frequently diagnosed among elderly (due to increased chemosensitivity during NREM sleep), male patients, patients with cardiovascular comorbidities, especially congestive heart failure (CHF) and patients with neurological or neuromuscular diseases [1,4].

The gold standard for diangosis is polysomnography. A central apnea on polysomnogram is characterized by cessasion of airflow for at least 10 seconds associated with absence of thoracical and abdominal movement. According to polysomnographic findings and clinical manifestations central sleep apnea can be divided into several syndromes: primary CSA, CSA with Cheyne-Stokes Breathing (CSB), CSA due to a medical disorder without CSB, CSA due to a periodic high-altitude breathing, CSA due to a medication or substance and treatment-emergent CSA [1,4,5].

Primary central sleep apnea (CSA) is identified on polysomnogram by the presence of more than 5 central apneas/hypopneas per hour of sleep, more than 50% of the total events recorded are central, absence of Cheyne-Stokes breathing pattern and at least one symptom is present [1,4].

CSA with Cheyne-Stokes breathing(CSB) is characterized by all the findings of primary CSA with the addition of Cheyne-Stokes breathing pattern – at least 3 consecutive events starting with central apnea/hypopnea followed by a crescendo-descrescendo breathing pattern with a cycle lasting more than 40 seconds [1,4].

CSA due to a medical disorder without CSB meets all the criteria for primary CSA but it lacks the Cheyne-Stokes breathing pattern and patients present with a history of cardiac, renal or neurologic disorder (stroke, brainstem neoplasm, mutiple system atrophy)[1,4].

CSA due to a periodic high-altitude breathing requires a history of ascending 2500 meters or more [1,4].

CSA due to a medication or substance it is documented in patients with history of usage of medications or substances that cause respiratory depression, especially opioids [1,4].

Treatment-emergent CSA also called Complex sleep apnea requires to have the diagnosis of obstructive sleep apnea, usage of positive airway pressure with the resolution of obstructive events and the persistence or emergence of central events that has no other medical explaination [1,4].

In the last few years researchers tried to evaluate the accuracy of home sleep apnea test using peripheral arterial tonometry (PAT) as an alternative to polysomnography in detecting sleep apnea. Peripheral arterial tonometry uses the finger plethysmography method and determines the amplitude of the arterial pulse wave. Respiratory events (apneas/hypopneas) lead to sympathetic activation which produces peripheral arterial

vasoconstriction. An algorhitm analyzes the variability of amplitude in the PAT signal and corroborates the signal with the changes in pulsoxymetry (heart rate and oxygen saturation) leading to identifying respiratory events [16].

The first studies conducted showed that the HSAT-PAT performs very well in identifying sleep apnea but could not distinguish between central and obstructive events.

In a recent study on 84 patients with high suspicion of CSA from 11 participating sleep centers, Penzel et al. suggested that with a new algorithm central events can be distinguished from obstructive ones. A device called WATCH-PAT that records finger pulse, oximetry and actigraphy with an optional sensor for body position and snoring was used. This device with the aid of a digital algorithm identifies apnea events as well as REM sleep by analyzing pulse waveform variability, reflecting sympathetic tone changes. Its sensitivity in detecting central events compared to polysomnography was 66% with a specificity of 100% and a positive predictive value of 100%. The study was limited by the low number of patients with CSA thus further studies are needed [16].

2.1.2. Narcolepsy

Polysomnography is an essential part of the diagnosis of central disorders of hypersomnolence, such as narcolepsy. It not only provides suggestive evidence of the disease but it also excludes other sleep disorders when used in combination with the multiple latency sleep test (MLST) [17].

Narcolepsy is a rare, underdiagnosed sleep disorder that is characterized by instability of sleep-wake regulation. Symptoms often show before the age of 18 and they include excessive day time sleepiness, sleep disruption, sleep paralysis, cataplexy and hallucinations [18].

Narcolepsy is divided into two types: narcolepsy type 1(NT1) and narcolepsy type 2(NT2). Narcolepsy type 1 is associated with cataplexy and hypocretin deficiency and is hypothezied to be an autoimmune disease. Narcolepsy type 2 previously known as narcolepsy without cataplexy is defined by less severe symptoms and normal hypocretin levels [19]. The diagnostic criteria are detailed in Table 1 [1].

