

# Sleep Related Movement Disorders

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Sleep-related movement disorders are primarily characterized by relatively simple, usually stereotyped movements that disturb sleep or its onset. Restless legs syndrome (RLS) is an exception in that patients typically engage in walking or non-stereotypical limb movement to reduce leg discomfort. However, RLS is closely associated with periodic limb movements (PLMs), which are usually simple and stereotyped within a series. Nocturnal sleep disturbance or complaints of daytime sequelae are a prerequisite for a diagnosis of a sleep-related movement disorder. For example, many people exhibit periodic limb movements of sleep (PLMS) but have no complaint of a sleep disturbance, nor significant objective disturbance of their sleep due to the movements. Such persons should not be classified as having periodic limb movement disorder (PLMD), but instead, the presence of PLMS should simply be noted. Similar considerations relate to the distinction between rhythmic movement disorder and the presence of rhythmic movements.

Body movements that disturb sleep are also seen in other sleep disorder categories (e.g., in parasomnias such as sleepwalking, sleep terrors, and rapid eye movement (REM) sleep behavior disorder (RBD)). However, these parasomnias differ from the simple stereotyped movements categorized as sleep-related movement disorders in that they involve complex behaviors during the sleep period. Parasomnia-related movements may appear purposeful and goal-directed but are outside the conscious awareness of the individual. Parasomnias are discussed in a separate chapter of ICSD-3-TR.

Although the history may be diagnostic, polysomnography is sometimes necessary to make a firm diagnosis of sleep-related movement disorders and distinguish them from other sleep disorders. To establish a diagnosis, it is helpful to add all-night video recording to the polysomnographic recording. The documented movements must be correlated with the level of consciousness and the technologist's description of the patient's behavior. If the presentation during sleep is significantly different from that during wakefulness, or if the movement is entirely confined to sleep, then the movement disorder is classified here (e.g., the occurrence of bruxism exclusively in sleep).

## Restless Legs Syndrome

*ICD-9-CM code: 333.94*

*ICD-10-CM code: G25.81*

## *Alternate Names*

Willis-Ekbom disease.

## *Diagnostic Criteria*

Criteria A-C must be met

- A. A complaint of an urge to move the legs, usually accompanied by or thought to be caused by uncomfortable and unpleasant sensations in the legs.<sup>1,2</sup> These symptoms must:
  1. Begin or worsen during periods of rest or inactivity such as lying down or sitting;
  2. Be partially or totally relieved by movement, such as walking or stretching, at least as long as the activity continues;<sup>3</sup> and
  3. Occur exclusively or predominantly in the evening or night rather than during the day.<sup>4</sup>
- B. The above features are not solely accounted for by a condition that mimics RLS (e.g., leg cramps, positional discomfort, myalgia, venous stasis, leg edema, arthritis, habitual foot tapping).<sup>5</sup>
- C. The symptoms of RLS cause concern, distress, sleep disturbance, or impairment in mental, physical, social, occupational, educational, behavioral, or other important areas of functioning.<sup>6</sup>

## Notes

1. The urge to move the legs may be present without any other distinct uncomfortable sensation. The arms or other parts of the body may also be involved.
2. For children, the description of these symptoms should be in the child's own words.
3. When symptoms are very severe, relief by activity may not be noticeable but must have been previously present.
4. As a result of severity, treatment intervention, or treatment-induced augmentation, the worsening in the evening or night may not be noticeable but must have been previously present.
5. The RLS criteria may be met in the context of certain medical conditions (e.g., chronic renal failure), in which case the separate diagnosis of RLS can still be made.
6. For certain research applications, such as genetic or epidemiological studies, it may be appropriate to omit criterion C. If so, this should be clearly stated in the research report.

## *Essential Features*

RLS is a sensorimotor disorder characterized by a complaint of a strong, nearly irresistible urge to move the limbs. This urge to move is often, but not always, accompanied by other uncomfortable sensations felt in the limbs or by a feeling that is simply difficult or impossible to describe. Although the legs are most prominently affected, "restless legs" is a misnomer, in that 21% to 57% of individuals with RLS also describe some arm sensations. However, isolated arm involvement is extremely rare. Topographic analysis of RLS has found the calves are most frequently and severely affected. Limb sensations may be

superficial or deep and symmetric or asymmetric, but not limited to the joints. The most common adult RLS descriptors in English are "restless", "uncomfortable", "twitchy", "need to stretch", "urge to move", and "legs want to move on their own". Some express their RLS sensations as painful. "Numb" and "cold" are very uncommon descriptors for RLS.

The criteria specify the necessary characteristics of the RLS symptoms: worse at rest, better with movement, and predominant occurrence in the evening or night. The separation of worsening at rest from worsening in the evening/night is based on circadian rhythm studies that show an increase at night, independent of activity level. RLS must be differentiated from other conditions that can mimic RLS. Clinically significant RLS is defined by symptoms that cause substantial distress, sleep disturbance, or impairment of function.

### *Associated Features*

Disturbed sleep is a common, prominent, and distressing aspect of RLS. In individuals with RLS, sleep onset and maintenance complaints are notably higher than in controls, with odds ratios (OR) between 1.7 and 3.5. In clinical populations, disturbed sleep is reported in 60% to 90% of individuals with RLS, is typically the most troubling symptom, and is often the primary reason for seeking medical care. The Medical Outcomes Study Sleep Questionnaire scores for sleep quantity, sleep disturbance, sleep adequacy, and sleep problems are significantly worse for RLS patients than controls.

Daytime fatigue and daytime sleepiness are also common complaints; however, patients tend not to nap, implying hyperarousal in RLS. In contrast to obstructive sleep apnea, Epworth Sleepiness Scale scores in RLS are typically in the normal range and either no different or marginally elevated compared to normal controls, possibly because the RLS prevents patients from falling asleep during the day. Clinical sleep disturbance correlates with both severity of RLS and health impact of RLS. Some individuals with RLS may choose to work at night, thereby shifting quiet activities and their sleep schedule away from the circadian peak of their RLS symptoms.

Periodic limb movements (PLMs) are present in a high percentage of RLS patients (see Objective Findings). The presence of PLMs, a family history of RLS, and response to dopaminergic therapy support a diagnosis of RLS. Periodic limb movements can occur in sleep (PLMS) or wakefulness (PLMW). PLMW occurs during quiet rest and frequently at the transition between waking and sleep, disrupting sleep onset or the return to sleep. PLMS are frequently associated with arousal from sleep. In almost all cases, RLS sensory and motor features respond initially to treatment with dopaminergic therapy.

Multiple clinic-based and population-based studies have shown an increased prevalence of mood and anxiety disorders in individuals with RLS. Most controlled studies using validated assessments have shown an increased incidence of depressive symptoms, major depressive disorder, generalized anxiety disorder, and panic disorder. In addition, a positive correlation is reported between the severity of RLS and depression/anxiety symptoms.

Similarly, increased rates of attention-deficit/hyperactivity disorder (ADHD) have been found in RLS, both in pediatric and adult studies. Data indicate that about one-fourth of individuals with RLS have ADHD symptoms, and conversely, that 12% to 35% of those with ADHD meet the criteria for RLS.

### *Clinical and Pathophysiological Subtypes*

Evidence in the literature is not sufficient to support well-defined subtypes of RLS. Early-onset RLS (before age 45) is more familial and associated with slower progression than late-onset RLS. In addition, the classification of “secondary” RLS has been suggested when the condition occurs in association with conditions that demonstrate higher than average rates of RLS, such as iron deficiency, pregnancy, and chronic renal failure. However, this construct has been challenged based on pathophysiological, family history, genetic, and clinical course data.

### *Demographics*

The overall prevalence of RLS is estimated at 5% to 10% in European and North American population-based studies. In Asian countries, studies indicate a lower prevalence. Prevalence is about twice as high in women than in men. The prevalence increases with age up to 60-70 years in most studies. Various metrics have been applied to population-based studies to determine a measure of “clinically significant” RLS. These measures include frequency ( $\geq 1$ -2 times/week), severity (moderate to severe distress), differential diagnosis, and impact. These analyses suggest a prevalence of “clinically significant” RLS of 2% to 3% in Europe and North America, but lower in Asia. Annual incidence rates have been reported as 0.8% to 2.2%.

Pediatric prevalence rates are 2% to 4% in UK/US and Turkish studies, with moderate to severe RLS in about 0.5% to 1%. Adolescents are more likely to have moderate to severe RLS symptoms than younger children—one-half of 12- to 17-year-olds with RLS fall into this range of severity, compared to one-fourth of 8- to 11-year-olds with RLS. Boys are affected as often as girls, with the sex difference not emerging until the late teens or twenties.

### *Predisposing and Precipitating Factors*

A positive family history of RLS, the genetic variants noted below, and female sex confer increased risk for RLS. The most well-characterized precipitating factors are iron deficiency, certain medications, pregnancy, chronic renal failure, and prolonged immobility. Mild iron deficiency, characterized by serum ferritin below 50  $\mu\text{g/L}$ , has been associated with increased severity of RLS. Medications that may precipitate or aggravate RLS and PLMS include sedating antihistamines, some centrally-active dopamine receptor antagonists, and antidepressants. An exception is the antidepressant bupropion, a dopamine/norepinephrine reuptake inhibitor.

Many other conditions are associated with higher rates of RLS than in the general population. The prevalence of RLS during pregnancy is two to three times greater than in the general population. There is a peak in the number of women affected by RLS in the third trimester, with resolution of symptoms for most, but not all, shortly after delivery. Predictors of RLS in pregnancy include a family history of RLS, RLS in a prior pregnancy, and, possibly, low hemoglobin, low folate, and high estradiol. RLS in pregnancy has also been associated with gestational hypertension, pre-eclampsia, and peripartum depression but not with overt offspring complications. Parity, the number of previous pregnancies, appears to account for the 2:1 sex difference between women and men in the general population prevalence of RLS.

In chronic renal failure patients, the prevalence of RLS is two to five times greater than in the general population, with prevalence rates of 11% to 58% in US and European chronic renal failure clinics. Compared to patients with chronic renal failure without RLS, those with RLS have more significant sleep disturbance, report poorer quality of life, and more often discontinue dialysis prematurely. Typically, RLS symptoms improve dramatically within one month after successful kidney transplantation but become severe again with transplant failure.

Multiple sclerosis (MS) is consistently associated with RLS symptoms. MS risk factors for RLS include chronic progressive sub-type and spinal cord involvement. In addition, Parkinson's disease (PD) is associated with RLS symptoms, but RLS usually occurs after the onset of PD motor symptoms.

Migraine is likely associated with RLS. There is limited or contradictory evidence for RLS associations with sleep deprivation, peripheral neuropathy, radiculopathy, and pain. Caffeine use, obesity, and tobacco use have been inconsistently associated with RLS.

### *Familial Patterns*

The risk of RLS is two to six times greater for first-degree relatives of patients with RLS than for those from the general population. Early-onset RLS is especially familial, with 40% to 92% of cases reporting affected family members. High concordance rates are observed in monozygotic twins. Although many family studies suggest an autosomal dominant model of RLS, recent genome-wide linkage and association studies suggest a more complex gene-environment pattern. Linkage analyses have reported multiple different gene loci associated with RLS but, to date, no single causative gene. However, genome-wide association studies have identified many single nucleotide polymorphisms in RLS, the most robust of which include *BTBD9*, *MEIS1*, and *PTPRD*.

