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Non-Respiratory Indications for Polysomnography and Related Procedures in Children: An Evidence-Based Review

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Objective: This evidence-based review provides a systematic and comprehensive review of the literature regarding the utility of polysomnography for the evaluation of non-respiratory sleep disorders in children including hypersomnias, parasomnias, sleep-related movement disorders, and sleep in other special populations.

Methods: A task force of pediatric sleep medicine experts performed a systematic review of the literature regarding the use of polysomnography for non-respiratory sleep disorders in children. They identified and graded 76 papers as evidence.

Results: The main results include (1) polysomnography combined with the multiple sleep latency test is useful for evaluating disorders of excessive somnolence to objectively quantify sleepiness. The results have to be interpreted with consideration of the pubertal stage and regularity of the sleep patterns of the child; (2) polysomnography is indicated in children with parasomnias or sleep related movement disorders who have a high likelihood of having obstructive sleep apnea (OSA); (3) polysomnography is not routinely indicated in children with enuresis unless there is a high likelihood of OSA; (4) polysomnography can be helpful in evaluating children with restless legs syndrome (RLS) and when periodic limb movement disorder (PLMD) is suspected.

Conclusions: These findings suggest that, in children with non-respiratory sleep disorders, polysomnography should be a part of a comprehensive sleep evaluation in selected circumstances to determine the nature of the events in more detail or when the suspicion of OSA is relatively high.

Keywords: Clinical utility, indications, non-respiratory disorders, pediatric, polysomnography

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1.0 INTRODUCTION

In the last three decades, the knowledge and practice of pediatric sleep medicine has grown dramatically, as reflected in the exponential growth of peer reviewed publications regarding pediatric polysomnography (PSG). Comprehensive, attended, in-laboratory (level I) PSG is most often conducted to evaluate and/or monitor treatment of sleep-related breathing disorders (SRBD), including obstructive sleep apnea (OSA). Less commonly, PSG is performed to characterize the nature of recurring paroxysmal nocturnal events, sleep-related movements or behaviors, or hypersomnia.

In 2007, the American Academy of Sleep Medicine (AASM) Standards of Practice Committee (SPC) and the Board of Directors empowered a task force to provide an evidence-based review of the indications for pediatric PSG. The task force was directed to analyze and summarize the evidence for respiratory and non-respiratory indications for PSG in infants, children and adolescents. The task force identified approximately 3,500 candidate papers in initial searches, most of which focused on respiratory indications for PSG. With approval of the AASM SPC and Board of Directors, the task force decided that the most expeditious method was to divide and publish the project in three sections: respiratory indications for pediatric PSG, non-respiratory indications, and indications for PSG in children with attention-deficit/hyperactivity disorder. In March 2011, the American Academy of Sleep Medicine published an evidence-based review and practice parameters for the respiratory indications for PSG in children.[1] Here we present a comprehensive, evidence-based systematic review of the literature regarding non-respiratory indications for PSG in children. Since the multiple sleep latency test (MSLT) is a daytime extension of the concept of polygraphic monitoring, and essential to confirming severity of sleepiness, it is included in this document as well.

2.0 BACKGROUND

2.1 Summary of Previously Published Practice Parameters

Indications for level I PSG (comprehensive, in-laboratory, attended PSG) in infants and children have been published by the American Academy of Pediatrics,[2,3] the American Thoracic Society,[4] the German Sleep Society[5] and the College of Physicians and Surgeons of Ontario guidelines for sleep medicine.[6] However, these only provide *respiratory* indications for PSG in children.

In 2005, the AASM SPC published evidence-based practice parameters updating the indications for polysomnography and related procedures. These included *non-respiratory* indications for PSG and related procedures,[7] and were a revision of earlier guidelines and indications for PSG.[8,9] These did not specifically address children, but advised that a level I PSG may be indicated in order to: (1) evaluate sleep-related behaviors that are atypical, violent or potentially injurious to the patient or others; (2) diag-

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Table 1—Literature Search Criteria

Inclusion Criteria	
	Greater than or equal to 10 subjects
	Subjects must be less than or equal to 18 years of age (at least > 1 month, no newborns)
	Must have PSG data (not home PSG) including EEG, EMG, and respiratory parameters
Limits	
	English language
	Human subjects
Publication Date Range	
	1966 through September 2010

nose certain other atypical or unusual parasomnias; (3) evaluate narcolepsy or idiopathic hypersomnia, along with a MSLT; (4) determine nocturnal seizures when clinical evaluation and daytime electroencephalography (EEG) remain inconclusive; (5) clarify whether paroxysmal arousals or other sleep disruptions are due to an epileptic or non-epileptic parasomnias, and/or (6) confirm a strong suspicion of periodic limb movement disorder (PLMD).[7]

The 2005 AASM guidelines further emphasize that a PSG is *not* the best primary test to evaluate patients with insomnia or circadian rhythm disorders. An earlier AASM SPC guideline specified that a PSG may be indicated in patients with insomnia when: (1) a SRBD or PLMD is suspected; (2) the initial diagnosis is uncertain; or (3) violent or potentially injurious precipitous arousals occur.[9-12]

In 2005, the AASM published an evidence-based review[13] and practice parameters for the clinical use of the MSLT and the maintenance of wakefulness test (MWT) in adults.[14] These recommended that: (1) the MSLT is indicated as part of the evaluation of patients suspected to have narcolepsy or idiopathic hypersomnia; and (2) a MWT *may* be indicated in the assessment of individuals in whom the inability to remain awake constitutes a safety issue or in patients with narcolepsy with cataplexy/idiopathic hypersomnia to assess the effects of alertness-enhancing treatments.

2.2 Composition of the Task Force

The task force was composed of specialists with established clinical expertise and experience in pediatric sleep medicine. All completed AASM conflict of interest forms confirming none had relevant conflicts of interest or commercial bias. Most had authored the 2011 Respiratory Indications for Polysomnography in Children paper, with the exception of Dr. Kotagal who replaced Dr. Wise as task force chair when Dr. Wise became a member of the AASM Board of Directors in 2010.

2.3 Objectives

The objectives of the task force were to: (1) provide a systematic and comprehensive review of the relevant medical literature regarding non-respiratory indications for PSG in children; (2) grade the strength of the evidence contained in the literature using a standardized grading system; (3) summarize the information regarding the validity, reliability, and clinical utility of PSG for non-respiratory sleep disorders in children; (4) address important areas where there is insufficient evidence for the clinical utility of PSG; and (5) identify strengths and limitations of the current medical literature regarding this subject.

3.0 METHODS

The task force and SPC liaisons made a list of questions or issues regarding non-respiratory indications for PSG in children. From this, Population, Intervention, Comparison, and Outcome (PICO) tables were developed which guided the review process to be focused on clinically relevant issues. PICO tables for this project are available on the AASM website (http://www.aasmnet.org/practiceguidelines.aspx). We then: (1) reviewed previous AASM publications and papers produced by other organizations for PSG indications; (2) developed a literature search strategy; (3) established criteria for selecting relevant papers; (4) developed procedures for extracting data and grading the strength of evidence of selected papers; and (5) collated and summarized the evidence. The task force, SPC liaisons, and AASM support staff held monthly telephone conference calls and yearly face-to-face meetings.

3.1 Literature Search Strategy

The project was divided into sections in order to systematically analyze the medical literature for the indications for and clinical utility of comprehensive attended level I PSG in: (1) narcolepsy and other hypersomnias; (2) parasomnias; (3) sleep-related movements disorders (SRMD); and 4) sleep in special populations. Searches were also performed for evidence on the use of MSLT and MWT in children. Technical guidelines for PSG are not addressed because these have been addressed in the AASM Scoring Manual.[15] Also not reviewed is the use of nap studies or home PSG because of limited evidence for these in children.

Search terms and search strategies with which to query the medical literature for the indications for and clinical utility of comprehensive, attended level I PSG in pediatric patients were developed. Table 1 summarizes the explicit inclusion criteria, publication date range, and other search limitations that were used. A complete list of search terms for each category is provided on the AASM website (http://www.aasmnet.org/practiceguidelines.aspx). Using PubMed for the literature search, a master list of potential evidence papers was assembled. Two task force members were assigned to review the candidate abstracts and identify those papers that definitively met the criteria for inclusion. If the two members disagreed regarding inclusion/exclusion of a particular paper, additional ratings were obtained by other task force members. The task force chair provided the final opinion in cases of disagreement. Accepted articles were assigned to the appropriate section(s) of the review paper.