The hypnogram component of PSG is a graph that represents sleep stages measured in hours of sleep. It shows a visual summary of the brain activity during sleep aqcuired through EEG. The sleep stages are represented by stage W (wake), stage N1, stage N2, stage N3and stage R (REM sleep). In healthy subjects, a non REM sleep is observed predominantly in the first half of the night while REM sleep is observed in the second half (typically absent in the first 90 minutes of sleep). In narcolepsy, the subject usually falls asleep rapidly, enters REM sleep fast(usually in the first 15 minutes of sleep) and may present frequent awakenings during the night [19-21].

Table 1. ICSD-3's diagnostic criteria for narcolepsy

Nacrolepsy type 1	**Narcolepsy type 2**
Required criteria: 1. Daily EDS ≥3 months 2. One or both the following: • Cataplexy and mean sleep latency 8 minutes and 2 SOREMPs on MLST • Hypocretin levels ≥110 pg/ml or 1/3 of mean values with the same assay in healthy patients	Required criteria: 1. Daily EDS ≥3 months 2. Mean sleep latency 8 minutes and 2 SOREMPs on MLST 3. Absence of cataplexy 4. One of the following: • Hypocretin levels 110 pg/ml or 1/3 of mean values with the same assay in healthy patients • EDS and/or MSLT results not better explained by other causes

Abbreviations: EDS, excessive day sleepiness; MSLT, multiple sleep latency test; SOREMP, sleep-onset rapid eye movement period.
Note: Adapted from M. J. Sateia, "International classification of sleep disorders-third edition: highlights and modifications," Chest, 2014.

Generally, pediatric patients manifest symptoms differently from adults and are often confused with attention-deficit hyperactivity disorders. They experience excessive daytime sleepiness, poor school performance, deficite of attention, memory disorders and depression. As the become adults, the clinical picture becomes more suggestive of narcolepsy.

Pizza et al., in a recent study compared daytime continuous polysomnography with the standard method of diagnosis PSG and MSLT in children with narcolepsy type 1. It showed no significant difference between the results from the two methods, offering a new perspective by using a simplified procedure that is done outside the sleep laboratory. It is particularly useful for patients that do not want or are not able to comply to in laboratory testing [20].

2.1.3. Movement disorders of sleep

Movement disorders associated with sleep are an important group of sleep disorders that must be evaluated and treated thoroughly. Often referred to as sleep-related myoclonus or nocturnal myoclonus syndrome, periodic limb movement disorder, or PLMD is a movement disorder characterized by periodic and stereotypic limb movements [21]. Hip flexion and knee flexion, along with dorsiflexion of the foot with the big toe extended, are common movements. A sleep study will often reveal this finding, but its presence alone is not sufficient for a diagnosis of PLMD if clinical symptoms are not present. The majority of periodic limb disorders are associated with a variety of sleep-related conditions. There is no clear etiology for periodic limb movement disorder in primary cases, but there are a number of conditions associated with PLMS, including restless leg syndrome (associated in 80-90% of the cases), obstructive sleep apnea, narcolepsy, REM behavioral disorders, uremia, spinal cord tumors, and attention deficit hyperactivity disorder. Patients with subjective sleep complaints and evidence of PLMS without other sleep disorders are eligible for a diagnosis of primary PLM.

In order to make a diagnosis, there must be > 15 periodic limb movements per hour of sleep in adults and > 5 in children that are causing difficulties with sleep which affects daytime activities when no other medical, psychiatric or sleep disorders are present [20,21].

According to the American Academy of Sleep Medicine (AASM) scoring criteria, each limb movement(LM) is scored if there is an increase in anterior tibialis EMG activity of >8 mV above the EMG activity at rest, lasting for a duration of 0.5 to 10 seconds. If there are > 4 LMs, then they can be included as PLM series (PLMS) as long as they are 5 to 90 seconds apart [5].

Recently, it has been noticed that PLMS can be associated with upper airway resistance syndrome or a slight form of obstructive sleep apnea, and the usage of CPAP to correct this improved the symptoms [22,23,24].

Research has revealed that subjects with movement disorders during sleep have an abnormal reaction to blood pressure regulation caused by an imbalance between the sympathetic and parasympathetic nervous systems. Because of the increased sympathetic activity in these patients, they are more likely to develop hypertension and suffer its consequences such as stroke and heart disease [20,21].