### *Onset, Course, and Complications*

The onset of RLS symptoms occurs at all ages, from childhood to late adult life. The mean age of onset for familial RLS is in the third or fourth decade, with onset before age 21 in about one-third of cases. The clinical course of RLS differs based on age of onset. In early-onset RLS (before age 45), slow progression

of symptoms occurs in about two-thirds of cases. Most of the remaining one-third report stable symptoms over time, although remission may occur. In late-onset RLS, rapid progression is more typical, and aggravating factors are common.

Significant impairment of health-related quality of life (HRQoL) occurs in moderate to severe RLS. Physical and mental health scores are consistently lower for individuals with RLS, based on standard QoL assessment tools. The HRQoL impairments are strongly associated with severity of RLS and remain after controlling for age, sex, and disease comorbidity. In addition, patients with cancer, type 2 diabetes, or renal failure who also have RLS have poorer quality of life than those without RLS. Most large population-based studies find positive associations between RLS and hypertension, but less consistent association with cardiovascular disease, including coronary heart disease and stroke. Repetitive surges in heart rate and blood pressure associated with PLMS potentially mediate these associations. Limited mortality data suggest an increased risk of mortality in women and in chronic renal failure patients with RLS. In addition, the data possibly indicate a mild increase in mortality in the general RLS population.

### *Developmental Issues*

The accurate diagnosis of RLS in children and adolescents requires an understanding of developmental language and cognitive skills. Modified pediatric-specific diagnostic criteria and severity scales criteria exist but are not well validated. Adequate verbal skills are needed for children to communicate the sensory component of RLS, and the description must be in "the child's own words" rather than by a parent or caretaker. For criterion A, children rarely use or understand the word "urge". Instead, they describe that their legs "need to", "have to", or "got to", move and use descriptors such as bugs, ants, weird/funny feelings, tingle, wiggly, and shaky. Younger children often use the word "kick" rather than "move" (e.g., "my legs want to kick"). Sitting in class, lying in bed, reading a book, and riding in a car are situations in which children report the onset or worsening of symptoms. Relief is typically achieved by moving around, walking, rubbing, kicking, or distraction. Perhaps due to prolonged periods of sitting in class, two-thirds of children and adolescents with RLS report daytime leg sensations. Because of this, diagnostic criterion A3 (worse in the evening/night) appears less consistent in children. A significant subset of children do not report worsening at evening/night, yet meet all other diagnostic criteria and have supportive features for RLS, including a positive family history. Developmentally-normal children aged six years or older can often report detailed, adequate descriptors for RLS symptoms. For children who are developmentally delayed or too young to adequately describe RLS sensations, a PLMD diagnosis may be the initial diagnosis, with complete RLS symptomatology evident over time. Diagnosis by observational techniques has been suggested but not yet validated.

Four specific domains affected in pediatric RLS are sleep, daily activities, mood, and energy/vitality. Difficulties with sleep onset, sleep maintenance, and sleep quality are common. The negative influence of RLS on waking activities includes academic impact due to disruption of schoolwork, homework, and ability to concentrate. As previously noted, there is a strong association between pediatric RLS and attention-deficit disorders.

Because pediatric RLS is highly familial, the presence of RLS in a first-degree relative helps to increase diagnostic certainty in childhood RLS. Similarly, the presence of PLMS or a history of PLMD is quite helpful in supporting an RLS diagnosis in children. As noted above, pediatric RLS is comorbid with ADHD in about one-fourth of cases, and, as in adults, higher rates of anxiety and depressive symptoms are found. RLS is common in pediatric patients with chronic kidney disease.

Prevalence rates of RLS increase with age until late adulthood then stabilize or decrease slightly in the elderly. Anxiety, mood disorders, and reduced QoL measures remain strongly associated with RLS in the elderly. Diagnostic criteria for RLS in the cognitive-impaired elderly have been suggested but not validated.

### *Pathology and Pathophysiology*

There is substantial literature demonstrating physiologic abnormalities in RLS, but a comprehensive understanding remains elusive. Brain iron deficiency, central nervous system dopamine regulation, and genetics appear to be primary factors in the pathophysiology of RLS. Iron is an essential element in brain dopamine production and synaptic density, as well as in myelin synthesis and energy production. A connection between RLS and low brain iron is supported by autopsy data, MRI, brain sonography, and cerebrospinal fluid analysis. Evidence for central nervous system dopaminergic system involvement comes mainly from multiple randomized clinical trials that have clearly demonstrated the effectiveness of dopaminergic drugs for RLS and PLMS. Despite clinical response to dopaminergics, there is no evidence of overt dopamine deficiency, and some data suggests increased dopamine turnover. Several other neurotransmitter/neuromodulator systems, including histamine, adenosine, glutamate, and opioid, are also implicated. The involvement of diencephalic spinal dopaminergic tracts is hypothesized and modeled, although the neuroanatomy is not established. Functional MRI demonstrates altered activity in several areas (medulla, cerebellum, and thalamus) as well as altered brain system connectivity. Numerous gene associations provide specific clues but have not yet coalesced into a unified understanding of RLS physiology.

### *Objective Findings*

Although polysomnography is not routinely indicated in the evaluation of RLS, polysomnographic studies demonstrate significant objective sleep abnormalities in RLS. The most consistent findings are increased latency to persistent sleep and a higher arousal index. PLMS  $\geq 5$ /hour occur in 70% to 80% of adults with RLS on single-night testing but in  $> 90\%$  when multiple nights are sampled. In adult RLS, PLMS are more prominent during the first half of the night and vary in frequency from night to night. About one-third of PLMS are associated with cortical arousals, and most have associated autonomic arousals. PLMS arousals can contribute to the primary RLS morbidity of sleep disturbance. Furthermore, RLS sensory symptoms impair return to sleep and thereby result in more prolonged awakening.

Approximately 70% of children with RLS demonstrate PLMS  $\geq$  5/hour on a single night and nearly 90% when multiple nights are sampled. PLMS  $\geq$  5/hour are uncommon in pediatric normative samples. However, analysis of PLMS over the lifespan has shown that leg movements in young children with RLS have low periodicity and do not approach the periodicity of adults until the adolescent years.

The Suggested Immobilization Test (SIT) evaluates PLMW and related sensory components of RLS during resting wakefulness. A standard polysomnographic recording without respiratory measures is used for one hour before the usual bedtime while the subject sits comfortably awake and upright in bed with the legs outstretched. A finding of more than 40 PLMW/hour supports an RLS diagnosis.

### *Differential Diagnosis*

The differentiation of RLS from other conditions that may have characteristics of RLS is essential because approximately 40% of individuals without RLS will report some urge or need to move the legs while at rest. Fulfilling diagnostic criteria A2 (better with movement) and A3 (worse in the evening/night) improves specificity for an RLS diagnosis to only about 70%, based on studies that have used structured diagnostic interviews. However, differentiating RLS from *leg cramps* and *positional discomfort* improves specificity to 94%, emphasizing the importance of differential diagnosis.

**Leg cramps, positional discomfort, arthralgias/arthritis, myalgias, leg edema, peripheral neuropathy, radiculopathy, and habitual foot tapping** are the most important “mimics” of RLS. Sustained painful muscle contraction (cramps), relief with a single postural shift (positional discomfort), limitation to joints (arthritis), soreness to palpation (myalgias), exclusively superficial paresthesia (neuropathy), and abnormalities on physical examination are not characteristic of RLS.

**Neuroleptic-induced akathisia, myelopathy, symptomatic venous insufficiency, peripheral artery disease, eczema, orthopedic problems, painful legs and moving toes, and anxiety-induced restlessness** are less common conditions that must be distinguished from RLS. Neuroleptic-induced akathisia differs from RLS in that akathisia is associated with the need to move the entire body and occurs in association with the use of dopamine-receptor antagonists. Painful legs and moving toes have predominate pain and neither a clear circadian pattern nor an urge to move.

**Pain** involving the legs occurs with numerous conditions, including arthritis, vascular problems, sports/orthopedic injuries, and neuropathy. Pain can have a nocturnal presentation and may be worse at rest, but improvement with movement does not occur or requires more than a simple leg movement. If present, the urge to move usually stems from awareness that movement produces relief rather than the strong primary urgency to move felt with RLS. However, the presence of pain does not exclude a diagnosis of RLS because about 50% of patients with RLS report their symptoms as painful.

Although it is essential that RLS symptoms not be attributable solely to one of these mimics, any of these mimics can occur in an individual who also has RLS. For example, some subjects may have both RLS and

leg cramps. Therefore, when the diagnosis of RLS is uncertain, evaluation for the supportive features such as the presence of PLMS or a family history of RLS may be helpful. In addition, validated diagnostic interviews that include differential diagnosis for RLS are available. These demonstrate sensitivity and specificity of > 90%.

## **Pediatric RLS**

**Restless sleep disorder** is a recently proposed condition with consensus criteria defined for ages 6-18. The disorder is characterized by restless sleep, observed large body movements during sleep, and video-polysomnographic documentation of five or more large body movements/hour. A true urge to move the legs is absent. There is no distinct pathology for this but anecdotal improvement with iron supplementation suggests some relationship to RLS.

The differential diagnosis of pediatric RLS also includes *positional discomfort, sore leg muscles, joint/tendon injury, and bruises*, all of which are common mimics. RLS is also frequently misdiagnosed as “growing pains.”

## *Unresolved Issues and Further Directions*

The diagnosis of RLS relies on the subjective report of sensory symptoms that lie outside the range of common sensory experience. Many patients have difficulty describing the sensations. Further studies of the biological bases for RLS may lead to better classification of RLS and possibly to objective tests for diagnosis. Investigations of the role of Iron, dopamine, and genetics hold particular promise. The diagnostic standards and severity assessment for children and cognitively impaired adults require further development. Clarification of the natural course and potential exacerbating factors is needed. A better understanding of RLS comorbid with conditions such as mood disorders and attention-deficit/hyperactivity disorder might improve outcomes in those disorders. Further evaluation of long-term complications is important, including clarifying associations with hypertension, cardiovascular disease, and stroke.

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## Periodic Limb Movement Disorder

ICD-9-CM code: 327.51

ICD-10-CM code: G47.61

### Alternate Names

Periodic leg movement disorder, periodic movement disorder of sleep, sleep myoclonus syndrome, nocturnal myoclonus syndrome.

### Diagnostic Criteria

Criteria A-D must be met

- A. Polysomnography demonstrates periodic limb movements during sleep (PLMS), as defined in the latest version of the American Academy of Sleep Medicine (AASM) Manual for the Scoring of Sleep and Associated Events.
- B. The frequency is > 5/hour in children or > 15/hour in adults.<sup>1</sup>
- C. The PLMS cause clinically significant sleep disturbance or impairment in mental, physical, social, occupational, educational, behavioral, or other important areas of functioning.<sup>2,3,4</sup>
- D. The PLMS and the symptoms are not better explained by another current sleep disorder, medical disorder, or mental disorder (e.g., PLMS occurring with apneas, hypopneas, and respiratory effort-related arousals (RERAs) should not be scored).<sup>5,6</sup>

### Notes

1. The PLMS Index must be interpreted in the context of a patient's sleep-related complaint. In adults, normative values greater than five per hour are reported in studies that did not exclude respiratory effort-related arousals (RERAs) identified with sensitive respiratory monitoring and other causes for PLMS. Data suggest a partial overlap of PLMS Index values between symptomatic and asymptomatic individuals, emphasizing the importance of clinical context over an absolute cutoff value.
2. If PLMS are present without clinical sleep disturbance or daytime impairment, the criteria for a diagnosis of PLMD are not met. Instead, the PLMS should be noted as a polysomnographic finding.
3. The causal relationship between PLMS and symptoms may be difficult to prove. However, elements that can support a cause-and-effect relationship between PLMS and symptoms include 1) improvement in symptoms after drug suppression of PLMS; 2) a positive correlation between PLMS index and symptoms over several recording nights; 3) a strong association between PLMS and cortical arousals and, possibly, autonomic activations.
4. The presence of insomnia or hypersomnia with PLMS is not sufficient to establish the diagnosis of PLMD. Studies have shown that in most cases, the cause of the accompanying insomnia or

hypersomnia is something other than the PLMS. Therefore, to establish the diagnosis of PLMD, it is essential to establish a reasonable cause-and-effect relationship between the insomnia or hypersomnia and the PLMS. This requires that other causes of insomnia such as anxiety or other causes of hypersomnia such as obstructive sleep apnea or narcolepsy be ruled out. PLMS are common, but PLMD is thought to be rare in adults.