A second method of finding candidate papers called "pearling" was also used. Pearling identifies additional papers suitable for evidence by searching the citations of papers already included as evidence or alternatively, utilizing a task force member's personal knowledge of literature in the field. Pearled articles underwent the same review process. The results of the literature search are discussed in Section 4.0.

3.2 Data Extraction and Evidence Grading Process

The data extraction and evidence grading process was similar to that used in Respiratory Indications for Polysomnography in

Children,[16] except an Excel spreadsheet was used to summarize and manage the data extraction and evidence grading. The completed evidence table is available at (http://www.aasmnet.org/practiceguidelines.aspx).

The evidence grading system (Table 2) was modified from one developed by the American Academy of Neurology (AAN) specifically for assessing the clinical utility of diagnostic tests.[17] The system designates four levels of evidence: studies judged level 1 have stronger scientific evidence and a lower risk of bias, while level 4 have weaker scientific evidence and a higher risk of bias. Weaker levels of evidence indicate the need to integrate greater clinical judgment when applying the results to clinical decision making.

Table 2—Levels of Evidence[17]

Level	Description
1	Evidence provided by a **prospective** study in a **broad spectrum** of persons with the suspected condition, using a **reference (gold) standard** for case definition, where test is applied in a **blinded fashion**, and enabling the assessment of appropriate test of diagnostic accuracy. All persons undergoing the diagnostic test have the presence or absence of the disease determined. Level 1 studies are judged to have a low risk of bias.
2	Evidence provided by a **prospective** study of a **narrow spectrum** of persons with the suspected condition, or a **well designed retrospective** study of a **broad spectrum** of persons with an established condition (by "gold standard") compared to a **broad spectrum of controls**, where test is applied in a **blinded** evaluation, and enabling the assessment of appropriate tests of diagnostic accuracy. Level 2 studies are judged to have a moderate risk of bias.
3	Evidence provided by a **retrospective** study where either person with the established condition or controls are of a **narrow spectrum**, and where **the reference standard, if not objective, is applied by someone other than the person that performed (interpreted) the test**. Level 3 studies are judged to have a moderate to high risk of bias.
4	Any study design where **test is not applied in an independent evaluation** or evidence is provided by expert opinion alone or in **descriptive case series without controls**. There is **no blinding or there may be inadequate blinding**. The **spectrum of persons tested may be broad or narrow**. Level 4 studies are judged to have a very high risk of bias.

4.0 RESULTS

Our initial literature search identified 3,500 candidate papers for respiratory and non-respiratory indications for PSG. We later divided the project into 3 parts: (1) Respiratory Indications, which were published March 2011, (2) the current paper on Non-Respiratory Indications for PSG, and (3) indications for PSG in children with attention-deficit/hyperactivity disorder. We performed two additional literature searches in 2009 and 2010, specifically for non-respiratory indications, and identified another 887 papers. Specialized searches and pearling were also employed to ensure the inclusion of any extra articles that may have been missed. Approximately 4,450 total candidate papers were identified and screened using the inclusion criteria, and 76 were selected as evidence.

The evidence in each article was graded by a primary and secondary reviewer of the task force, with grades obtained from additional reviewers if the two disagreed. Grading by the primary and secondary reviewers were in excellent agreement (gamma = 0.94, $P < 0.05$) overall. For the papers on which there was disagreement, the secondary reviewer was in better agreement with the additional reviewers (gamma ranged from 0.92-1.0 with $P < 0.05$ for all additional comparisons to the secondary rating, but gamma ranged from 0.39-1.0 for the additional comparisons to the grade of the primary reviewer).

The interpretation of sleep research in children with non-respiratory sleep disorders was challenging, at times, due to the significant procedural variability between studies. Methodological concerns identified included: (1) variability in diagnostic, recording, and scoring methods, (2) presence of identified or unidentified comorbid conditions that potentially account for the PSG findings, (3) variability in the age range and pubertal status of the subjects, (4) normative values and selection of appropriate control groups, and (5) potential risk of both type 1 and type 2 error when multiple measures are obtained and analyzed on small samples of subjects. These concerns were identified and cited in the evidence tables.

The results are presented in four sections: hypersomnias, parasomnias, sleep related movement disorders (SRMD), and sleep in special populations.

4.1 Clinical Utility of PSG in Children with Daytime Sleepiness (Including Narcolepsy), Idiopathic Hypersomnia, Hypersomnia due to Medical Conditions, and Other Hypersomnias

The MSLT is used to characterize and objectively measure daytime sleepiness. Although some of the earliest uses of the MSLT were in children,[18] the test is mostly used to evaluate adults. Our search identified 22 articles regarding the use of the MSLT in children and adolescents. The aims of these papers were to describe normative sleep patterns in children and adolescents or evaluate sleepiness in relation to particular disease states; none were designed to specifically evaluate the clinical utility of the MSLT. Two papers provided level 1 evidence,[19,20] seven level 3,[21-27] and thirteen level 4 evidence.[18,28-39] With the exception of a level 3 paper that included 3-year-olds,[22] all studies were restricted to children ≥ 5 years of age (an age when children typically stop taking daytime naps). All showed the feasibility of performing MSLTs in developmentally normal school-aged children.

4.1.1 Normative MSLT values in children and adolescents

Several studies provided normative data based on children of different ages/Tanner stages, but most were level 3 or 4 and had small sample sizes. Our search identified six studies, including two with level 3 evidence,[21,22] and four level 4.[18,29,34,37] All showed that developmentally normal, prepubertal, school-aged children rarely fall asleep during standard 20-minute daytime nap opportunities,[18,29,34,37] and that older (Tanner stages 3-5) adolescents are sleepier on MSLT.[18,21,34] Because of this so-called ceiling effect (mean sleep latencies of 16 to 18 minutes), some studies lengthened the nap opportunities to 30 minutes.[22,37]

Some, but not all, studies show older adolescents may exhibit a midday increase in sleepiness which could impact the decision of whether to perform 4 or 5 naps during an MSLT. One

level 4 study showed a midday increase in daytime sleepiness in Tanner stage 3 and 4 adolescents on a constant routine protocol (but not at baseline); an effect not seen in Tanner 1 and 2 children.[29] A second level 4 paper by this group found the same effect in children of Tanner stages 3-5.[18] Another level 4 study showed decreased sleep latency at 14:00 in adolescents aged 13-17 years.[34] A level 4 study mentioned a nonsignificant trend for decreased sleep latency at 12:00 in children ages 8-12 years old.[37] A level 3 study mentioned that children were more likely to fall asleep at 14:00 but did not provide statistical details.[22]

Based on these studies, the preponderance of evidence suggests that older adolescents may have increased sleepiness mid-day, but further data are needed, particularly regarding the impact of early school start times and sleeping in on weekends on the results of the MSLT. One level 3 study showed that an early school start time of 07:20 in 10th graders was associated with a shorter mean sleep latency (MSL) on the MSLT of 8.5 minutes compared to 11.4 minutes in the 9th graders whose school start time was 08:25. The sleep latency was particularly short for the first nap at 08:30 (5.1 vs. 10.9 minutes).[21] Morning wake times may also impact the MSLT findings, but this has not been well studied.

Very few studies have reported or even commented upon sleep onset REM periods (SOREMPS) during the MSLT in normal controls. One level 4 study reported no SOREMPS in young children,[18] whereas a level 3 study of older adolescents found 48% had at least one SOREMP and 16% had 2 SOREMPs.[21] Our search found no normative data for the MWT in children.

4.1.2 Clinical utility of PSG and MSLT for the assessment of primary hypersomnias in children

As is the case for adults, PSG and MSLT are frequently used in the assessment of narcolepsy and other hypersomnias in children. Our search identified nine articles regarding the use of PSG/MSLT in childhood narcolepsy and one in Kleine-Levin syndrome. The lower age limit for clinical application of the MSLT was 5-5.5 years.[30,39] Among these 10 papers, one provided level 1 evidence,[20] two level 3,[23,24] and seven level 4.[30-33,36,38,39] These studies were not homogeneous with respect to the age groups studied (range 2.1 to 21 years), and only a few reported MSLT data for preschool children.