2.1.4. Parasomnias

Parasomnias are undesirable physical events or experiences that occur during entry into sleep, within sleep, or during arousal from sleep. They are depicted as abnormal movements, behaviours, emotions or autonomic nervous system activity and are more common in childhood (resolving with aging without any medical interventions) but they can be present in adulthood as well [25].

They can be classified into two broad categories: parasomnias associated with NREM sleep and parasomnias associated with REM sleep.

2.1.4.1. NREM parasomnias

NREM parasomnias arise predominantely but not exclusively from slow wave stage (N3 stage) and include sleep terrors, sleepwalking, confusional arousals, sleep related eating disorder and sexsomnia [25].

Generally they are characterized by no cognition during the episode and partial or complete amnesia for the episode. The diagnosis is a clinical one, based on the patient history alone and PSG is usually not required. If the suspicion for other sleep disorders associated (i.e. OSA) is high then PSG is useful for evaluating them as treatable causes of the NREM parasomnias [26]. Studies have reported the presence of concomitent sleep disorders (OSA and PLMS) in NREM parasomnias. Their presence is considered a precipitant factor for parasomnia behavior. Drakatos et al., showed in a recent study that 1/3 of patients with NREM parasomnias had a concomitant sleep disorders, especially obese, older and male patients. The same study suggested that video PSG provides data to support the final diagnosis in 64% of cases and should be taken into consideration in unusual and complex cases and in the differential diagnosis of epilepsy[25].

2.1.4.2 REM parasomnias

REM sleep behavior disorder in which muscle atonia is lost during REM sleep, with dream enactment occurring during this period, varying from mild activity to violent behavior that can put subjects and bed partners in danger [26].

In contrast to NREM parasomnias, they occur in the latter half of the sleep period, behavior is less complex and video PSG and extended EMG electrodes are mandatory for the diagnosis. Findings on the PSG show occurence of the abnormal behavior during REM sleep, presence of REM sleep without atonia and the absence of epileptiform activity during REM sleep [27].

Postuma et al. showed in their multicentric study (1280 patients from 24 centers) that the presence of isolated REM parasomnia can be an early predictor for developing neurodegenerative diseases (for example, Parkinson disease). The median latency to the diagnosis of neurodegenerative disease was 8 years. Also, the rate of phenoconversion was 6.25% per year. After 8 years, 51.4% of patients developed neurodegenerative diseases, with a rate of 73.5% after 12 years [28]. Another study done by Postuma et al. showed similar results, the phenoconversion rate being 8% per year and after 5 years, 41% of patients developed parkinsonism or dementia. These results highlight the importance of early recognition and diagnosis in REM parasomnias [29].

2.2. Contraindications and limitations of polysomnography

Aside from its diagnostic utility, PSG assessment also has contraindications, limitations, and technical issues to be aware of. First of all, PSG is usually performed in a clinical setting and requires considerable technical expertise in the areas of instrumentation, data processing, and analysis.

PSG should not be performed on individuals with certain medical conditions such as fever, uncontrolled high blood pressure, acute infection, recent facial surgery, and certain types of pacemakers. The test is also not advisable for individuals who struggle with claustrophobia, as it may produce feelings of anxiety or panic. In addition, PSG should not be performed in a noisy or hot environment, as this can cause disruption to a person's sleep and lower the accuracy of the results [4,5]. PSG is typically conducted in a sleep

laboratory, which may not fully replicate an individual's natural sleep environment. This artificial setting can influence sleep patterns, potentially leading to results that may not entirely reflect an individual's typical sleep at home.

One of the most important limitations is that it cannot provide conditions that closely resemble home settings. Traditional PSG requires overnight monitoring in a sleep center, making it less convenient for some patients. Home sleep apnea testing (HSAT) is an alternative, but it may have limitations in capturing the complexity of certain sleep disorders that necessitate more comprehensive monitoring.

Another limitation is its short duration, lasting for up to eight hours, which limits its ability to accurately measure longer sleep processes such as circadian rhythm and sleep duration [4,5]. PSG involves attaching numerous sensors and electrodes to the patient, which can be uncomfortable and may disrupt natural sleep. This invasiveness can affect the validity of the recorded sleep patterns.

Another potential limitation of PSG lies in the subjectivity of the scoring system. The interpretation of PSG results relies on trained professionals, and variations in interpretation may occur, leading to inconsistencies in diagnosis and treatment recommendations [4,5,30].