5. PLMD cannot be diagnosed in the context of RLS, narcolepsy, untreated obstructive sleep apnea, or REM sleep behavior disorder. PLMS occur commonly in these conditions, but the sleep complaint is more readily ascribed to the accompanying disorder. The diagnosis of RLS takes precedence over that of PLMD when potentially sleep-disrupting PLMS occur in the context of RLS. In such cases, the diagnosis of RLS is made, and the PLMS are noted as an accompanying finding.
6. When it is reasonably certain that the PLMS have been induced by medication and full criteria for PLMD are met, the more specific diagnosis of PLMD should be used, rather than sleep-related movement disorder due to a medication or substance.

### *Essential Features*

PLMD is characterized by periodic episodes of repetitive, stereotyped limb movements during sleep (PLMS), in conjunction with clinical sleep disturbance or daytime impairment that cannot be accounted for by another primary sleep disorder or other etiology. As only a limited number of studies have focused on "pure" PLMD, a significant portion of the available knowledge on PLMS comes from studies focused on PLMS in the context of restless legs syndrome (RLS).

PLMS occur most frequently in the lower extremities. They typically involve an extension of the big toe, often combined with partial flexion of the ankle, the knee, and sometimes, the hip. Similar movements can occur in the upper limbs. Individual movements may be associated with an autonomic arousal, a cortical arousal, or an awakening. Typically, the patient is unaware of the limb movements or their possible impact on sleep stability. A cortical or autonomic arousal may precede, coincide with, or follow the limb movement or occur in a continued series without a limb movement. The latter is sometimes described as "missing PLM." A clinical history of sleep onset problems, sleep maintenance problems, or unrefreshing sleep attributable to the PLMS is necessary to diagnose PLMD. These symptoms have most consistently been associated with PLMS, and the presence of these clinical symptoms differentiates PLMD from asymptomatic PLMS. Although excessive daytime sleepiness has been reported with PLMD in the past, more recent data do not find significantly elevated Epworth Sleepiness Scale scores or Multiple Sleep Latency Test (MSLT) values in subjects with PLMS. Therefore, symptoms of fatigue, unrefreshing sleep, and daytime impairment may be elicited rather than sleepiness itself. If the only complaint is sleep disruption for the bed partner, then PLMD should not be diagnosed, but the bed partner's sleep disturbance can be noted.

The PLMS index should exceed 15 per hour in adult cases to diagnose PLMD. At frequencies > 15 per hour, there is a significant increase in sleep disturbance symptoms in adults. In children, an index of > 5 per hour is required. This criterion is based on substantial normative data in children.

The PLMS and the symptoms of sleep disturbance or nonrestorative sleep should not be better explained by another etiology, especially RLS, REM sleep behavior disorder (RBD), or narcolepsy. Research studies indicate that five or more PLMS per hour occur in 80% to 90% of patients with RLS, in about 70% with RBD, and 45% to 65% with narcolepsy. If significant daytime sleepiness and PLMS are present, a diagnosis of narcolepsy should be considered. PLMD should not be diagnosed when the criteria for one of these three disorders are met. However, the primary disorder “with PLMS” can be specified (e.g., “RLS with PLMS”).

A sensitive technique, such as pressure transducer airflow monitoring, should be used to monitor breathing during polysomnography to identify or exclude sleep-related breathing disorders (SRBDs) associated with PLMS. If an SRBD is noted and PLMS and unexplained sleep disturbance persist despite adequate treatment of the SRBD, a separate diagnosis of PLMD may be considered. Ideally, polysomnography for the diagnosis of PLMD should be performed after the biological effect of a medication or substance, such as an antidepressant known to induce or aggravate PLMS, has ended.

### *Associated Features*

Higher rates of mood disorders, anxiety, attention deficits, oppositional behaviors, and parasomnias have been reported in some studies of patients with PLMD. In children with PLMD, a family history of RLS is common. A sustained clinical response to dopaminergic therapy is supportive of the diagnosis of PLMD. Although PLMD symptoms may be responsive to benzodiazepines, benzodiazepine responsiveness is not supportive of the diagnosis due to the nonspecific effect of benzodiazepines on sleep.

PLMS can be severe and even violent in some individuals, simulating or triggering abnormal sleep behaviors and unpleasant dream recall. In such cases, a causal relationship between PLMS, sleep disruption, and the efficacy of dopamine-agonists is more evident.

### *Clinical and Pathophysiological Subtypes*

Not applicable or known.

### *Demographics*

Although PLMD is thought to be rare, the exact prevalence is not known. PLMD has been reported in both children and adults. PLMS >5/hour are very uncommon in children without significant comorbidities or medication use, but the frequency increases progressively with age. The population prevalence of PLMS

>15/hour has been estimated at 7.6% in 18- to 65-year-olds, at 28% in 35- to 75-year-olds (31.3% in men and 26.0% in women), and up to 60% in those older than 65 years.

Around 4.5% of the total population with PLMS > 15/hour also report sleep disturbance or excessive sleepiness. However, RLS and medication-induced PLMS were not exclusionary criteria in the study population, suggesting much lower rates for PLMD. The increase in PLMS with age may occur as a partial expression of familial or genetic factors associated with RLS. This observation is based on data that show very little increase in PLMS with age when individuals who have RLS or first-degree relatives with RLS are excluded. PLMS are less common in black adults and children than in whites. In contrast to RLS, PLMS are more frequent in males than in females, while no sex difference has been described for PLMD.

### *Predisposing and Precipitating Factors*

A positive family history of RLS confers increased risk for PLMS. The genetic variants noted below may be a mediator of this risk. Several medications may precipitate or aggravate PLMS. Selective serotonin/norepinephrine reuptake inhibitor antidepressants, tricyclic antidepressants, lithium, and dopamine receptor antagonists have most often been associated with PLMS. A higher frequency of PLMS has been described in children taking anti-seizure medication.

Low brain iron, as reflected by serum ferritin level, may worsen PLMS in RLS via the role of iron in dopamine receptor function. However, in the absence of RLS, a clear relationship between ferritin and PLMD has not been established.

Increased rates of PLMS are reported in multiple system atrophy, dopa-responsive dystonia, sleep-related eating disorder, spinal cord injury, end-stage renal disease, congestive heart failure, Parkinson's disease, sickle cell disease, posttraumatic stress disorder, autism spectrum disorder, Williams syndrome, sleep bruxism, and multiple sclerosis. Dopaminergic impairment and diminished inhibition of the central pattern generator for PLMS have been proposed as common factors linking various disorders and PLMS.

### *Familial Patterns*

The familial pattern of PLMD has not been studied in detail. Families with RLS include first-degree relatives without RLS but with increased rates of PLMS or PLMD, raising the possibility that PLMD is an attenuated manifestation or a precursor to RLS. Linkage analysis in large family cohorts showed that some individuals had PLMS without RLS and that these subjects could develop RLS later in their life. The gene variants *BTBD9* and *MEIS1*, found in genome-wide studies of RLS, appear to influence the expression of PLMS.

### *Onset, Course, and Complications*

Although the typical age of onset is unknown, PLMD occurs in both children and adults, with onset as early as infancy. The natural history is not described in detail, but some pediatric cases of PLMD progress to RLS. Incidence and remission rates are unknown. Impaired performance in a simulated driving task has been reported in patients with PLMD. Increased PLMS are associated with a higher risk of hypertension, while the relative risk for cardiovascular disease, stroke, and mortality is still controversial. PLMS-related overactivity of the sympathetic nervous system and repetitive PLMS-related blood pressure and heart rate fluctuations over time are postulated to be a potential mechanism for these associations.

### *Developmental Issues*

Given the low background rates of PLMS in children, PLMD has emerged as a meaningful diagnostic category in pediatric sleep medicine. Pediatric PLMD has significant clinical and polysomnographic correlates that are comparable in severity to pediatric OSA. However, PLMS and PLMD normative data remain sparse for children younger than two years. In children, PLMS are less frequent than in adults and occur with a lower level of periodicity. A typical periodicity with an inter-movement interval around 20-30 seconds tends to appear later in life, usually after age 15.

In the elderly, frequent occurrence of other conditions that can account for sleep disturbance and fatigue makes application of PLMD criteria difficult, even though PLMS are very common.

### *Pathology and Pathophysiology*

Dopaminergic impairment is implicated in the pathophysiology of PLMS and PLMD. In addition, the study of PLMS in children and in individuals with RLS suggests genetic diathesis and iron status as factors. Cyclic alternating pattern, a marker of nonrestorative sleep, is increased in individuals with PLMS and may influence the periodicity of PLMS. Cortical arousals can precede, coincide with, or follow PLMS, indicating that PLMS do not cause the arousals. PLMS can be dissociated from arousals pharmacologically, suggesting an indirect relation, possibly mediated by a central generator. In addition, typical PLMS suppression by dopamine agonists has been documented in patients with complete transverse spinal cord damage. This observation suggests the presence of a spinal cord generator of PLMS under the influence of the arousal and autonomic systems. This, in turn, may indicate the existence of different generators that show a high tendency to synchronize each other. The autonomic arousals associated with PLMS are characterized by significant heart rate and blood pressure surges, a mechanism that may explain the possible increased cardiovascular and cerebrovascular disease risk.

### *Objective Findings*

The recording of both tibialis anterior muscles by surface electrodes during polysomnography is required to diagnose PLMS and thus PLMD. PLMS are recognized and scored based on standard criteria, as defined

in the latest version of the American Academy of Sleep Medicine (AASM) Manual for the Scoring of Sleep and Associated Events. However, additional features such as periodicity, inter-movement interval distribution, and time course across the night may also be reported to better characterize the time structure of PLMS. PLMS typically occur in discrete episodes that last from a few minutes to an hour. The tibialis anterior electromyogram (EMG) shows repetitive contractions, each lasting 0.5 to 10 seconds. The movements may affect one or, more typically, both of the lower limbs, but not necessarily in a symmetric or simultaneous pattern. PLMS can appear immediately with the onset of stage N1 sleep, are frequent during stage N2 sleep, and decrease in frequency in stages N3 and REM sleep. Movements of the upper limbs may be sampled, if clinically indicated, and recorded from the forearm compartment muscles, particularly from the flexor digitorum superficialis or the extensor digitorum communis. The variance of the periodicity of PLMS is greater in children and adolescents than in adults or the elderly.

Self-reports, bed partner observations, or parental reports for children do not demonstrate sufficient specificity or sensitivity to replace objective testing for PLMS.

PLMS may be associated with electroencephalographic (cortical) arousals or with awakenings. Autonomic arousals—measured by a change in heart rate, blood pressure, or pulse transit time—are more frequent than cortical arousals. In some cases, periodic arousals may persist even though the PLMS have subsided. The arousals are typically more difficult to measure than are the PLMS, and their clinical significance is a topic of ongoing debate. As with obstructive sleep apnea, the associated cortical arousal index has not proven more useful than the PLMS index in making clinical decisions.