All studies that reported MSLT data for children with a clinical diagnosis of narcolepsy documented reduced mean sleep latencies compared to control subjects or published pediatric norms.[18] Most reported mean sleep latencies < 5 minutes[20,23,30-32,38]; whereas two level 4 studies reported mean sleep latencies between 6-7 minutes.[33,39] Eight studies documented that multiple (often 3-5) SOREMPs were observed on MSLT in the majority of children with narcolepsy.[20,23,30-33,38,39] Four level 4 studies reported a few children (primarily prepubertal), who had < 2 SOREMPs, in whom the diagnosis of narcolepsy was made based upon concurrent cataplexy and low cerebrospinal fluid hypocretin 1 levels.[32,33,38,39] A level 4 study found all 29 of the prepubertal children with childhood narcolepsy-cataplexy had ≥ 2 SOREMPs, 26 had ≥ 3, and 28 had a MSL < 5 minutes (mean 2.0 ± 1.3 minutes).[32] A level 3 study found 10 adolescents with narcolepsy (3 with cataplexy, 7 without cataplexy) had 2-5 SOREMPs on their MSLT.[23]

None of the reviewed studies had the specific objective of determining the sensitivity and specificity of MSLT for diagnosing narcolepsy. However, some studies performed MSLTs in patients with a clear phenotype of narcolepsy with cataplexy. Our search identified six relevant retrospective studies: one level 3 evidence[23] and five level 4 evidence.[28,30-32,38]

One level 4 study evaluated 58 patients younger than 21 years, all of whom had excessive daytime sleepiness for at least a year and unequivocal symptoms of narcolepsy. They found that 79% met MSLT criteria for narcolepsy (MSL ≤ 8 minutes and ≥ 2 SOREMPs).[30] In another level 4 study of children (mean age 11 years) with excessive daytime sleepiness and cataplexy, 28 of 29 children had a MSL ≤ 5 minutes on MSLT, and 28 of 29 had ≥ 2 SOREMPs.[32] In a small level 4 case series of 14 children (10 with cataplexy), 12 had mean sleep latencies ≤ 8 minutes on MSLT and 13 had ≥ 2 SOREMPs.[38] In a level 3 study of adolescents recruited from the community by means of questionnaires, 9 of 20 children with a positive telephonic screening for narcolepsy symptoms had an MSLT consistent with narcolepsy (2 were diagnosed as having narcolepsy with cataplexy and 7 narcolepsy without cataplexy).[23] This article is less convincing of the diagnostic sensitivity and specificity of the MSLT for childhood narcolepsy as subjects did not present clinically, and few had cataplexy, suggesting that the diagnosis of narcolepsy may not have been definitive. Another level 4 study reported on 44 prepubertal children with clinically diagnosed narcolepsy who underwent MSLT.[31] In some cases, MSLTs were repeated. The authors noted that all children had a MSL ≤ 5 minutes and ≥ 2 SOREMPs on initial or repeat testing, suggesting a high sensitivity for MSLT testing. However, it is not clear from this paper how the diagnosis of narcolepsy was established or how many children had initial negative MSLTs and required repeat testing. A level 4 study of 51 children diagnosed with narcolepsy found that 3 (15%) prepubertal children had a negative MSLT (defined as a MSL ≥ 8 minutes and ≤ 2 SOREMPs); 2 of these children had undetectable cerebrospinal fluid hypocretin 1 levels.[28]

In summary, retrospective surveys have shown that MSLT is highly sensitive in confirming narcolepsy in children with presumptive narcolepsy based on a history of excessive daytime sleepiness and cataplexy. The sensitivity of MSLTs in diagnosing children with narcolepsy without cataplexy is unclear. The specificity of the MSLT in diagnosing narcolepsy could not be determined from the published literature.

Evidence regarding the use of MSLT to assess the response to treatment of childhood narcolepsy is scant. One level 1 study of adolescents with narcolepsy found that treating them with either modafinil or sodium oxybate was associated with modest improvements in their MSL compared to baseline, although their MSL remained < 6 minutes.[20] A level 4 study of children with narcolepsy found mean MSLT scores increased from 6.6 ± 3.7 minutes at baseline to 10.2 ± 4.8 minutes when they were treated with modafinil.[33]

Although PSG is almost universally performed the night prior to MSLT to assess sufficient nocturnal sleep duration and screen for other sleep disorders which may contribute to or cause daytime sleepiness, few studies have systematically examined nocturnal PSG measures in children with narcolepsy. Five level 4 studies of narcoleptic children have reported fre-

quent SOREMPs during PSG,[31,36,39] excessive arousals,[32,33] or excessive periodic limb movements in sleep.[39]

A single level 3 study correlated PSG and MSLT findings in 17 children and adolescents with recurrent hypersomnia (Kleine-Levin syndrome) during symptomatic and asymptomatic periods.[24] The authors found mildly reduced MSL scores on MSLTs performed during the symptomatic period, but nearly normal scores during asymptomatic periods. Nocturnal PSG for these subjects demonstrated reduced NREM 3 during the first half of symptomatic periods as compared to during the second half of the symptomatic and the asymptomatic periods.

4.1.3 Clinical utility of PSG and MSLT for the assessment of hypersomnia in children with other sleep disorders and medical conditions

There are no data on the relationship between chronic sleep deprivation and MSLT findings in children and adolescents (i.e., is one night's sleep of normal duration in the laboratory sufficient to control for the effects of chronic sleep deprivation on the MSLT?). Few studies have correlated MSLT data with clinical outcomes or with other measures of objective daytime sleepiness in children. Our search identified six articles which correlated MSLT with outcomes or measures: one level 1 evidence,[19] four level 3,[22,25-27] and one level 4.[35] Three evaluated the MSLT in children with suspected OSA or obesity. Two of these studies (levels 1 and 3) showed a significant correlation between the MSL on MSLT and the apnea or apnea-hypopnea index.[19,22] One level 4 study found no correlation between the apnea index and MSL but noted that two adolescents with severe OSA had mean sleep latencies on MSLT < 5 minutes.[35] Two studies (levels 3 and 4) showed an association between obesity and MSL.[22,35] One level 1 study showed a significant but weak correlation between sleep latency on MSLT and subjective sleepiness as measured by the sleepiness scale of the Pediatric Sleep Questionnaire ($r = -0.23$, $P = 0.006$).[19] Three uncontrolled level 3 studies of children with juvenile rheumatoid arthritis and/or hematologic disease showed that some children had short mean sleep latencies.[25-27]

4.1.4 Summary of MSLT data in children and adolescents

In summary, MSLT is useful in the evaluation of sleepiness in developmentally normal children as young as 5 or 5.5 years of age. Mean sleep latencies are significantly longer in school-aged children and adolescents than in adults. Although normative data are based on small samples, it is evident that prepubertal/early Tanner stage children rarely fall asleep during MSLT naps. For this reason, adult normative data are not applicable to prepubertal children, and mean sleep latencies for school-aged children that are normal by adult standards may indicate excessive daytime sleepiness when age-specific norms are used. There are also no data regarding normal preschool children, who would be expected to have shorter sleep latencies as napping is normal at this age. Children with narcolepsy have significantly reduced sleep latencies on MSLT that are similar to adult narcolepsy patients, although a small proportion of affected prepubertal children have < 2 SOREMPs. One study suggested that 1-2 SOREMPS on a MSLT can be relatively common in adolescents following their usual sleep/wake schedules; therefore, the results of excessive sleepiness or SOREMPs on a MSLT have to be interpreted with consideration of the child's sleep schedules and routines.[21] Further evidence is needed regarding the clinical implications of finding SOREMPS on a MSLT in children and adolescents.

Overall, these data support the routine use of PSG and MSLT with 20-minute naps in children with suspected narcolepsy in order to screen for MSLT findings that are usually essential for confirming the diagnosis and to screen for other disorders associated with excessive sleepiness which may mimic narcolepsy, such as idiopathic hypersomnia, depression, inadequate sleep hygiene, and delayed sleep phase syndrome. As young children have a long sleep latency, research is needed to determine whether nap opportunities longer than the standard 20 minutes would better evaluate sleepiness in prepubertal children.