2.3 Home versus laboratory settings

Understanding patients' perspectives regarding comfort, accessibility, and preference for home versus laboratory settings is essential for optimizing the delivery of sleep medicine services.

Comfort during PSG procedures is a critical factor influencing patient satisfaction and compliance. Traditional PSG conducted in laboratory settings may pose challenges related to unfamiliar sleeping environments, intrusive monitoring equipment, and discomfort associated with electrode placement. Patients often report difficulties in falling asleep or achieving natural sleep patterns under such conditions, which may impact the accuracy of diagnostic data obtained.

In contrast, home-based PSG systems offer the advantage of allowing patients to undergo sleep studies in the comfort of their own homes. This setting promotes a more relaxed and natural sleep environment, potentially enhancing the validity of recorded data. Patients often express a preference for home-based PSG due to increased comfort and convenience, leading to higher levels of satisfaction and compliance with the procedure.

Accessibility to PSG services is another crucial aspect influencing patient experiences. Laboratory-based PSG studies may be subject to long wait times and limited availability, resulting in delays in diagnosis and treatment initiation. Additionally, logistical challenges such as travel to and from the sleep center can pose barriers to access for certain patient populations.

Home-based PSG systems offer a solution to these accessibility issues by providing a more convenient and accessible option for sleep studies. Patients can undergo testing at their convenience, eliminating the need for travel and minimizing disruptions to daily routines. This approach not only enhances patient satisfaction but also facilitates timely diagnosis and intervention for sleep disorders.

2.3 Developments and future directions

Sleep medicine is in a constant evolution, aiming towards a different and better approach which is precision medicine. Precision medicine aims to shift from a universal practice to personalized medicine for the individual, integrating different types of data such as, clinical history and physical examination, imaging, biomarkers and test in order to get the best outcome for each patient.

2.3.1. Artificial intelligence and wearable devices

One important step towards development is integrating Artificial Intelligence in sleep studies. As AI technologies continue to develop its uses expand and become more

complex. It can be used for diagnosis such as integrating AI in wearable devices for remote monitoring, using it for faster and a more accurate scoring, as well as using it to offer personalized treatment for each individual and monitoring and changing parameters in real time [31,33].

Interscorer variability is large due to epochs that are difficult to classify. Researchers are in a constant search to find and develop an algorithm that achieve an accurate scoring thus minimizing the variability of results. AI-enhanced sleep scoring algorithms offer improved accuracy and efficiency compared to manual scoring methods.

By leveraging AI, sleep laboratories can streamline the scoring process, reduce labor costs, and expedite the delivery of diagnostic results to patients and healthcare providers.

Alloca et al. developed an algorithm named Somnivore and studied its accuracy compared to manual scoring done by humans. The algorithm underwent testing on various subjects, encompassing both animals and humans..In the human category, it was tested evaluations were conducted on young subjects, older subjects, and healthy young individuals after alcohol consumption. Somnivore demonstrated excellent performance under optimal conditions, exhibiting approximately an 85% concordance with visual scoring by human interscorers. Its performance was equivalent to, if not better than, visual scoring. Notably, the accuracy of Somnivore is contingent upon the quality of polysomnography acquisition. In instances of poor signal and recording quality, its performance was observed to be inferior to manual scoring. Humans possess a remarkable ability for pattern recognition and can discern when acquired data is corrupted. Nevertheless, in ideal conditions, AI scoring with Somnivore remains a reliable method [32].

These findings align with similar results reported in the literature. For instance, Thiesse et al. introduced an AI scoring algorithm called Somno-art, which exhibited strong performance across various sleep parameters. The only notable exception was its tendency to misclassify N3 and REM stages [34].

Advanced wearable devices, such as smartwatches have have seen significant improvements due to technological advancements and have gained widespread usage in the general population.Chinoy et al. conducted a study comparing the sleep monitoring accuracy of these devices with polysomnography in healthy young adults yielding promising results. The epoch by epoch sensitivity was high but the specificity was low to moderate, these devices being able to accurately detect sleep but to less accurately detect wake compared with the gold-standard (PSG). Notably, their performance was suboptimal on nights characterized by poor sleep quality. Further testing is essential to identify and delineate their vulnerabilities and limitations accurately [35].