Although some patients with PLMD report subjective excessive daytime sleepiness, mean sleep latency measured by MSLT is not consistently abnormal and does not correlate with the PLMS cortical arousal index.

The movements should be reported as an index of total sleep time, called the PLMS index. The PLMS index is the number of periodic limb movements per hour of total sleep time, as determined by polysomnography. The PLMS arousal index is the number of PLMS associated with a cortical arousal, expressed per hour of total sleep time.

Leg actigraphy has been validated against PSG to evaluate PLMS and provides a methodology to assess PLMS in large populations and night-to-night variability.

### *Differential Diagnosis*

**Other sleep disorders** as described in the essential features section, PLMD is a diagnosis of exclusion. It is important to differentiate it from other conditions in which PLMS occur, particularly *RLS*, *RBD*, *narcolepsy*, and *SRBDs*. In RBD, contrary to the usual sleep stage distribution, PLMS occur more frequently during REM than in non-rapid eye movement (NREM) sleep and often are not associated with cortical arousals during NREM sleep. In narcolepsy, PLMS do not follow a clear declining frequency trend across the night, as is

usually seen in RLS or PLMD. In both narcolepsy and RBD, the degree of periodicity of PLMS is generally less than in RLS or PLMD.

**Other sleep-related movement** care must be taken to discriminate PLMS from other movements such as *large body movements or change in body position, stretching of a limb, myoclonic jerks, obstructive sleep apnea-related arousal, or muscle cramps*. PLMS are longer in duration than myoclonic jerks, which, by definition, are typically 50 to 150 milliseconds long. Movements associated with respiratory events, *hypnagogic foot tremor, or alternating leg muscle activation (ALMA)* during sleep should not be included in the PLMS index. *Sleep starts (hypnic jerks)* need to be differentiated from PLMS. They are typically limited to the transition from wakefulness to sleep, are not periodic, and are briefer (20 to 100 milliseconds) than PLMS. Normal *phasic REM activity* is limited to REM sleep, typically occurs in 5- to 15-second clusters and is usually associated with bursts of REM. Phasic REM EMG twitches are more variable in duration and do not have the periodicity of PLMS. *Fragmentary myoclonus* is characterized by EMG activity that is briefer (75 to 150 milliseconds), more variable in duration, less periodic than PLMS, and has little or no associated visible movement. PLMS must also be differentiated from movements associated with *nocturnal epileptic seizures and myoclonic epilepsy* and from various forms of myoclonus seen while awake, such as in *Alzheimer's disease, Creutzfeldt-Jakob disease, and other neuropathologic conditions*. However, in these disorders, the involuntary movements are pronounced during the daytime, often do not disappear with activity, are prominent in the arms and other body parts in addition to the legs, and do not display the periodicity seen with PLMS.

**Other insomnia and hypersomnolence conditions** when insomnia or hypersomnolence symptoms are present, other conditions that may explain these symptoms must be considered. These include most commonly, *chronic insomnia disorder, sleep-related breathing disorders, and primary hypersomnolence conditions*.

### *Unresolved Issues and Further Directions*

There has been controversy over the clinical significance of PLMS. To date, the interpretation of most studies has been confounded by multiple factors that include: imprecise diagnostic criteria, different scoring criteria and methodological assessment; confusion between PLMS and PLMD; inadequate monitoring for subtle SRBDs; a lack of consideration of medications known to induce, worsen, or suppress PLMS; and inadequate measurement of the known night-to-night variability of PLMS. More sensitive respiratory monitoring techniques for polysomnography and the use of actigraphy over several nights should help address a number of these issues. A key issue in the diagnosis of PLMD remains the demonstration of a causal role of PLMS for day and nighttime symptoms. A clear relationship between the severity of PLMS and symptoms, and an evident improvement of symptoms with dopamine agonists, may support the causal link. The relationship of associated arousals to clinical symptoms is yet to be determined, but the appreciation of autonomic arousals, in addition to cortical arousals, may be critical. PLMS may be a measurable marker of unstable sleep, related to genetic diathesis and dopaminergic impairment.

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## Nocturnal Muscle Cramps

ICD-9-CM code: 327.52

ICD-10-CM code: G47.62

### *Alternate names*

Leg cramps, “charley horse,” nocturnal leg cramps.

### *Diagnostic Criteria*

Criteria A-C must be met

- A. A painful sensation in a muscle, associated with sudden, involuntary muscle hardness or tightness, indicating a strong muscle contraction.
- B. The painful muscle contractions occur during the time in bed, although they may arise from either wakefulness or sleep.
- C. The pain can be relieved by forceful stretching of the affected muscles, thus releasing the contraction.

### *Essential Features*

Nocturnal muscle cramps are painful sensations caused by sudden and intense involuntary contractions of muscles or muscle groups during which there is muscle spasm and hardness for seconds to minutes. These painful sensations are usually in the calf or small muscles of the foot but can occur in any striated muscle. Nocturnal muscle cramps occur during the time in bed and may arise from either wakefulness or sleep.

Nocturnal muscle cramps usually start abruptly but may, in some cases, be preceded by a less painful warning sensation. The muscle contractions last for a few seconds up to several minutes and then remit spontaneously. The frequency of nocturnal muscle cramps varies considerably from less than yearly to multiple episodes every night.

The cramps can be relieved by strongly stretching the affected muscle and sometimes also by local massage, application of heat, or movement of the affected limb. The muscle cramps can be present primarily during the daytime.

### *Associated Features*

The muscle cramp affects sleep. The pain from the cramp itself and the activities used to relieve it commonly disturb sleep onset or cause an awakening from sleep. Tenderness and discomfort in the muscle may persist for several hours after the cramping. Persistent discomfort after the cramping episode often delays subsequent return to sleep.

## *Clinical and Pathophysiological Subtypes*

Nocturnal muscle cramps are either idiopathic or secondary to other medical conditions. Nevertheless, there are no indications of significant differences in the clinical features of the disorder related to the cause. Exercise-associated cramps occur during or after strenuous muscle use. Many people report cramps after exercise and in the evening. There is no discernable physiological difference between nocturnal cramps and exercise-associated cramps.

## *Demographics*

Nocturnal muscle cramps are common. It is likely that nearly every adult older than 50 years has experienced cramps at least once. Both the prevalence and the frequency of these events increase with age. About 7% of children and adolescents report cramps compared with 33-56% in those over 60. Prevalence also increases from age 50 to 80, and cramps occurring every night have been reported in 6% of adults older than 60 years. Studies report either no prevalence difference between sexes or a modestly higher rate in females.

## *Predisposing and Precipitating Factors*

Precipitating factors include pregnancy, liver disease, renal disease, amyotrophic lateral sclerosis, cramp fasciculation syndrome, neuropathy, and peripheral vascular disease, with less robust or mixed data associating diabetes mellitus, sedentary lifestyle, alcohol consumption, hypokalemia, hypocalcemia, hypomagnesemia, and other metabolic disorders. Cramps, in general, can be associated with prior vigorous exercise, prolonged standing at work, dehydration, fluid and electrolyte disturbances, endocrine disorders, neuromuscular disorders, and disorders of reduced mobility. Medications associated with sleep-related leg cramps include oral contraceptives, intravenous iron sucrose, teriparatide, raloxifene, thiazide diuretics, long-acting  $\beta$ -agonists, and statins. However, actual case-control data are lacking or non-confirmatory. Nocturnal muscle cramps occur in about 40% of pregnant women and generally resolve after delivery.

## *Familial Pattern*

Not known.

## *Onset, Course and Complications*

Nocturnal muscle cramps have not been reported in infancy nor in children younger than eight years. The peak onset is usually in adulthood, but the condition may occur for the first time in old age, and overall

prevalence rates increase into the 8<sup>th</sup> decade. The natural history of nocturnal muscle cramps is not well understood. Many patients describe a waxing and waning course of many years' duration. Complications include muscle tenderness, insomnia, and occasional daytime fatigue due to interrupted sleep. No marked mental or social dysfunction has been described due to nocturnal muscle cramps alone.

### *Developmental Issues*

Nocturnal muscle cramps are less prevalent in children than adults but impact 6% of children. As noted, the prevalence rises significantly with aging.

### *Pathology and Pathophysiology*

Many nocturnal muscle cramps appear to be idiopathic. Cramp physiology is poorly understood, but the preponderance of data suggests cramps originate in the motor neuron. Electrophysiologic recordings show that the cramps typically start with spontaneous firing of anterior horn cells in the spinal cord followed by motor unit discharges at 50 – 300 Hz (considerably higher than with voluntary muscle contractions). This causes muscle motor unit potentials of 30-90 Hz that rapidly diminish. Cramps are abolished with nerve blocks. Intrinsic afferent inhibition (possibly mediated by GABAergic spinal interneurons) is reduced, and there is evidence of increased efferent stimulation. Thresholds for artificial cramps elicited by rapid electrical stimulation are lower in people who have cramps and following a recent cramp. The pain may result from local metabolite accumulations or local ischemia.

Since cramps usually begin when the muscle is contracted, tendon shortening due to age or lack of stretching exercise may contribute to nocturnal muscle cramps. Stretching the affected muscles is thought to help prevent or reduce their occurrence.

### *Objective Findings*

Polysomnographic studies of patients with chronic nocturnal muscle cramps reveal non-periodic bursts of EMG activity in leads near the affected muscle. Episodes arise from sleep or awake without any specific preceding physiologic changes during sleep.

### *Differential Diagnosis*

**Restless legs syndrome** is sometimes confused with nocturnal muscle cramps because both can present with leg discomfort during the sleep period, and RLS patients may complain of a cramping sensation. However, if patients meet the diagnostic criteria for RLS and do not describe an actual cramp or hardening of the muscle, the diagnosis should be RLS. Because leg cramps can mimic RLS and can loosely meet all the

criteria for RLS, the description of an actual spasm or hardening of the muscle is a critical differentiating factor. A leg cramp is also a much briefer event than the typical symptoms of RLS, which can persist for hours. However, RLS and leg cramps may sometimes occur in the same individual.

**Other movement disorders** *Dystonia* is patterned, usually action-induced, and often a very task-specific, involuntary movement that is more persistent but not necessarily painful. It occurs exclusively while awake. Dystonia can be focal, as in the case of neck muscles (torticollis), hand muscles (writer's cramp), or generalized, as in multiple genetic conditions or brain injury. Secondary dystonia from CNS injury often overlaps with spasticity and is usually persistent.

*Spasticity, parkinsonism, stiff person syndrome, tetany*, and other diseases of increased motor tone have persistent rather than episodic muscle contraction and are usually more diffuse. *Clonus*, seen in spastic conditions, consists of episodic jerking movements that resolve by flexing the knee and plantar flexing the ankle. *Myokymia* and *fasciculations* are typically not painful and involve only small muscle fascicles rather than the entire muscle. *Painful legs and moving toes* produce a more continuous and writhing movement compared to cramps.

**Other pain conditions** *Myalgias, muscular pain fasciculation syndrome, growing pains, neuropathic pain*, and *claudication* lack demonstrable muscle contraction.

### *Unresolved Issues and Further Directions*

Nocturnal muscle cramps are common and can affect sleep. Their association with other disorders and different medications complicates the acquisition of accurate epidemiological data and underestimates their effect on sleep and quality of life. Instruments to quantify the severity of the disorder and its impact are needed to adequately address clinical relevance, treatment, and potential occupational hazards. Effective therapies for nocturnal muscle cramps are not available. The prophylactic benefits of stretching exercises remain to be adequately validated.