The few studies of children with OSA suggest that the sleep latency on MSLT correlates with the severity of obstructive sleep apnea. Descriptive studies suggest that other chronic medical conditions may be associated with short sleep latencies on MSLT, but further confirmation is needed. Although data regarding the use of PSG and MSLT for assessment of recurrent hypersomnia (including Kleine-Levin syndrome) and other non-narcolepsy hypersomnias in children are limited, these tests are feasible in school-aged children, permit objective measurement of the severity of daytime sleepiness, and may facilitate proper diagnostic classification of the underlying sleep problem.

4.2 Clinical Utility of PSG in Children with Parasomnias

Parasomnias are unusual or undesirable motor, behavioral and/or experiential events which occur during or in the transition to and from sleep.[7] We found a total of 26 studies, two of which we graded as level 2,[40,41] eleven as level 3,[42-52] and thirteen as level 4 evidence.[53-65]

In 2005, the AASM published the clinical practice parameters for in-laboratory video-polysomnography (video-PSG) to evaluate parasomnias.[7] Though not specific for children, it is recommended that comprehensive in-laboratory video-PSG be used to evaluate parasomnias which are: (1) unusual or atypical because of patient's age at onset; the time, duration, or frequency of occurrence of the behavior; or the specifics of the particular motor patterns in question (e.g., stereotypical, repetitive, or focal); (2) occurring more than 2-3 times per week; (3) potentially injurious or have caused injury to the patient or others; and/or (4) potentially seizure-related but the initial clinical evaluation and a standard EEG are inconclusive.[7] Video-PSG was specifically, not routinely, indicated for "typical" sleep terrors or sleepwalking (particularly those which occur in young children).[7] These practice parameters further recommend that PSG with expanded EEG, electromyography (EMG) channels, and good quality video are needed but provide no evidence for this nor how many channels of EEG need to be recorded.[7]

The number of nights of study required to establish the diagnosis of parasomnia has been reported in adults, but there are limited data for this in children. A study in adults found more than one night of video-PSG could be needed to confirm a parasomnia.[66] One to two consecutive nights of video-PSG provided valuable diagnostic information in 69% of 41 patients whose paroxysmal motor behaviors were "prominent," 41% of 11 patients referred for minor motor activity in sleep, and 78% of 36 patients with known epilepsy.[66] Another study found video-PSG

was diagnostic in 65% and "helpful" in another 26% of 100 consecutive adults referred for frequent sleep-related injuries.[67]

4.2.1 Clinical utility of PSG in children and adolescents at high risk for parasomnias

Several studies have examined whether parasomnias were more common in children or adolescents with habitual snoring and/or OSA: one level 2,[40] one level 3,[46] and one level 4 evidence.[54]

One level 3 study found 58% of 84 children who had a history of recurrent and chronic sleep walking and/or sleep terrors also had symptoms of OSA.[46] OSA was often relatively mild: 58% were judged to have upper airway resistance syndrome (UARS) and 31% OSA (with a mean apnea-hypopnea index [AHI] 1.6 ± 0.6).[46] OSA and parasomnias resolved in all 43 children who underwent upper airway surgery but persisted in 6 who declined treatment for OSA.

Another later and smaller level 2 case-control study by the same group recorded two consecutive nights of in-laboratory PSG in 12 children (mean age 8.6 years) referred for chronic sleepwalking (not OSA) and 12 age- and gender-matched controls.[40] Again, they found mild OSA in two (AHI 3 and 4/h) and UARS in the other 10 sleepwalkers. A third level 4 case series found varying degrees of OSA or UARS on video-PSG in all 51 patients referred for parasomnias (including 11 children ages 10 months to 16 years).[54] Histories of chronic sleepwalking and OSA were reported in many of their relatives. Identifying and treating OSA in patients and other family members resulted in improvement or resolution of their parasomnia(s). The authors suggested that inherited small upper airways predispose to OSA and UARS; and fragmentation of sleep related to this contributes to NREM parasomnias.

4.2.2 Video-polysomnographic features of NREM arousal disorders and REM sleep behavior disorder in children

Two studies were identified which described video-PSG features of NREM arousal disorders and REM sleep behavior disorder in children: one level 3 evidence[46] and one level 4.[61] The level 3 study described video-PSG findings in 84 children with chronic sleep terrors and sleep walking who underwent two consecutive nights of video-PSG.[46] All parasomnia events occurred in the first third of the night and in N3. Confusional arousals were characterized by the child sitting up or moving in the bed and coherent or incoherent talking. Sleep terrors were observed in 12, and confusional arousals with attempts to leave the bed and varying degrees of aggression recorded in 32. Subjects rapidly returned to sleep following these, and had amnesia of the events the following day. The duration of confusional arousals ranged from 47 seconds to 4 minutes 38 seconds. The use of video with PSG rather than PSG alone was crucial for confirming the parasomnia in these studies.

REM sleep behavior disorder (RBD) rarely occurs in children; we found isolated case reports of video-PSG confirmed RBD in children or adolescents with narcolepsy with cataplexy,[68-70] Tourette syndrome,[71] as well as in a pair of siblings.[72] A level 4 case series found REM sleep without atonia on video-PSG in 11 of 18 children with autism.[61] Based upon the clinical history and PSG findings, they were able to diagnose RBD in five (with increased EMG during REM sleep accompanied by many sudden jerky body movements of the limbs and episodes of sitting up in bed on video-PSG). Other PSG findings in this cohort included OSA in 3, periodic limb movement index (PLMI) 4-19/h in 8, sleep bruxism in 2, and nocturnal seizures in 1. The diagnosis of RBD could not be made in these children without video-PSG.

Studies in adults with RBD and/or REM sleep without atonia (RSWA) show that excessive phasic EMG activity and RSWA during REM sleep is: (1) more frequent in distal than proximal limb muscles; (2) more frequent in upper limbs than lower limbs; and (3) RSWA cannot be scored based on chin EMG alone but requires recording and scoring of excessive phasic EMG activity in the upper and lower distal limb muscles.[73-75] Our search found no studies regarding this in children.

In summary, although the evidence for the utility of PSG in children with parasomnia is limited, the evidence suggests parasomnias should be evaluated in the sleep laboratory using video and expanded EEG montages. Children with parasomnias can have some alterations in their sleep architecture. If children with a parasomnia are suspected to also have OSA, video-PSG is indicated as OSA may impact the severity or frequency of the parasomnia. PSG is also indicated in children with violent arousals, regardless of other symptoms of sleep maintenance difficulty or parasomnias.

4.2.3 Clinical utility of PSG in children with suspected or known sleep-related seizures or epilepsy

Children with epilepsy are two to three times more likely to have sleep problems than the general pediatric population.[76-85] The etiology of sleep disruption in children with epilepsy may be multi-factorial including: epilepsy per se, frequent nocturnal seizures disrupting nocturnal sleep organization, increased arousals, effects of antiepileptic medications on daytime alertness and nighttime sleep, and treatable primary sleep disorders. Comorbidities such as physical disability,[84] intellectual disability,[76,86,87] neurodevelopmental syndromes,[88,89] autism spectrum disorder,[90] and behavioral disorders[53,77,78,82,84] further increase the likelihood of sleep disorders in a child with epilepsy.

Our search identified 12 studies which examined whether children with epilepsy were more likely to have abnormalities in sleep architecture/organization and/or sleep disorders than children without epilepsy, including five level 3[44,48-51] and seven level 4 studies.[53,55,57,60,63-65]

One level 3 study compared PSG findings in 40 children with epilepsy referred for various sleep complaints with 11 children who only had symptoms and PSG findings consistent with moderate OSA (AHI 5-10/h). The children whose seizures were poorly controlled had significantly lower sleep efficiency, a higher arousal index, and a higher percentage of time spent in REM sleep compared with the children with moderate OSA but without epilepsy or the children with well-controlled epilepsy. Sleep disordered breathing (SDB) was present in 42.5% of children with epilepsy referred for evaluation: OSA in 20%, obstructive hypoventilation in 12.5%, UARS in 7.5%, and primary snoring in 18%. PLMs were observed in another 10%. Interictal epileptic discharges (IEDs) were observed in overnight PSG in 40% of the children with epilepsy, at times making it difficult to score sleep stages. Sleep studies were entirely normal in only 7.5% of the children with epilepsy.[48]

Another level 3 study recorded two nights of video-PSG with 24-channel EEG in 17 children with partial epilepsy and 11 controls.[51] They found that the children with seizure(s) during their PSG had significantly less time in bed as a group compared to those who did not have seizures or the normal controls. Children with epilepsy had significantly fewer stage shifts per hour of sleep compared with controls. Seizures most often occurred during NREM 2 sleep, a few during NREM 3, occasionally from NREM 1, wake after sleep onset (WASO), and in the transition from REM sleep to wakefulness.