2.3.2 Polysomnography in rehabilitation medicine

With its continuous development, the applicability of polysomnography emerges in various medical fields. One that deserves to be mentioned is rehabilitation medicine, as patients admitted in rehabilitation centers often experience sleep disturbances resulting in poor sleep quality. It was demonstrated that poor sleep quality is associated with poor rehabilitation outcomes.

In patients with chronic pain, insomnia is reported in 80-90% of patients requiring pain treatment. The lack of restorative sleep impacts patients' daily life leading to daytime sleepiness, fatigue, and concentration difficulties. Dos Santos Bento et al. conducted a study on polysomnographic changes and sleep quality assessment in patients with chronic pain. The mean pain intensity was 6.7 with 72% presented central sensitization. Polysomnography results indicated that 90% of patients experienced one or more episodes of sleep apnea, lasting an average of 17 seconds.Additionally, 86% of patients had one or more nocturnal micro-awakenings, and nearly half experienced a REM sleep phase latency greater than 70–120 min. The study identified a correlation between sleep quality scores and central sensitization scores, highlighting an association between presence of

central sensitization signs and changes in blood oxygen saturation [36]. Similar results have been reported by other studies. Matias et al.,in their study showed that people with chronic pain present problems in sleep continuity, sleep architecture, and sleep fragmentation, affecting their daily activities [37].

The prevalence of OSA is notably highin stroke is high with over 50% of patients presenting significant respiratory events. However, OSA remains undiagnosed and untreated. Fort patients with a history of stroke an in lab PSG is recommended for diagnosing OSA. In this category of patients, it is difficult to perform a full in lab PSG due todisability and immobility in these patients, long waiting times, limited experience with stroke patients in many sleep laboratories. In a recent randomized controlled trial, Boulos et al. studied the differences between in lab PSG and HSAT in patients with a diagnosis of stroke or transient ischemic attack (TIA) within 6 months prior to enrollment. Patients were also followed up at 6 months. They observed that in the HSAT arm a greater number of patients were diagnosed with OSA (48,8% vs 35,2%) and more patients were prescribed CPAP therapy compared to the PSG arm. At the 6 months follow-up, patients who underwent HSAT reported a lower Epworth Sleepiness Scale (ESS) score which reveals the subjective measurement of a patient's daytime sleeppiness. They also presented a higher score on the activities subscale of the Stroke Impact Scale with no improvent on Memory subscale. The study also aimed to study patients' feedback and the cost-effective aspect of using HSAT instead of PSG. In the HSAT arm, the patients' feedback was more positive and it was proven to be less costly ($p<0,001$) and more effective [38].

These results are in concordance with other studies, for example, Saletu et al. studied the feasability of HSAT in a stroke rehabilitation center in subacute (>1month and <1 year from stroke) adult stroke patients. The parameters acquired through HSAT compared to PSG showed no difference in the AHI classification, thus confirming good feasability and sufficient accuracy to be at least used a screening tool for suspect OSA in stroke patients [39].

Pulmonary rehabilitation programs have proved to ameliorate symptoms such as dyspnea and fatigue in chronic obstructive pulmonary disease(COPD) patients. Nobeschi et al. conducted a study on 30 moderate to severe COPD patients to evaluate the effects of pulmonary rehabilitation (12 weeks program) on sleep quality. Pittsburgh Sleep Quality Index (PSQI) and Epworth Sleepiness Scale(ESS) were used as subjective evaluation of sleep quality and daytime sleepiness. Patients underwent PSG testing before the rehabilitation program. PSQI showed poor sleep quality in 73% cases with an improvement of 66% after completing the rehabilitation program. As far as ESS is concerned, 87% of patients reported daytime sleepiness with a 34% improvement after the 12 weeks of rehabilitation [40].

3. Materials and Methods

This narrative review aims to comprehensively explore the clinical aspects of polysomnography as a diagnostic tool. To achieve this, we conducted a systematic literature search to identify relevant articles from the period of 2015 to 2024. The search was performed using two widely recognized academic databases: PubMed and Google Scholar.The search strategy employed a combination of Medical Subject Headings (MeSH) terms and free-text keywords relevant to polysomnography and sleep disorders. The following search terms were utilized, either individually or in combination: "polysomnography", "PSG", "sleep breathing disorders", "sleep apnea", "sleep movement disorders", "rehabilitation", "artificial intelligence", and "wearable devices".