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## Sleep-Related Bruxism

ICD-9-CM code: 327.53

ICD-10-CM code: G47.63

### Alternate Names

Nocturnal bruxism, tooth grinding, tooth clenching.

### Diagnostic Criteria

Criteria A and B must be met.

- A. The presence of repetitive jaw-muscle activity characterized by grinding or clenching of the teeth in sleep.
- B. The presence of one or more of the following clinical symptoms or signs consistent with the above reports of tooth grinding or clenching during sleep:
  1. Abnormal tooth wear
  2. Transient morning jaw muscle pain or fatigue, or temporal headache.

## Notes

1. Tooth grinding may occur with or without awareness of waking with jaw clenching.
2. The frequency of jaw muscle contractions during sleep can be quantified as an index per hour of rhythmic masticatory muscle activity (RMMA).
3. Although polysomnography (PSG) is not required to diagnose bruxism in otherwise healthy individuals, when performed, masseter EMG and audio-video recording increase diagnostic reliability. Scoring definitions for bruxism are included in the latest version of the AASM Manual for Scoring of Sleep and Associated Events.
4. The RMMA Index must be interpreted in the context of a patient's subjective complaint.
5. If RMMA is present without clinical signs and symptoms, the RMMA can be noted as a polysomnographic finding, but criteria are not met for a diagnosis of sleep-related bruxism (SRB).

## *Essential Features*

Bruxism is defined as repetitive jaw-muscle activity characterized by grinding of the teeth or clenching. Bruxism is divided into two distinct circadian manifestations: sleep-related bruxism (SRB) and awake bruxism. In sleep, jaw muscle contractions may be repeated frequently and are termed rhythmic masticatory muscle activity (RMMA). These contractions can take two forms on electromyographic traces: a series of repetitive activity (phasic muscle contractions) or isolated sustained jaw clenching (tonic contractions), or a combination of both (mixed). More phasic bursts are observed in association with tooth grinding events. Longer duration, tonic muscle contraction is associated with self-reports of jaw muscles fatigue or tenderness in the morning. Very brief myoclonic bursts (less than 250 milliseconds) may be observed in otherwise healthy individuals with sleep bruxism. These contractions during sleep may or may not produce actual tooth-grinding sounds.

SRB can lead to abnormal tooth wear, tooth pain, tooth fracture, temporomandibular pain, joint noise, jaw lock, or headache. Headaches are frequently reported by both adults and children with this disorder. The headache usually involves the temporal regions and has the characteristics of a tension headache. It is experienced either in the morning (more frequently) or during the day (with awake bruxism).

There is high individual variability in the intensity and duration of bruxism. In the most severe cases, hundreds of events can occur during a night of sleep. Individuals with a mild to moderate EMG RMMA frequency index (2 to 4 RMMA episodes/hour of sleep) seem to have a higher risk of reporting painful jaw muscles upon awakening (OR 3.9) and masticatory muscle fatigue (OR 5.1) compared to individuals with high indices (> 4 RMMA episodes/hour of sleep).

The condition is typically brought to dental or medical attention because of the tooth damage, pain, morning headache, or sounds disturbing to the bed partner.

### *Associated Features*

Additional symptoms include a variety of unpleasant muscle and tooth sensations, limitation of jaw movements, and orofacial pain. Buccal lacerations can also occur. SRB may induce these symptoms, but the causality may not be apparent to the affected individual, and diagnostic discrimination is weak. SRB may also result in sleep disruption. In addition, the sounds made by the friction of the teeth are usually perceived as unpleasant and can be loud and disturbing to those nearby. As a result, the disruption may affect not only the patient but also the bed partner.

Studies have inconsistently reported associations between stress/anxiety and SRB in adults, but this may apply only to a subset of affected individuals. Causality between stress and SRB has never been clearly established.

### *Clinical and Pathophysiological Subtypes*

SRB without identifiable cause or comorbidity is termed primary or idiopathic.

Secondary forms of SRB can be observed in many conditions. For example, both awake and sleep bruxism are reported in children with attention-deficit/hyperactivity disorder, cerebral palsy, and intellectual disability. In adults, awake and sleep bruxism may occur in association with the use of psychoactive medications, recreational drugs, and a variety of medical disorders (e.g., Parkinson's disease).

Jaw clenching occurs mainly during wakefulness (awake bruxism) but may reappear during the sleep period. Awake and sleep bruxism may coexist in the same individual. Recent evidence suggests that awake and sleep bruxism can be present in about 30% of patients with bruxism.

### *Demographics*

The prevalence of SRB, based on reports from parents or the sleep partner, is highest in childhood (approximately 14% to 17%) and then decreases over the life span. In the adolescent to young adult range, prevalence is in the 12% range. In young to middle-aged adults, it is approximately 8% and as low as 3% in older persons. The reported reduction in tooth grinding in the elderly probably overestimates the actual decline because edentulism, use of dentures, and changes in sleeping behaviors (i.e., sleeping alone) may influence reporting. Women tend to have a higher prevalence of self-reported combined awake and sleep bruxism, but this has not been confirmed by recording. Recent findings suggest that middle-aged women with confirmed sleep bruxism report more insomnia symptoms.

### *Predisposing and Precipitating Factors*

Predisposing factors include Type A personality. Individuals who are highly goal-directed or who characteristically maintain high vigilance may have an increased prevalence of the disorder.

Precipitating factors can include anxiety or stress related to current life events, tasks requiring high performance, and repetitive tasks with short deadlines. The use of cigarettes or caffeine in the hours before sleep also increases SRB incidence (probably due to the increased arousals and sleep instability).

The role of dental morphologic “defects” (occlusal interferences) remains controversial in the etiology of SRB. Tooth contacts do not usually set in motion a bruxism episode; they are usually late in the series of events occurring during SRB/tooth grinding. Hence, the evidence-based literature does not strongly support the causality link between tooth contact and SRB.

### *Familial Patterns*

SRB tends to occur in families; approximately 20% to 50% of affected individuals have at least one direct family member with a history of tooth grinding.

Genetic predisposition is plausible but still under investigation. Familial predisposition may be due to either environmental or shared genetic factors. Serotonin and dopamine genetic variants have been associated with awake, sleep, and combined awake and sleep bruxism risk.

### *Onset, Course, and Complications*

The onset of SRB may occur during childhood, adolescence, adulthood, or possibly in late life. It is difficult to establish the time of onset with precision because this is mainly based on the self-awareness of clenching or grinding and is subject to recall bias and the presence of a sleep partner. Parents have reported the onset of the disorder as soon as both upper and lower teeth have erupted. Secondary SRB may occur at any age but is more common in younger and middle-aged adults.

Even without a tooth grinding history or complaints, RMMA may be observed in normal sleepers (on average, one episode per hour of sleep) across the life span. However, jaw muscle contractions are more frequent and intense in individuals with SRB. These factors may contribute to secondary tooth damage, pain, and other symptoms.

Dental damage and abnormal tooth wear are the most frequent oral signs of the disorder. However, they are not direct proof of current SRB, and many contributing conditions (e.g., oral breathing, gastric reflux, OSA, and eating disorders such as bulimia) must be ruled out. In addition, there is a poor correlation between the severity of tooth damage and the frequency of RMMA.

SRB may lead to temporomandibular joint (TMJ) disorders (e.g., pain, joint sound [click], or jaw movement limitations) in some individuals with pre-existing risk factors for TMJ. However, there is little evidence to support a more general association. Transient morning orofacial pain or tenderness, including temporal headache, is not uncommon, as described above. Hypertrophy of the masseter and temporalis muscles can occur, but the diagnostic specificity of this finding for SRB is also weak.

The natural course of this sleep disorder is usually benign. Many individuals with SRB remain asymptomatic for most of their lives. Others can experience associated symptoms (i.e., pain) that may interfere with their quality of life or sleep and require treatment. Further diagnostic investigations and assessment are recommended if SRB is associated with other more severe sleep or medical disorders.

### *Developmental Issues*

SRB is frequently reported in childhood and probably decreases with age, although reliable longitudinal data are lacking. Childhood SRB appears to persist into adulthood in two-thirds of reported cases.

Conceptualizations of SRB in children vary. Some consider this a physiological oral parafunction while teeth are erupting or exfoliating, whereas others view this as a sleep disorder with many associated signs and symptoms. SRB, especially in children, has been associated with attention-deficit/hyperactivity disorder, parasomnias, SRBD, oral breathing, respiratory allergy, snoring, and many other psychological and medical conditions.

In adults, SRB may occur in association with insomnia, snoring/OSA, PLMS, movement disorders (e.g., Parkinson's disease or oral tardive dyskinesia), RBD, and dementia.

### *Pathology and Pathophysiology*

Most RMMA episodes during sleep (up to 80% in young and otherwise healthy individuals) occur with sleep arousals. RMMA-related episodes typically follow a clear arousal sequence, starting with increased sympathetic-cardiac activity and fast electroencephalographic (EEG) waves in the minutes to seconds preceding the onset of an RMMA episode. The jaw muscle contractions are then followed by or are concomitant with increased blood pressure and ventilation. RMMA episodes sometimes conclude with swallowing.

In most individuals with SRB, the frequency of sleep arousals is within the normal range. However, they may have an exaggerated response to ongoing sleep arousals. Individuals with the disorder show more cyclic alternating pattern (CAP), phase A3 (as described by the scoring and analysis of CAP during sleep), than controls, an expression of increased arousal pressure, and increased sleep instability. This increased sleep instability may represent a "permissive window" for the occurrence of RMMA during sleep.

## *Objective Findings*

Polysomnographic (PSG) monitoring of individuals with SRB, although not usually performed for routine clinical purposes, demonstrates increased masseter and temporalis muscle activity during sleep, as well as grinding sounds. Phasic and tonic bruxism episodes are scored according to the latest version of the American Academy of Sleep Medicine (AASM) Manual for the Scoring of Sleep and Associated Events. RMMA episodes can occur during all sleep stages but are most common in N1 and N2 (more than 80% of episodes), whereas fewer than 10% of RMMA episodes occur during REM sleep. However, SRB occurs predominantly in REM sleep in some individuals for reasons not well-understood. The night-to-night variability in episodes of audible tooth grinding sounds is large (greater than 50% coefficient of variation). In-lab polysomnographic recordings indicate that the corresponding variability in the frequency of RMMA is less (approximately 25%), although ambulatory recording has suggested somewhat higher RMMA variability. First-night effect on the RMMA index is present in both sleep laboratory and in-home recording environments.

Most SRB episodes are temporally associated with arousal and are preceded by signs of autonomic/cardiac activation (e.g., increased heart rate and blood pressure). Young and otherwise healthy individuals with this disorder appear to have otherwise normal sleep architecture.

In some cases, PSG may be indicated to demonstrate the disorder and to rule out associated respiratory disturbances, RBD, night terrors, faciomandibular myoclonus, or sleep-related epilepsy. For adults, the sensitivity of PSG in detecting SRB with higher RMMA frequency ( $\geq 4$  events/hour) is moderate to high. In individuals with lower RMMA frequency (2-4 events/hour), sensitivity may be low due to the night-to-night variability in RMMA and tooth grinding. In children, 2 RMMA/hour is considered high frequency.

Ambulatory home monitoring may be used for screening, diagnosis, and treatment outcome assessment. It is characterized by lower diagnostic specificity due to the absence of audiovisual recordings. Overestimation in RMMA frequency is expected due to concomitant nonspecific activities. A single outcome measure, such as EMG for RMMA, may not allow distinction from other sleep disorders (e.g., OSA, PLMS).

A minimum of one masseter muscle monitor, ideally with audiovisual recording, is required to record and score sleep-related bruxism activity (i.e., RMMA). Bilateral masseter and, optionally, temporalis muscle EMG recordings produce the greatest diagnostic specificity and sensitivity.