Another level 3 study recorded two consecutive nights of in-laboratory PSG with extended EEG in 11 children with primary generalized epilepsy who were seizure-free but still receiving maintenance antiepileptic drug therapy and 8 age- and gender-matched controls.[49] The children with epilepsy exhibited a significantly higher percentage of time spent in NREM 1 sleep and longer REM latency compared with controls. IED activity most often occurred during NREM 1 or 2 sleep, rarely during NREM 3, never in REM sleep, and usually did not fragment sleep. Another study compared sleep architecture in 10 children with benign rolandic epilepsy and 10 age-matched normal controls.[91] In the children with rolandic epilepsy they found: (1) reduced total sleep time, sleep efficiency and REM sleep percentage; and (2) a reduced total cyclic alternating pattern (CAP) rate primarily in NREM 2, and reduced EEG slow oscillations and arousals during NREM 1 and NREM 2.

In a case-control study of 15 children with primary generalized epilepsies (9 untreated, 6 treated) and 47 age- and gender-matched controls without epilepsy, no differences in sleep architecture or sleep spindles were found between the children with treated primary generalized epilepsy and controls.[92] However, some abnormalities in sleep spindle density and frequency were observed in children whose epilepsy was diagnosed but untreated.

A level 4 study using PSG with expanded EEG found 80% of 30 prepubertal children with epilepsy had sleep/wake complaints.[53] OSA was diagnosed using PSG in 80% (AHI $\geq$ 1.5, mean AHI 7.6 $\pm$ 8.8). The mean duration of respiratory events was significantly longer in the children who had more frequent epileptic seizures.

Two of the level 3 studies evaluated PSG findings in children with epilepsy and substantial comorbid conditions: tuberous sclerosis complex (TSC)[44] and intellectual disability (ID).[50] One study recorded two nights of PSG in 10 prepubertal children with TSC and 10 healthy controls. The authors found that the TSC group showed shorter sleep time, reduced sleep efficiency, increased number of awakenings and stage shifts, increased NREM 1 and WASO, and decreased REM sleep compared with the control subjects. Sleep architecture was significantly more disrupted in the three children who had at least one seizure recorded during their PSG compared to the TSC children who did not.[44] The other study recorded two consecutive nights of PSG in 11 Italian children with severe ID and epilepsy and 11 age-matched healthy controls without sleep/wake complaints.[50] Children with ID and epilepsy showed a mean AHI of 4.6 $\pm$ 3.4/h, 27% had an AHI > 5, 3 had AHI 8.7 to 11.1/h, and 27% had PLM Index > 5. None of the patients had seizures during their PSGs. The children with ID and epilepsy had longer sleep latency, higher percentage of WASO and NREM 3 sleep, lower sleep efficiency, and more awakenings and stage shifts than controls. Compared with controls, the children with epilepsy had a higher CAP rate with increased A1 index and longer and less numerous CAP sequences.

Vagus nerve stimulation (VNS) is a treatment for medical refractory epilepsy. Sleep-related decreases in airflow and respiratory effort coinciding with VNS activation have been reported in three case series of adults[93-95] and four level 4 studies in children.[57,63-65] Two studies, recording PSG, found sleep (and sometimes seizure severity) improved with VNS treatment.[96,97]

In summary, sleep problems are much more common in children with epilepsy, especially those whose epilepsy is medically refractory. Non-specific, non-diagnostic alterations in sleep architecture, organization, and cyclic alternating patterns are reported. Potentially treatable SDB, excessive motor restlessness, periodic limb movement syndrome (PLMS), behavioral insomnia, parasomnias, and excessive daytime sleepiness are more common in children with epilepsy. Video-PSG with expanded EEG is useful in distinguishing episodes of confusional arousal from epileptic seizures or other parasomnias. The use of a video-PSG in such patients with epilepsy should be determined in the context of the clinical history of possible SDB.

4.2.4 Clinical utility of PSG in children with nocturnal enuresis

Nocturnal enuresis is the involuntary voiding of urine into the bed or clothes when sleeping that persists beyond the normative maturation age for bladder control.

In 2006, the International Children's Continence Society (ICCS) published updated terminology for pediatric lower urinary tract function including enuresis.[98] They define enuresis as intermittent urinary incontinence when sleeping. Enuresis may be called *nocturnal enuresis* "to add extra clarity," but the ambiguous term, *diurnal enuresis* was declared obsolete and to be avoided. A child with *primary* enuresis has never been consistently dry through the night past an age at which bladder control should have been attained. *Secondary* enuresis is resumption of bedwetting after at least six months of dryness. *Monosymptomatic* enuresis occurs in the absence of any daytime voiding symptoms (frequency, urgency, or incontinence). *Non-monosymptomatic* enuresis is more common, and detailed history-taking reveals the majority of children with enuresis have at least subtle daytime symptoms.[99,100] Enuresis with daytime urinary symptoms is often persistent and resistant to treatment.

In 2010, the ICCS published evidence- and consensus-based recommendations for evaluating and treating monosymptomatic enuresis.[99] They recommend screening for symptoms of OSA during the initial evaluation of children with enuresis who snore loudly because their enuresis may remit once their OSA is successively treated.

4.2.4.1 Prevalence and risk factors for enuresis in children

The prevalence of enuresis in the general pediatric population varies widely depending upon how it is defined (especially frequency and duration), data collection methodology, age ranges of children studied, reference periods for determining the rates (i.e., point prevalence vs. 12-month prevalence), ethnicity, and how a particular culture regards bedwetting.[101]

The 12-month prevalence of enuresis (> 2 wet nights per week) in a nationally representative prospective sample of 8- to 11-year-old US children (n = 1,136) was 4.45%.[102] The preva-

lence of enuresis decreases with increasing age.[102-105] Prevalence is increased in males,[43,106-112] those with a family history of enuresis,[110,113-118] and those with attention-deficit/hyperactivity disorder,[101,106,110,119-122] neurodevelopmental delay, and/or lower urinary tract symptoms. Six studies have found enuresis to be more common in children with NREM arousal disorders,[56,123-127] although two others found no connection.[125,128]

4.2.4.2 Clinical utility of PSG to evaluate sleep architecture in children with enuresis

Early studies evaluating sleep using overnight PSG in children or adolescents with enuresis are limited by varying inclusion criteria, poor differentiation between the types of enuresis, or lack of control groups.[58,129-131] Six studies comparing sleep architecture in children or adolescents with and without enuresis were found: one level 2,[41] three level 3,[45,47,52] and two level 4 evidence.[56,58]

A study using unattended ambulatory PSG found children with enuresis had significantly greater sleep time, shorter sleep latency, and greater time in NREM 2 sleep than children without enuresis.[132] The present literature search found that children with enuresis had: (1) increased sleep efficiency and stage 4 sleep among a cohort of habitually snoring children[41]; (2) were more likely to have PLMS and EEG arousals[45]; (3) no significant differences in sleep architecture in overnight PSG compared with normal controls[47]; (4) no significant differences in PSG findings between dry and wet nights, nor desmopressin responders and non-responders[56]; and (5) paroxysmal runs of rhythmic activity (6-7 Hz in NREM and 3-5 Hz in REM sleep), which could last 15 to 40 seconds in NREM sleep were often observed 5 minutes before an episode of enuresis.[47]

No, or only minor, differences in sleep macroarchitecture were seen in children with NE compared with age-matched controls. Differences, when reported, were modest but showed significant increases in sleep latency, sleep efficiency, total sleep time, and time and/or percentage of NREM 3 sleep. No significant differences in PSG findings were observed on wet compared to dry nights.

Two level 3 and two level 4 studies have shown that enuresis can occur in any stage of sleep and any time of night but more often in NREM sleep, perhaps because NREM sleep normally accounts for 75% to 80% of the total sleep time.[47,52,56,58]

Several of the enuresis study results are contradictory and may reflect methodological issues pertaining to the definitions used to define enuresis, the age of the children, and the specific criteria used to assess the PSG. Nonetheless, PSG studies in enuresis have helped establish its relationship to time of the night and to sleep stages. The literature has not, however, identified any specific characteristics of PSG that are helpful in the clinical evaluation of enuresis that is unaccompanied by sleep disordered breathing.