Inclusion Criteria:

- Published in peer-reviewed journals.
- Written in English.
- Investigated aspects related to polysomnography as a diagnostic tool, including indications, contraindications, limitations, and future directions.
- Focused primarily on clinical applications and implications of polysomnography.
- Pertained to research conducted between 2015 and 2024.

Exclusion Criteria:

- Were not relevant to the scope of polysomnography as a diagnostic tool.
- Were not available in full-text format.
- Were conference abstracts, case reports, editorials, or letters to the editor.

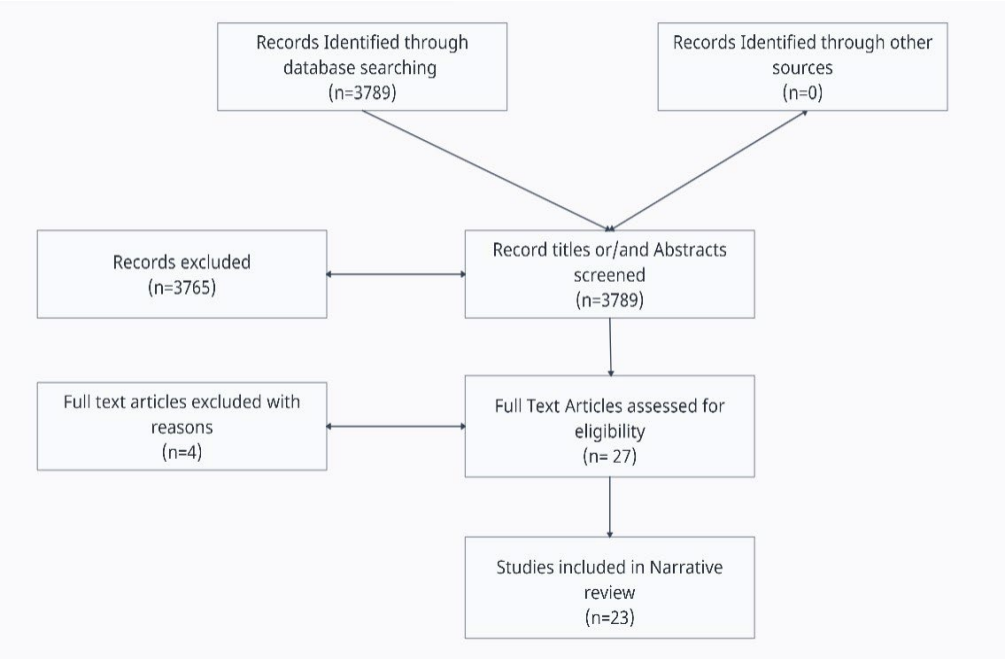

Figure 1. Flowchart for the search strategy.

4. Conclusions

Polysomnography stands as the cornerstone for diagnosing various sleep breathing disorders, offering unparalleled insight into sleep physiology. While its efficacy is undisputed, the significant time and resource requirements associated with PSG highlight the imperative for exploring alternative approaches.

Studies have illuminated the potential of home sleep apnea testing (HSAT) as a viable alternative to PSG in select cases, particularly in adult populations. However, challenges persist, notably in the assessment of young children under six years old, where PSG remains the recommended diagnostic modality.

Exciting advancements in HSAT, particularly with peripheral arterial tonometry, underscore its promise in identifying sleep apnea with high accuracy. Emerging algorithms show potential in distinguishing between obstructive and central respiratory events, enhancing diagnostic precision.

Furthermore, the expansion of PSG beyond traditional settings into daytime continuous monitoring offers new avenues for investigation, particularly in pediatric populations with conditions such as narcolepsy type 1.

Research underscores the critical role of early recognition and diagnosis in REM parasomnias, serving as predictive markers for neurodegenerative diseases. Integration of artificial intelligence (AI) in wearable devices holds immense promise for remote monitoring and personalized treatment approaches, revolutionizing the field of sleep medicine.

Moreover, PSG's integration into rehabilitation medicine has demonstrated significant benefits, improving sleep quality and enhancing rehabilitation outcomes for patients with sleep disorders.

As PSG continues to evolve, it opens myriad possibilities for investigating sleep disorders and enhancing patient care. By leveraging these advancements, healthcare practitioners can deliver tailored interventions and improve management of sleep-related disorders, ultimately improving overall sleep health and quality of life.

In conclusion, polysomnography remains indispensable, offering a comprehensive overview of an individual's sleep health and paving the way for advancements in sleep medicine.

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