## *Differential Diagnosis*

The disorder seldom poses diagnostic problems if identified on PSG.

**Other oromandibular activity** *Snoring/sleep-related breathing disorders, faciomandibular myoclonus, RBD, abnormal swallowing, gastro-esophageal reflux, night terrors, confusional arousals, dyskinetic jaw movements persisting in sleep (dystonia, tremor, chorea, dyskinesia), and, rarely, sleep-related epilepsy* may be associated with oromandibular activity that must be differentiated from SRB.

**Oromandibular or faciomandibular myoclonus** has been observed in approximately 10% of individuals with severe SRB, but it can also occur without abnormally increased RMMA events. Unlike SRB, *faciomandibular myoclonus* consists of EMG bursts of brief duration (less than 250 milliseconds in length) in the facial muscles. These can occur either as isolated bursts or as a cluster of regularly or irregularly occurring brief bursts. A high index of sleep-related oromandibular myoclonus and RMMA during REM has been observed in idiopathic RBD patients.

*Tooth tapping* may occur without an identifiable cause or with REM sleep behavior disorder (RBD) and sleep epilepsy. Rhythmic jaw movements also have been reported in association with *partial complex or generalized seizure disorders*. Therefore, epilepsy must be considered in the differential diagnosis, although the presentation of epilepsy as relatively isolated SRB is rare.

### *Unresolved Issues and Further Directions*

The overall pathophysiology of idiopathic SRB is poorly understood.

Parental and adult self-reports of tooth grinding do not correlate well with polygraphic EMG home or sleep laboratory recordings. Variability over time may be a contributing factor to this.

The most accurate and clinically relevant SRB metrics for the identification and diagnosis of SRB remain to be identified. In addition, the lack of standardization in the literature is a recurrent issue.

Further work to distinguish the primary benign forms of SRB from those that are an epiphenomenon of other more severe sleep and medical disorders is necessary. This will require a better understanding of the clinical relevance of SRB comorbid with other health problems (e.g., anxiety, stress, sleepiness, attention-deficit/hyperactivity disorder, headache and orofacial pain/temporomandibular pain, snoring, sleep-related breathing disorder, insomnia, and RBD).

There is currently no solid evidence that patients with primary SRB are at increased risk of neurological or cardiovascular disorders; prospective risk assessments are required before any conclusion can be drawn. Investigation of genetic associations to SRB requires larger sample sizes and the employment of standardized and valid assessment tools. This approach will allow for the discrimination of RMMA from other oromandibular activities and identification of gene candidates specific for bruxism from those related to its comorbidities (e.g., anxiety, stress, insomnia, sleep-disordered breathing, cardiovascular conditions, or other related triggers of RMMA).

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## Sleep-Related Rhythmic Movement Disorder

*ICD-9-CM code: 327.59*

*ICD-10-CM code: G47.69*

### *Alternate Names*

Body rocking, head banging, head rolling, body rolling, jactatio capitis nocturna, jactatio corporis nocturna, rhythmie du sommeil.

### *Diagnostic Criteria*

Criteria A-D must be met

- A. The patient exhibits repetitive, stereotyped, and rhythmic motor behaviors involving large muscle groups.
- B. The movements are predominantly sleep-related, occurring near nap or bedtime, or when the individual appears drowsy or asleep.
- C. The behaviors result in a significant complaint as manifest by at least one of the following:<sup>1</sup>
  1. Interference with normal sleep.
  2. Significant impairment in daytime function.
  3. Self-inflicted bodily injury or likelihood of injury if preventive measures are not used.
- D. The rhythmic movements are not better explained by another movement disorder or epilepsy.

Notes

1. When there are no clinical consequences of the rhythmic movements, the rhythmic movements may be noted, but criteria for a diagnosis of rhythmic movement disorder are not met.

### *Essential Features*

Sleep-related rhythmic movement disorder (SRRMD) is characterized by repetitive, stereotyped, and rhythmic motor behaviors involving large muscle groups (not tremors) that occur predominantly during drowsiness or sleep. The occurrence of significant clinical consequences differentiates SRRMD from developmentally normal sleep-related movements.

SRRMD is typically seen in infants and children but may also occur in adults. The disorder comprises several subtypes (discussed below), including body rocking, head banging, head rolling, and other variants. Episodes often occur near sleep onset, although they may occur during any time of the night and even during quiet wakeful activities, such as listening to music or traveling in vehicles. The movement frequency can vary, but the rate is usually between 0.5 per second and two per second. Duration of the individual movement clusters also varies but generally is less than 15 minutes. Cessation of movements may occur following environmental disturbance or verbal intervention.

Sleep-related rhythmic movements are common in normal infants and children. Without evidence for significant consequences, the movements alone should not be considered a disorder. Sleep-related rhythmic movements should be regarded as a disorder only if the behaviors significantly interfere with normal sleep, cause significant impairment in daytime function, or result in self-inflicted bodily injury (or would result in injury if preventive measures are not used).

### *Associated Features*

When asked about event recall in the morning, children with sufficient language development typically report amnesia for the episodes. Adults may, on rare occasions, report a volitional component. The vast majority of infants and children with sleep-related rhythmic movements are otherwise developmentally and intellectually normal, as are most adolescents and adults.

Rhythmic humming or inarticulate sounds often accompany the body, head, or limb movements and may be quite loud.

### *Clinical and Pathophysiological Subtypes*

**Body Rocking** typically involves the entire body, with the individual on hands and knees. However, it may be limited to the torso, with the individual sitting.

**Head banging** The head is forcibly moved, striking an object. Head banging often occurs with the person prone, repeatedly lifting the head or entire upper torso and forcibly banging the head back down into the pillow or mattress. Alternately, the individual may sit with the back of the head against the headboard or wall, repeatedly banging the occiput. Combining head banging and body rocking, they may rock on hands and knees, banging the vertex or frontal region of the head into the headboard or wall. An atypical type of head banging has been described in which the head is punched or slapped.

**Head Rolling** The head is moved laterally, typically while the individual is supine. Head rolling consists of side-to-side head movements, usually with the individual supine.

**Other** Includes body rolling, leg rolling, and leg banging.

**Combined** Involves two or more of the individual types.

### *Demographics*

At nine months of age, 59% of all infants are reported to exhibit one or more of the following sleep-related rhythmic movements: body rocking (43%), head banging (22%), or head rolling (24%). At 18 months, the overall prevalence declines to 33%, and by five years, to only 5%. Most pediatric studies have found no sex difference.

Over 50 cases of SRRMD have been reported in adolescents and adults, with a male preponderance found in adults.

### *Predisposing and Precipitating Factors*

The soothing effect of vestibular stimulation has been proposed as the initiating factor in infants and toddlers. Environmental stress and lack of environmental stimulation have also been proposed as factors. One study found higher anxiety scores in children with body rocking than in controls. Efforts to self-stimulate may play a role, particularly in intellectually disabled, autistic, and emotionally disturbed children. Rhythmic movements have been postulated to be a calming technique employed by children to combat insomnia. In preschoolers, sleep-related rhythmic movements are associated with lower maternal sensitivity, higher maternal depressive symptoms, lower socioeconomic status, and higher risk for internalizing behaviors.

Rhythmic movements may be associated with RLS, OSA, narcolepsy, RBD, and ADHD. They may be employed as a conscious strategy to relieve the urge to move or the uncomfortable sensations associated with RLS. OSA-associated SRRMD often improves with positive airway pressure. Individuals with narcolepsy may initiate rhythmic movements to terminate episodes of sleep paralysis.

Stereotypic movements may be associated with an intellectual disability or autism spectrum disorder in older children or adults. However, in most of these cases, the movements are not predominantly sleep-related, and an additional diagnosis of SRRMD is not indicated.

### *Familial Patterns*

A familial pattern has been reported rarely, as has occurrence in monozygotic twins and triplets.

### *Onset, Course, and Complications*

The onset of sleep-related rhythmic movements is typically in early childhood. Body rocking has a mean age of onset of six months, head banging of nine months, and head rolling of ten months. The condition may rarely persist into adulthood or present at an older age following central nervous system trauma. Sleep-related rhythmic movements commonly resolve in the second or third year of life. Persistence at five years of age occurs in about 5% of children. Sleep-related movements rarely continue into adolescence and adulthood. Worsening or spontaneous onset in adults is very rare. In some adult cases, the chief concern is disturbance of the bed partner's sleep. Most adolescents and adults have only a single form of SRRMD, although some have two or more.

Head banging is the most disturbing form of the problem. Typical cases in infants and toddlers pose little risk of serious injury. However, vigorous rhythmic movements can produce loud noises when the patient hits the bed frame or when the bed bangs against the wall or floor. The noises can be very disturbing to other family members. Parental concern is common, and psychosocial consequences in the older individual can be distressing. It is important to discuss appropriate safety precautions with the patient's caretakers. Under extraordinary circumstances, particularly in the developmentally disabled, injury to soft tissues or bone has been reported.

## *Developmental Issues*

Because age-related factors are a critical dimension for SRRMD, developmental issues are discussed under Essential Features and other sections.

## *Pathology and Pathophysiology*

In infants and young children, rhythmic movements are hypothesized to promote motor development by stimulation of the vestibular system. The role of inhibitory control on the central motor pattern generator has also been suggested as a physiologic mechanism to explain both pediatric and adult forms of sleep-related rhythmic movements.

## *Objective Findings*

Polysomnographic scoring rules for sleep-related rhythmic movements are defined in the AASM Manual for the Scoring of Sleep and Associated Events. Video-polysomnographic studies have shown that rhythmic movements can occur during wakefulness and in all sleep stages. However, SRRM occurs most often in association with stages N1 and N2 sleep; 46% occur while falling asleep or during NREM sleep; 30% during both NREM and REM sleep; and 24% only during REM sleep. The exclusively REM-related rhythmic movements occur more frequently in adults.

Polysomnographic studies in clinical cases of SRRMD have shown disturbed nighttime sleep characterized by altered sleep continuity, low sleep efficiency, and increased wake time after sleep onset. Most EEG studies have shown normal activity during and between episodes of rhythmic behavior.

## *Differential Diagnosis*

**Other repetitive movements** SRRMD must be distinguished from movements involving restricted small muscle groups, such as *sleep-related bruxism*, *thumb sucking*, and *rhythmic sucking* of a pacifier or the lips. In addition, other specifically defined rhythmic movements of sleep, such as *hypnagogic foot tremor*, must be excluded. Rhythmic movements may occur as a conscious or unconscious strategy to relieve *RLS* symptoms. If the rhythmic movements are clearly in response to *RLS* sensations, then a separate diagnosis of SRRMD is not needed. However, SRRMD may be diagnosed if SRRMD criteria are met, and *RLS* does not adequately explain the presence or extent of rhythmic movements.

**REM sleep behavior disorder** in adults, SRRMD can be misdiagnosed as *RBD* or be comorbid with *RBD*. Video polysomnography is particularly helpful in these cases.

**Autism spectrum disorder** is often associated with repetitive behaviors, but these movements typically occur during wakefulness and are not predominantly sleep-related.

**Stereotypic movement disorder** is typically associated with intellectual disability and is not predominantly sleep-related. In children with autism spectrum disorder or intellectual disability, an additional diagnosis of SRRMD should only be made if the movements are predominantly sleep-related.

**Autoerotic or masturbatory behaviors** may involve body rocking or other repetitive body movements, but the primary focus is genital stimulation, evidenced by direct genital contact. These movements do not fit the criteria for SRRMD.