4.2.4.3 Clinical utility of PSG in correlating enuresis to habitual snoring and/or OSA

The literature search identified five studies which evaluated whether children with enuresis were more likely to habitually snore and/or have OSA; one was level 2,[41] two level 3,[42,43] and two level 4 evidence.[59,62]

A level 2 cross-sectional, community-based, parent-reported questionnaire study found 11.2% of 17,646 5- to 7-year-olds habitually snored; enuresis was reported in 27% of the snorers compared to 12% of non-snorers.[41] However, enuresis did not correlate with AHI severity, nadir SpO_2, or respiratory arousal index on overnight PSG. The authors concluded that the prevalence of enuresis increased among children with habitual snoring, but the severity of OSA did not appear to impact its prevalence.

A level 3 study found 41% of 160 children referred for suspected OSA had at least an eight-fold higher prevalence of enuresis than the general pediatric population.[43] Body mass index did not correlate with presence or absence of enuresis. Enuresis was significantly more common in those with an AHI > 1 (47%) than those with an AHI ≤ 1 (17%). The percentage of children having enuresis ≥ 3 nights/week was higher among children with an AHI ≥ 1 compared to those with an AHI < 1 (32% vs. 14%). However, the prevalence of enuresis did not increase with increasing AHI severity.

Another study reported enuresis in 29% of 144 children who had an AHI > 1 on overnight PSG (mean AHI 8.1/h).[133] They also found no significant differences in AHI, nadir SpO_2, desaturation index, or sleep efficiency between the children with or without enuresis. AHIs were not higher in the children whose enuresis occurred frequently, sometimes, or rarely.

Another level 3 study examined relationships between obesity, enuresis, and OSA in 149 children referred for suspected OSA and 139 controls recruited from a general pediatric clinic.[42] They found 80% of control subjects were at risk for being overweight, and 80% of the children with monosymptomatic enuresis had some degree of OSA on overnight PSG. Using logistic regression analyses, they found both monosymptomatic enuresis and obesity were independently associated with OSA but *not* with each other.[42]

If enuresis is a symptom of habitual snoring and OSA, then enuresis should improve or resolve following treatment of the OSA. Two studies have evaluated whether enuresis resolved soon after pediatric upper airway surgeries.[133,134] One large prospective study found no statistically significant difference in cure or improvement rates of enuresis in 257 children undergoing tonsillectomy for tonsillar hypertrophy compared with 69 controls who had other surgeries.[135] The study suggests that enuresis resolves in children around a certain age, and it may or may not be related to the presence of OSA.

To summarize, enuresis is strongly associated with habitual snoring, witnessed apnea, and OSA, but the severity of the OSA above an AHI > 1/h does not appear to impact the prevalence of enuresis. The clinical evaluation of a child with enuresis should include consideration of OSA, especially if the child is obese and/or has failed standard treatments for enuresis. Enuresis often improves or resolves after adenotonsillectomy in children with tonsillar and/or adenoid hypertrophy, habitual snoring, and/or OSA.[133] Spontaneous resolution of enuresis with age may explain why enuresis often remits following adenotonsillectomy in children.

4.3 Clinical Utility of PSG in Children with Sleep Related Movement Disorders

4.3.1 Clinical utility of PSG in children with RLS

Restless legs syndrome (RLS) is a clinical disorder characterized by uncomfortable sensations in the legs, which tend to

be worse in the evening or night and are relieved by movement. Up to 80% of adults with RLS also have PLMS on PSG.[136] Although the presence of PLMS is not part of the diagnostic criteria for RLS, it can provide supportive evidence.[137] It can be particularly challenging to determine the prevalence of RLS in children, as they often do not complain of their symptoms or may be too young to verbalize them. The literature search regarding PSG in children with RLS identified nine studies: two level 2 evidence,[138,139] five level 3,[140-144] and two level 4.[145,146]

A prospective level 2 study reported a relationship between attention-deficit/hyperactivity disorder and PLMS but noted that many of the children had evidence of coexisting OSA. Researchers also found a high hyperactivity index T score in 59% of the children who had been referred for suspected OSA. Those with both PLMS and OSA (n = 16) showed increased hyperactivity compared with those children with OSA alone (n = 43).[138] In a related level 2 study by the same group, it was shown that parental report, using structured parental questionnaires and a composite PLMS score, was poor at predicting PLMS on PSG. The positive predictive value of this parental questionnaire was 0.38, suggesting that the clinical assessment may be helpful, but it is unlikely to replace PSG as a diagnostic tool.[139] Consistent with this poor relationship between laboratory findings of PLMS and parent report of symptoms of RLS, a level 3 study reviewed PSG data obtained over a 6-month period and correlated PLMS findings to three questions related to restlessness during sleep.[140] Data from a total of 101 children (mean age 6.5 years) were examined; the majority of PSGs were performed to rule out OSA, 10 children had a PLMI > 5/h, and 60% of these had concurrent evidence of OSA. Parental report of the child kicking their legs during sleep (sensitivity of 50%, specificity of 51%, PPV 10%) or restlessness during sleep (sensitivity of 70%, specificity of 26%, PPV 9%) was not predictive of PLMS on PSG.[140]

A level 3 study described PSG findings in 27/69 children newly diagnosed with ADHD whose parents observed PLMS occurring in sleep.[141] Eighteen had PLMS > 5/h noted on a subsequent PSG. Eight of these 18 children (44%) also had symptoms consistent with RLS. The authors concluded that PLMS and RLS are common comorbidities in children with ADHD. A subsequent level 3 study by the same investigator looked at 14 medication-naive children with a new diagnosis of ADHD and noted the presence of PLMS > 5/h in 64% (9/14) compared with none of the controls.[142] When biological parents were questioned for the presence of RLS in themselves, six of the nine children with PLMS had a parent with RLS compared with only one of the five children without PLMS. None of the parents in the control group met criteria for RLS. The RLS status of the children was not evaluated in this study.

A level 3 and two level 4 evidence papers support a relationship between PLMS and RLS in children. One level 3 study classified 129 children with PLMS into three categories based on severity of PLMS and noted that 25% (4/16) of those with moderate to severe PLMS (> 25/h) had RLS, despite a young mean age of 11.1 years and that 10/14 in whom a family history was available had a parent with RLS.[143] A level 4 article described the clinical course of 18 children with sleep disturbance who eventually met clinical criteria for RLS. Seventeen had a PSG study and 11 (65%) of these had PLMI > 5/h.[145] The remaining level 4 evidence paper[146] described a retrospective cohort of 37 children who had RLS or PLMD (PLMS > 5/h) as well as a biological parent with RLS.[146] Of these, 10 (27%) children had RLS. Only 41% of these children were noted by their parents to have limb jerks during sleep.

This high comorbidity of PLMS with or without RLS in children with ADHD was not confirmed by a level 3 study that looked at children with ADHD plus the complaint of "growing pains."[144] Criteria for RLS were met by 10/11 of the referred children, all of whom then underwent PSG. Ten children without ADHD who had symptoms of SDB but no PSG findings to support OSA formed the control group. Only one child in the control group, and no children in the RLS group, had PLMS > 5/h noted on PSG. Of note, 6/10 children with RLS had a diagnosis of ADHD, but there were no children in the control group with this disorder.

The strength of evidence in these latter papers is limited by the small numbers and retrospective design, but all, with the exception of one study,[144] support a relationship between the clinical entity of RLS and increased prevalence of PLMS on PSG study. The diagnosis of RLS and PLMD in children is challenging, particularly because many young children are unable to describe typical RLS symptoms. In addition, the poor relationship between parent report and PSG findings of PLMS further support a contributory role for PSG in children suspected of having RLS.[140] In adults, PLMS are considered an endophenotype for RLS.[147] As in adults, increased PLMS in children are associated with systemic iron deficiency.[148,149] Along with a positive family history, polysomnography is currently recommended by the ICSD-2 to confirm the presence of PLMS as an additional diagnostic criterion for RLS in children.[128]

4.3.2 Clinical utility of PSG in children with suspected PLMD

4.3.2.1 Normative values for PLMS in children, by age

Limited data are available regarding normative data for PLMS in the general population of children. The literature search identified 6 studies: one level 1 evidence,[150] one level 2,[151] and four level 3.[140,152-154]

The level 1 study reported PLMS > 5/h in 23% of 252 children referred for sleep complaints. The PLM Index in the group with PLMS averaged 16.2/h. Most with PLMS had concurrent OSA; only 0.8% had isolated PLMS.[150] Unfortunately, the diagnostic criteria for PLMS were not described.