**Neurological disorders**, rarely SRRMD needs to be differentiated from *epilepsy*, *tic disorders*, or *involuntary movements* associated with other neurological conditions. *Akathisia* is seen as a complication of neuroleptic medication and is not predominantly sleep-related.

### *Unresolved Issues and Further Directions*

There is controversy about the classification of hypnagogic foot tremor as a separate entity or as a subtype of sleep-related rhythmic movements. Further study of the relationship between the typical form seen in otherwise normal infants and young children and the rhythmic movements seen in children with intellectual disability and autism spectrum disorder is also needed. The pathophysiology of persistent SRRMD is poorly understood, as is the association with other sleep disorders in adults.

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## Benign Sleep Myoclonus of Infancy

ICD-9-CM code: 327.59

ICD-10-CM code: G47.69

### *Alternate Names*

Benign neonatal sleep myoclonus.

### *Diagnostic Criteria*

Criteria A-E must be met

- A. A caregiver or other observer reports repetitive myoclonic jerks that involve the limbs, trunk, or whole body.
- B. The movements occur in early infancy, typically from birth to six months of age.
- C. The movements occur only during sleep.
- D. The movements stop abruptly and consistently when the infant is aroused.
- E. The sleep disturbance is not better explained by another current sleep disorder, medical disorder, mental disorder, or medication use.

### *Essential Features*

Benign sleep myoclonus of infancy (BSMI) is characterized by repetitive myoclonic jerks that occur during sleep in neonates and infants. Although BSMI is benign and relatively rare, it is included in the sleep-related movement disorders section because it is commonly confused with epilepsy. However, unlike the jerks of myoclonic seizures and myoclonic encephalopathy, the jerks of BSMI occur exclusively during sleep. The jerks are often bilateral and massive, typically involving large muscle groups. The movements can occur in the whole body or exclusively in the limbs, the trunk, or rarely, the face.

### *Associated Features*

Not applicable or known.

### *Clinical and Pathophysiological Subtypes*

Most infants with BSMI are neurologically normal and born to mothers with no history of illicit drug use. However, BSMI has been described in more than half of infants with neonatal opioid withdrawal

syndrome, suggesting a subtype with this specific etiology. However, it must be stressed that some cases of neonatal abstinence syndrome do not follow a benign clinical course. Whether such cases should be included with those of BSMI is an unresolved matter.

### *Demographics*

The prevalence is unknown. The incidence is estimated at 3.7 per 10,000 live births. More than 300 cases are described in the literature. Males are affected more than females by a ratio of about 2:1. The disorder is typically observed between birth and six months of age.

### *Predisposing and Precipitating Factors*

Predisposing factors have not been delineated. Rocking or repetitive noises may precipitate individual episodes of BSMI.

### *Familial Patterns*

Although most cases appear to be sporadic, familial occurrence has been reported. Siblings may be affected, and some families demonstrate a pattern suggesting autosomal dominant inheritance.

### *Onset, Course, and Complications*

Onset generally occurs between birth and one month of age in a neurologically normal infant. The course is self-limited and benign. The disorder may be present for only a few days or may last for several months. Maximum expression is usually between 15 and 35 days of age. BSMI resolves by three months of age in 64% of affected infants, by six months in 95%, and by 12 months in 97%, with persistence rarely into the second year of life or later. There are no known complications. Long-term follow-up in a limited number of children has shown normal psychomotor development and normal cognitive function at five to 10 years of age. There is no evidence of an increased risk of seizures.

### *Developmental Issues*

Because age-related factors are a critical dimension for BSMI, developmental issues are discussed throughout this section.

### *Pathology and Pathophysiology*

Inadequate inhibition of a cervical spinal cord generator due to immature myelination of descending pathways has been hypothesized.

### *Objective Findings*

Video-polysomnographic EEG and EMG monitoring has demonstrated paroxysmal muscle activity without epileptiform EEG abnormalities. Theta band waves may be seen on central and vertex electrodes following the myoclonus. BSMI occurs predominantly during NREM but also may be present during REM sleep. The muscle jerks usually occur in clusters of four or five jerks per second, each jerk lasting 40 to 300 milliseconds. BSMI clusters typically repeat in irregular series for one to 15 minutes, but, in some cases, the clusters may recur for up to 60 minutes or longer and be mistaken for status epilepticus. One study demonstrated that 30% of the jerks involve the whole body, 20% the abdominal or proximal muscles, and 50% the arms or the legs only. The arms are usually more involved than the legs. Activity is symmetrical in over 90% of cases but can be lateralized. The myoclonus is not associated with arousals, awakenings, or sleep stage transitions.

Spontaneous or provoked awakening of the infant leads to prompt, abrupt, and consistent cessation of the movements. Gentle rocking of the infant or the infant's crib may provoke the myoclonus and may be a useful maneuver during EEG monitoring when differentiation from seizures is required. In contrast to jitteriness and other non-epileptic etiologies, BSMI will often increase rather than be suppressed by gentle restraint. Neuroimaging studies are normal.

### *Differential Diagnosis*

**Seizure disorders** BSMI should be distinguished from myoclonic seizures; misdiagnosis may lead to unnecessary diagnostic testing or medication use. The absence of episodes while awake in infants with BSMI is the single most helpful clinical feature. In addition, BSMI will stop abruptly and consistently when the infant is aroused. Whereas BSMI is typically present in neurologically normal infants, neonatal seizures often occur in the context of perinatal disorders such as hypoxic-ischemic encephalopathy, infection, or metabolic abnormalities. *Infantile spasms (West syndrome)* are most often seen after the first month of life but sometimes occur earlier. Infantile spasms are usually manifest by sudden head flexion with arm extension and lower extremity flexion. They are typically associated with a hypsarrhythmia EEG pattern. *Pyridoxine-dependency seizures* are responsive to treatment with vitamin B<sub>6</sub>. In cases that are difficult to differentiate, an EEG obtained during sleep will show normal patterns when BSMI is elicited by gentle rocking. Anticonvulsant medications are ineffective and unnecessary in BSMI.

**Myoclonic encephalopathies, hyperekplexia (startle disease), drug withdrawal, and jitteriness** BSMI should also be distinguished from these other disorders that occur during wakefulness. Benign sleep myoclonus of infancy usually occurs after the third month of life and only during wakefulness.

**Periodic limb movement disorder** can occur in infants but typically has a distinctly different duration and frequency. The muscle activity is of longer duration (0.5 to 10 seconds) and recurs at a more regular and longer interval (typically 20 to 40 seconds). PLMD can be associated with EEG arousals, whereas BSMI is not. BSMI is more often seen in the arms than the legs, whereas PLMD predominantly involves in the lower limbs.

**Phasic-REM muscle activity** typically involves smaller muscle groups and can be linked to observable eye movements.

**Sleep starts** occur at the wake-sleep transition and typically are not repetitive.

**Propriospinal myoclonus at sleep onset** is a rare disorder that has not been reported in children and is characterized by jerks involving the abdominal and truncal muscles at the transition from wakefulness to sleep.

**Fragmentary myoclonus** has been described in adults and is primarily a nonspecific EMG finding with little or no visible movement.

### *Unresolved Issues and Further Directions*

The prevalence, incidence, and pathophysiology of BSMI warrant further study.

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### **Propriospinal Myoclonus at Sleep Onset**

*ICD-9-CM code: 327.59*

*ICD-10-CM code: G47.69*

### *Alternate Names*

Propriospinal myoclonus, spinal myoclonus, plurisegmental myoclonus, intersegmental myoclonus, axial myoclonus.

### *Diagnostic Criteria*

Criteria A-E must be met

- A. The patient complains of sudden jerks, mainly of the abdomen, trunk, and neck.
- B. The jerks appear during relaxed wakefulness and drowsiness as the patient attempts to fall asleep.
- C. The jerks disappear upon mental activation and with the onset of a stable sleep stage.
- D. The jerks result in difficulty initiating sleep.
- E. The sleep disturbance is not better explained by another current sleep disorder, medical disorder, mental disorder, or medication/substance use.

### *Notes*

1. There is no current definitive evidence that propriospinal myoclonus confined to sleep onset is associated with significant structural lesions of the spinal cord. However, propriospinal myoclonus that is persistent during the day has been linked to structural spinal cord pathology in 16% to 20% of cases.

### *Essential Features*

Propriospinal myoclonus at sleep onset (PSM) consists of sudden myoclonic jerks occurring in the transition from wakefulness to sleep and, rarely, during intra-sleep wakefulness or upon awakening in the morning. The jerks arise mainly in the axial muscles and spread rostrally and caudally via intrinsic propriospinal pathways. The jerks may be of variable intensity; they are isolated, arrhythmic, and sometimes grouped in brief clusters of a few movements, separated by longer intervals. The jerks involve the abdominal and truncal muscles first and are then propagated to the proximal muscles of the limbs and the neck. The pattern of movement is usually flexor but may be an extension of the trunk. Vocalization due to diaphragmatic involvement occurs rarely. The jerks are most often spontaneous but, in some cases, can be evoked by external stimulation. They typically occur in the recumbent position, during a state of relaxed wakefulness as the patient tries to fall asleep. Mental activation abolishes the movements, at least temporarily. The myoclonus usually disappears at sleep onset and remains absent throughout all stages of sleep, even though they may reappear during intra-sleep wakefulness.

### *Associated Features*

Propriospinal myoclonus is often associated with severe sleep-onset insomnia due to the inability of the patient to fall asleep as a result of the recurrent disturbing muscular activity.

### *Clinical and Pathophysiological Subtypes*

Propriospinal myoclonus at sleep onset may be considered a variant of the more generally described propriospinal myoclonus seen during the daytime. In daytime propriospinal myoclonus, myoclonic jerks involve the thoracoabdominal/paraspinal or cervical muscles and spread caudally or rostrally to the other myotomes. The jerks are provoked or worsened by the recumbent position. They are often preceded by premonitory sensations, are stable over time, and respond unpredictably to drug treatment. The frequent pre-sleep worsening of daytime propriospinal myoclonus (around 50% of the cases) suggests that these patients may have a milder or variant form of a single clinical and neurophysiologic entity.

Based on the presence or absence of a spinal cord comorbidity, propriospinal myoclonus may be classified as idiopathic or symptomatic.

### *Demographics*

There are minimal epidemiologic data available. Propriospinal myoclonus is probably a rare condition. Reports indicate a higher prevalence in men.

### *Predisposing and Precipitating Factors*

Not applicable or known.

### *Familial Patterns*

Not applicable or known.

### *Onset, Course, and Complications*

Propriospinal myoclonus arises in adulthood and is usually a chronic, unremitting condition. Patients may develop a fear of falling asleep, anxiety, and depression. Intense myoclonic jerks may cause injury to the patient or the bed partner.

## *Developmental issues*

The disorder affects adults and has been reported in one child, in association with vertebral fracture.

## *Pathology and Pathophysiology*

The pathophysiology of propriospinal myoclonus is unknown. It is thought to originate from a focal spinal pattern generator, set into motion by supraspinal dysfacilitatory influences typical of relaxed wakefulness and drowsiness. The myoclonus is presumed to propagate up and down the spinal cord via slowly conducting, long propriospinal (intersegmental) pathways. Thus, a focal spinal generator can recruit muscles from multiple segments. Around 20% of reported cases of propriospinal myoclonus are associated with various spinal cord pathologies (hemangioblastoma, syringomyelia, dural arteriovenous fistula, multiple sclerosis, vertebral fracture, herpes zoster, HIV, and Lyme disease). However, the causal relationship between spinal cord pathology and propriospinal myoclonus is sometimes difficult to demonstrate.