The level 2 study found 48 (8.4%) of 570 children in the sample referred for sleep complaints had PLMI > 5/h compared with 42 (11.9%) of 351 children recruited from their community cohort.[151] None of the 52 controls had PLMS > 5. Forty-four percent of the children with PLMS > 5 had ADHD.[151]

One level 3 study found PLMS > 5/h in 7.8% of 982 pediatric PSGs (47% of whom also had OSA and 97% of whom had reduced serum ferritin levels averaging 26 μg/L).[152] Two other studies similarly found PLMS in 10% of 101 children (60% with concurrent OSA)[140] and 5.6% of 591 children (60% with concurrent OSA).[153] None provided age-specific prevalence data.

A fourth level 3 study found PLMS were more prevalent in Caucasian than African American schools.[154] PLMS > 5/h were observed in 16.5% of 391 Caucasian children compared with 7% of 151 African American children.[154] PLMS without

SDB was nine times more likely to occur in a Caucasian child, whereas PLMS were more likely to be found in African American children who had OSA.

In summary, there were limited data on the prevalence of PLMS in otherwise healthy children. The prevalence of PLMS among children referred for sleep concerns ranges from 7% to 16% and is associated with OSA in the majority of these children. The data support a contributory role for PSG in children suspected of having PLMS with or without a comorbid sleep disorder. Limited data suggest that PLMS may be more prevalent in children with ADHD, reduced serum ferritin levels, and Caucasian ethnicity, but further research is needed to confirm this.

4.3.2.2 Normative values for PLM arousal index in children

Four studies (one level 1[150] and three level 3[152-154]) which reported PLM arousal index (PLMA) in children were identified. The level 1 study reported a mean PLMA index of 6.1/h in 58 children with PLMS who had a mean PLMS index of 16.2/h.[150] A level 3 study found 1% of 591children had a PLMA > 5/h, 50% of whom had concurrent OSA.[153] Another level 3 study reported that PLMA averaged 4.5 ± 8.4/h in their profile of children with PLMS, roughly half the mean PLMS index in this cohort.[152] The other level 3 study found PLMA > 1/h in 4% of 151 African American and 5% of 391 Caucasian children.[154] In summary, the literature search identified very limited data related to normative values/prevalence of PLMA in children.

4.3.2.3 The degree of night-to-night variability in PLMS in children with PLMD

One level 3 study addressing night-to-night variability in PLMS in children was found.[155] Some variability in the frequency of PLMS was noted across study nights with a small percentage of children having PLMS > 5 on only one night of study; however, this was statistically insignificant. The study involved 36 children with ADHD who had two PSGs before and two after starting a placebo-controlled medication trial. Forty-seven percent of the total group met clinical criteria for RLS and 17% met criteria for PLMD. Based on PLMS > 5/h, the odds ratio was 7.0 with confidence intervals greater than 1 that a correct diagnosis of PLMS can be expected from a single night of study.[155]

4.3.3 Clinical utility of PSG in children with sleep bruxism

A level 1 single study evaluated sleep in children with sleep bruxism. This prospective study found no difference in sleep architecture between 10 children with bruxism and 10 controls during an overnight PSG.[156] However, children with bruxism had a higher arousal index than controls (36.7/h vs. 20.7/h). Researchers found moderate correlations between the arousal index and several behavior-problems scales in the children with bruxism, suggesting that it may be associated with an increased incidence of attention and behavior problems.

4.3.4 Clinical utility of PSG in diagnosing sleep related movement disorders in special populations of children

Four articles evaluated the use of PSG to diagnose sleep-related movement disorders in special populations of children: one level 2 evidence,[157] one level 3,[26] and two level 4.[149,158] The level 2 study demonstrated a tendency for children with Angelman Syndrome to have increased PLMS as compared to two control groups of children with mental retardation (one with epilepsy and one without).[157] Seventy percent of children with Angelman Syndrome had a PLMI > 5 compared to 38.5% of children with mental retardation from other causes and 46.7% of children without mental retardation. A level 3 study described the utility of PSG in children with chronic anemia by comparing PSG results of 10 children with β-thalassemia, 10 children with congenital dyserythropoietic anemia (CDA), and 13 controls.[26] The children with anemia had increased arousals during sleep compared to controls (β-thalassemia 28 arousals/h and CDA 24 arousals/h compared to controls 12.1/h). Thirty-eight percent of the arousals in children with β-thalassemia and 25% of the arousals in children with CDA were induced by PLMS. A retrospective level 4 study found increased PLMS on PSG in 29% of 17 children with sickle cell disease without OSA.[158] The level 4 study found 72% of 39 children with PLMS had serum ferritin levels less than 50 μg/L; 76% of those who subsequently completed a course of iron sulfate therapy had a significant reduction in their PLMS and improvement in daytime symptoms.[149]

4.4 Clinical utility of PSG in the evaluation of sleep in special populations of children with chronic pain syndromes, fibromyalgia, or other rheumatologic problems

Sleep disturbances are common in children with rheumatologic disorders such as rheumatoid arthritis or fibromyalgia. Sleep in these children is generally characterized by frequent arousals and poor sleep efficiency. These disturbances may be exacerbated by pain, PLMS, or SDB.

Seven studies of sleep in children with rheumatologic disorders were identified: one level 1 evidence,[159] two level 2,[27,160] three level 3,[25,161,162] and one level 4.[163] PSG was used in all to evaluate the sleep disturbances, not to diagnose the underlying rheumatologic disorder.

A level 1 study found children with fibromyalgia, compared with controls, had prolonged sleep latency, reduced total sleep time, decreased sleep efficiency, and increased wakefulness during sleep.[159] In addition, many of the children with fibromyalgia had excessive movements during sleep, with 6 children (38%) having PLMI > 5/hour.

Two level 2 studies evaluated sleep disturbances in children with juvenile rheumatoid arthritis (JRA).[27,160] One study recorded PSG in 16 patients with JRA and MSLT in 7.[27] They found the children with JRA had 90% more arousals and awakenings, and the median length of occurrences of uninterrupted sleep in NREM 2, NREM 3, and REM sleep was 60% shorter than in controls. Patients with JRA had significantly more stage shifts than controls. Alpha-delta sleep occupied 15% of NREM sleep in 15 of 16 patients compared to < 1% in the controls. Higher arousal indexes were seen in the children with higher pain scores. The MSL on the MSLT in the patients was 10.3 ± 2.6 minutes.[27] The other level 2 study also found children with JRA exhibited higher PLM indices and arousals, as well as increased alpha-delta activity in NREM sleep compared to controls. The greatest alpha activity was observed in children with greater joint involvement. Three level 3 studies showed overnight sleep was not altered in children with JRA, but daytime sleepiness was impaired as measured by MSLT, which suggests that there

could be either subcortical arousals or perhaps changes in sleep microarchitecture.[25,161,162]

One level 4 article evaluated PSG findings in children with chronic headaches.[163] This study suggested an association between children with tension headaches and bruxism, as well as between migraine headaches and sleep-disordered breathing. Children with chronic headaches tended to have more disrupted sleep on PSG.

In summary, the literature search identified a limited number of papers that address the issue of sleep disturbances in children with rheumatologic or other chronic pain disorders, and findings provide limited support for the potential role of PSG in children with chronic pain disorders.

5.0 SLEEP DISORDERS WITH INSUFFICIENT EVIDENCE FOR THE UTILITY OF PSG

Absence of evidence is not proof of absence. The cliché that "more and better studies are needed" holds very true here. The task force was unable to address the clinical utility of PSG in certain important categories of disorders simply because the number of papers identified by the search process was below the threshold for inclusion. Categories not discussed include rhythmic movement disorders, circadian rhythm disorders, and childhood cancer, depression, traumatic brain injury, and burns. Even though there is very little or no evidence to support the use of PSG in these disorders, the task force felt strongly that this does not indicate that PSG should *not* be used in the diagnosis, follow-up, or treatment of these disorders. Rather, clinical judgment should dictate if PSG is required in these conditions.

Some sleep disorders are best evaluated using alternatives to comprehensive, attended PSG or MSLT. Actigraphy and sleep logs may be the more appropriate tests for the evaluation of circadian rhythm sleep disorders.[7] The diagnosis of typical parasomnias is often established by a comprehensive clinical history and examination; video-PSG with expanded EEG is indicated for atypical parasomnias.

6.0 SUMMARY AND DISCUSSION

This review involved a systematic process of identifying relevant papers and grading the strength of the evidence. To date, this is the most extensive review of PSG and MSLT on non-respiratory sleep disorders of childhood.

Twenty-two studies (two level 1, seven level 3, and thirteen level 4) showed that the MSLT is feasible for the evaluation of daytime sleepiness in developmentally normal children of 5 or more years of age. The normative data for the MSLT is based upon age/Tanner stages, but is level 3 or 4 in strength and consists of small sample sizes. Retrospective studies have shown that the MSLT is highly sensitive in confirming narcolepsy-cataplexy. The sensitivity of this test in diagnosing narcolepsy without cataplexy is unclear. The specificity of the MSLT for diagnosing narcolepsy could not be determined from the literature. There are also no large case series that have studied whether serial PSG and MSLT are helpful in establishing the diagnosis of narcolepsy in the early stages of it evolution. Furthermore, there is insufficient information regarding the role of MSLT in the diagnosis of non-narcolepsy disorders with hypersomnolence.

Video-PSG is helpful in the evaluation of NREM parasomnias, especially sleepwalking and/or sleep terrors. Children with recurrent or chronic sleepwalking may have associated obstructive sleep apnea, which video-PSG may help uncover. Video-PSG with an expanded EEG montage is useful in distinguishing episodes of confusional arousal from epileptic seizures or other parasomnias. The procedure also helps diagnose REM sleep behavior disorder.

Our review also found that children with epilepsy were more likely to have abnormalities in sleep architecture/organization than children without epilepsy. Potentially treatable sleep-disordered breathing, PLMS, behavioral insomnia, parasomnias, and excessive daytime sleepiness are common in children with epilepsy.

With regard to primary enuresis, the review found none or only minor differences in sleep macroarchitecture as compared to age-matched controls. No significant differences in polysomnogram findings were observed on wet nights as compared to dry nights. When enuresis is associated with snoring or witnessed apnea, however, consideration should be given to underlying sleep disordered breathing.

There are limited data on the prevalence of PLMS in children. PSG is helpful in the assessment of PLMS and comorbid sleep disorders.

Polysomnography has utility in the assessment of special populations of children such as Angelman syndrome, chronic anemia, and β-thalassemia with suspected sleep related movement disorders.

The value of a diagnostic tool in clinical medicine is based upon the tenets of validity and reliability. The task force found that pediatric PSG and MSLT showed good content and face validity and good interrater reliability for non-respiratory sleep disorders in children. The strength of the evidence for polysomnography and MSLT was somewhat weak, consisting mainly of level 3 or 4 studies. This highlights the desperate need for more level 1 and 2 studies of sleep and its disorders in children.

Based on assessment and integration of findings of over 70 evidentiary papers, it is the consensus of the task force that pediatric PSG shows validity, reliability, and clinical utility that is commensurate with most other routinely employed diagnostic clinical tools or procedures. PSG and MSLT are vital for the assessment of disorders such as hypersomnias and parasomnias, of intermediate utility in periodic limb movement disorder, and of lesser but still important value in nocturnal enuresis when the likelihood of OSA is high. The skillful integration of clinical assessment and PSG findings by a pediatric sleep specialist are necessary for the diagnosis and management of non-respiratory pediatric sleep disorders.

7.0 FUTURE DIRECTIONS

This review highlights the need for well-designed, well-powered studies that evaluate the clinical utility of PSG and MSLT in the evaluation and management of non-respiratory sleep disorders across a broad population of children. The most pressing need is to take into consideration the change in sleep architecture that is associated with normal maturation, as well as the evolving process of sleep disorders such as narcolepsy among children and adolescents. The clinical utility of PSG and MSLT must take into account this changing process, with normative values being based on age or developmental levels.

More robust normative data on the MSLT in children and adolescents is needed along with some consideration of how best to conduct the test in this age group. It is necessary to understand whether four nap opportunities will suffice for the MSLT or if five are required. Should nap opportunities be lengthened to 30 minutes to accommodate for the ceiling effect? Clinicians have often observed longer sleep latency during the final nap opportunity ("last night effect"). However, the existence and significance of this presumed childhood phenomenon has not been systematically studied.

Methods of evaluating excessive daytime sleepiness in preschool children and the utility of the MWT in pediatric age groups also need evaluation. In order to establish normative data, the frequency of SOREMPs in healthy, community-based teens needs to be determined. Do serial PSG and MSLT help in the diagnosis of childhood narcolepsy during the early stages of evaluation? Early diagnosis of narcolepsy, as close to its onset point as possible, is critical to developing and applying potential early intervention techniques. The changes in the temporal organization of nocturnal REM sleep and a possible corresponding appearance of SOREMPs on the MSLT has not been investigated at this stage. These phenomena, thought to be almost independent rather than integrated, need further study.

REM sleep without atonia and REM sleep behavior disorder are well recognized phenomena in adults. Although these have been documented in small case series of children as well, they remain insufficiently characterized in the pediatric age group. Data on the relationship between possible chronic sleep deprivation and MSLT findings in either children or adolescents (i.e., will one night of normal duration in the sleep lab be enough to control for the effect of chronic sleep deprivation on the MSLT?) need to be systematically evaluated. With regard to the maintenance of wakefulness test, there are no normative data at all for teens. Notwithstanding this, clinicians frequently encounter adolescents with primary disorders of hypersomnolence such as narcolepsy that are satisfactorily treated with stimulant medications, with the patients expressing a desire to drive automobiles. The MWT might help in this decision-making progress, provided there were normative data to support its use.

Further research is also needed for the evaluation of atypical parasomnias in pediatric age groups, including how to increase the likelihood a parasomnia will be recorded in a single night of PSG and how often more than one night is needed. Unfortunately, only one-third of patients with paroxysmal nocturnal events will exhibit a typical spell during a single night of video-PSG.[66,164] Two studies in adults suggest that prolonged sleep deprivation coupled with delivering a loud auditory stimulus during non-rapid eye movement N3 sleep may increase the likelihood of recording a NREM disorder of arousal in a single night of in-laboratory PSG.[165,166] The current literature search found a lack of studies examining these issues in children.

Moreover, there is little or no evidence of whether fewer than 18 channels of EEG are needed when recording an expanded EEG montage in video-PSG. The AASM revised indications for PSG do not specify how many channels of EEG are needed when using an expanded EEG montage. Only two studies (both in adults) have examined this issue. They found that if the goal is to differentiate epileptic seizures from non-epileptic events (especially frontal lobe seizures) that 18 channels of EEG are needed.[167] However, recording even 18 channels of EEG during a video-PSG did not improve the ability to recognize frontal lobe seizures. Adding 7 or 18 channels of EEG improved the accuracy of temporal lobe seizure detection (sensitivity 67% for 4 channels, 82% for 7, and 86% for 18).[168]

PSG and MSLT are likely to play important diagnostic and therapeutic roles in managing secondary sleep disorders in children with comorbid medical conditions (i.e. childhood cancer, closed head injury, or mental health disorders), but more research is needed before recommendations can be made. Enuresis is common in children with undiagnosed or untreated OSA, but further studies are needed to identify if treating the OSA results in cure or improvement of the enuresis.[169-172] More data are also needed to confirm whether there are clinically significant differences in sleep macroarchitecture or arousal thresholds in children with enuresis compared with age-matched controls.

Other challenging questions for study include: Can molecular genetic studies identify children with narcolepsy or restless legs syndrome with high reliability and validity? Can ambulatory devices with home monitoring serve as an alternative to attended polysomnography? How well do questionnaire surveys of sleepiness correlate with findings on the MSLT?

We remain optimistic that future developments will provide more sophisticated methods for sleep data collection and analysis; integration of the testing with the clinical history remains the fundamental diagnostic challenge for the sleep specialist.

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DISCLOSURE

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