## *Objective Findings*

Polysomnography must be obtained with additional paraspinous leads. The sleep study demonstrates brief myoclonic EMG bursts recurring non-periodically with alpha activity present on the EEG. The myoclonic bursts occur particularly when alpha activity spreads from the posterior to the anterior brain regions. Epileptic EEG discharges are not observed in PSM. The jerks disappear with EEG desynchronization due to mental activation or with the onset of sleep spindles and K-complexes. The jerks remain absent throughout sleep but may occasionally reappear with awakening or arousal. Polysomnography with extended EMG recording demonstrates that the jerks arise initially in spinal-innervated muscles and then propagate to more caudal and rostral muscles in a propriospinal propagation pattern. The recognition of this propagation pattern requires the recording of several muscles belonging to different myotomes to demonstrate the spinal order of activation and the low velocity of propagation. There is no standard recommended montage, but it is important to record at least several of the same limb muscles bilaterally to demonstrate the synchronicity of bursts between the left and right sides. One or more muscles innervated by cranial nerves (e.g., chin or sternocleidomastoid muscles) should be included to differentiate propriospinal myoclonus from startle disease. Several thoracoabdominal muscles should also be included in the montage because the condition often starts from the abdomen. Detailed analysis of the jerks shows that the EMG activity originates in muscles innervated by thoracic or cervical spinal segments (sternocleidomastoid, paraspinalis, rectus abdominis) and then spreads to more rostrally and caudally innervated muscles at a slow velocity (2 to 16 milliseconds, around 5 milliseconds on average). Mild motor events may involve only focal-segmental axial muscles of the myotome from which propriospinal myoclonus originates. Rarely, the focal motor events may persist during sleep. Back-averaging of the EEG does not show any jerk-locked cortical activity. MRI of the spine is usually normal but demonstrates a focal lesion in around 20% of the cases. The causal relationship between PSM and

these spinal lesions is unclear, although magnetic resonance diffusion tensor imaging with fiber tracking may demonstrate spinal tract disorganization.

### *Differential Diagnosis*

**Intensified sleep starts**, demonstrate features similar to PSM. However, sleep starts (hypnic jerks) usually appear during the transition between wakefulness and sleep and during light NREM sleep, whereas PSM may sometimes be present during relaxed wakefulness. Unlike PSM, sleep starts (hypnic jerks) sometimes affect only one or a few body segments. Propriospinal propagation is not observed in neurophysiological studies of sleep starts.

**Phasic REM twitches**, which are a normal phenomenon during REM sleep, involve the distal muscles of the hands and face, often without displacement of the body segment.

**Other myoclonic activity** *Fragmentary myoclonus* resembles physiological hypnic myoclonus, but in an enhanced form, and persists throughout all stages of NREM and REM sleep. Both physiological hypnic myoclonus and fragmentary myoclonus are EMG findings not associated with overt muscular activity and do not involve muscles acting across large joints. In addition, when myoclonic jerks involving leg muscles appear, the PSM disappears. *Epileptic myoclonus* is not confined to relaxed wakefulness and may be associated with epileptic discharges on the EEG. *Sleep-related head jerks* (neck myoclonus) are a recently described frequent motor event characterized by a rapid head flexion or rotation that emerges from stable sleep and mainly from REM sleep.

**Periodic limb movements** are longer in duration, involve mainly the lower limbs, and usually spare truncal and abdominal muscles. PLMS may begin during pre-sleep wakefulness but generally occur during NREM sleep. They are longer in duration and periodic in their occurrence. Some patients with *RLS* may have prominent PLMs in wakefulness while sitting or lying down. However, prominent leg discomfort is usually present in these patients. Occasionally, PSM may be present in patients with *RLS/PLMS* during wake before sleep; however, the EMG morphology differs.

**Functional or psychogenic propriospinal myoclonus** has also been reported. Accurate neurophysiological studies may help in differentiating psychogenic jerking from propriospinal myoclonus. However, some studies showed that healthy subjects can voluntarily replicate the typical electromyographic pattern of PSM. Psychogenic myoclonus may simulate PSM, but the muscle recruitment pattern, the spread velocity, and the recording of cortical activity observed before voluntary movements may be helpful to differentiate the conditions.

### *Unresolved Issues and Further Directions*

Future studies are needed to better define the distinctions between PSM and related conditions such as sleep starts (hypnic jerks) and, in particular, the syndrome of intensified sleep starts. Also, neuroimaging and possibly postmortem studies may detect the neural structures responsible for initiating the myoclonic jerks.

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## Sleep-Related Movement Disorder Due to a Medical Disorder

ICD-9-CM code: 327.59

ICD-10-CM code: G47.69

### Diagnostic Criteria

Criteria A-C must be met

- A. The patient manifests sleep-related movements that disturb sleep or its onset.
- B. The movement disorder occurs as a consequence of a significant underlying medical or neurological condition.
- C. The symptoms are not better explained by another sleep-related movement disorder, another current sleep disorder, mental disorder, or medication/substance use.

### Notes

1. When a movement disorder meets the criteria of a more specific diagnosis listed elsewhere in the sleep-related movement disorder section (e.g., restless legs syndrome), the more specific diagnosis should be used, with annotation of the relationship to the medical or neurological disorder.

This diagnosis is intended for sleep-related movement disorders due to an underlying medical or neurologic condition that do not meet the criteria for another specific movement disorder. Many neurological conditions may be associated with movement abnormalities that are evident in wake and sleep. In some cases, the nocturnal manifestations of the movement abnormalities may be apparent before establishing a firm neurological diagnosis. Thus, in some cases, this diagnosis is temporary, given when a sleep-related diagnosis is required before the underlying medical or neurological condition is determined. Once a medical or neurological condition is established, that becomes the sole diagnosis unless the sleep complaint is the focus of independent clinical attention.

## **Sleep Related Movement Disorder Due to a Medication or Substance**

*ICD-9-CM code: 292.85 (drug-induced); 291.82 (alcohol-induced)*

*ICD-10-CM code: F11-F19 (see table in Appendix B for detailed coding instructions)*

### *Diagnostic Criteria*

Criteria A-D must be met

- A. The patient manifests sleep-related movements that disturb sleep or its onset.
- B. The movement disorder occurs as a consequence of current medication or substance use or withdrawal from a wake-promoting medication or substance.
- C. The symptoms are not better explained by another sleep-related movement disorder, other untreated sleep disorder, or, neurological, or mental disorder.
- D. The symptoms are not better explained by another sleep-related movement disorder, another current sleep disorder, medical disorder, or mental disorder.

### Notes

1. When a movement disorder meets the criteria of a more specific diagnosis listed elsewhere in the sleep-related movement disorder section (e.g., restless legs syndrome), the more specific diagnosis should be used, with annotation of the relationship to the medical or neurological disorder.

This diagnosis is intended for sleep-related movement disorders due to a medication or substance (toxin or other bioactive substance) that do not meet the criteria for another specific movement disorder. Many substances may be associated with movement abnormalities that are evident in wake and sleep. To the

extent that the movement abnormality is an expected complication of the substance(s) involved (e.g., tardive dyskinesia or akathisia associated with dopamine antagonists), this diagnosis is unnecessary unless the sleep-related aspects of the movement abnormality or its sequelae are the focus of independent clinical attention.

## **Sleep-Related Movement Disorder, Unspecified**

*ICD-9-CM code: 327.59*

*ICD-10-CM code: G47.69*

This diagnosis is assigned when patients have a sleep-related movement disorder that cannot be classified elsewhere or is suspected to be associated with an underlying psychiatric condition. In some cases, “sleep-related movement disorder, unspecified” is a temporary diagnosis before establishing an underlying psychiatric condition that may explain the sleep-related movement (e.g., movements associated with posttraumatic stress disorder nightmares before the firm establishment of the psychiatric diagnosis). However, once the psychiatric diagnosis is established, that becomes the sole diagnosis unless the sleep complaint is the focus of independent clinical attention.

## **Isolated Symptoms and Normal Variants**

### **Excessive Fragmentary Myoclonus**

Excessive fragmentary myoclonus (EFM) is a largely incidental polysomnographic finding on EMG, characterized by small movements of the corners of the mouth, fingers, or toes, or by no visible movement at all. The finding is associated with no known clinical consequence. Large limb movements across large joint spaces are not characteristic of EFM and, if present, should exclude the diagnosis of EFM. Scoring of EFM is described in the most recent version of the AASM Manual for the Scoring of Sleep and Associated Events. The condition is a NREM phenomenon. The movements resemble the phasic twitches seen in normal REM sleep but are more widely dispersed throughout a sleep epoch than phasic REM twitches. The latter are generally clustered within small groups in a sleep epoch. The significance of EFM is that it is within the differential diagnosis of other sleep-related movement disorders.

Patients usually are not aware of the twitch-like movements. Coexistent sleep disorders may be present, but EFM does not appear to contribute to the symptoms of these sleep disorders.

EFM, a NREM phenomenon, is less common than phasic REM twitches, which occur in normal individuals without sleep complaints. Most cases have been reported in adults. EFM is found predominantly in males. One study found EFM in 100% of 62 patients with various sleep disorders, bringing into question the specificity of EFM.

Numerous causes of chronic sleep fragmentation may be associated with EFM. The condition has been described in association with obstructive sleep apnea and primary central sleep apnea, sleep-related hypoxemic/hypoventilation syndromes, narcolepsy, PLMD, and insomnia disorder. In apneic patients, the twitching intensifies during periods of increased hypoxemia. Excessive fragmentary myoclonus is reported to occur commonly in children with Niemann-Pick disease, type C. No specific precipitating factors have been reported. The contribution of EFM to the symptomatology of any of these disorders is unknown. Employing the current scoring criteria, around 9% of healthy sleepers have EFM without awareness. The course is not well studied but appears to be benign and non-progressive.

The condition may be the sole abnormality in some cases of excessive daytime sleepiness, but causality is questionable. No other serious consequences have been described when it occurs in isolation. However, in a recently reported large case series of EFM, electrophysiological abnormalities have been found in 59% of subjects, most frequently polyneuropathy, radiculopathies, and benign fasciculations. Further data are needed before a recommendation of electrophysiological screening in asymptomatic subjects with EFM is warranted. In many cases, EFM is present in normal individuals. Its relatively benign course suggests that it is not associated with a neurodegenerative process. It is not known if a genetic or other physiologic basis predisposes individuals to develop the condition. In any case, it would appear to result from intensification of an otherwise normal motor phenomenon. The predominant topographic distribution of EFM in distal and facial muscles suggests that cortical motor centers participate in its generation.

PSG demonstrates associated sleep abnormalities and disruption in most reported cases, suggesting that EFM may be due to disruptions of normal motor-control mechanisms during sleep. EFM is detected as isolated, very brief (usually 75 to 150 milliseconds), asymmetrical, asynchronous EMG potentials in various muscles of the face, trunk, arms, and legs. The amplitude varies from approximately 50 to several hundred microvolts; the taller amplitudes are often associated with visible movement of the fingers, toes, or corners of the mouth, whereas the smaller ones may resemble fasciculation potentials and lack overt movement. Large movements across large joint spaces preclude a diagnosis of EFM. Small twitch-like movements may be observed on video recording. Episodes of these myoclonic potentials typically last from 10 minutes to several hours. They often appear at sleep onset and continue through the NREM sleep stages, including N3 sleep. The presence of EFM in REM is difficult to determine because it is superimposed on the normal phasic clusters of physiological phasic REM twitches. EFM is electromyographically similar to the latter. Occasionally, the EMG activity also persists during EEG periods of wakefulness within the sleep period or is present in drowsiness before sleep onset. The EEG usually shows no changes at the time of the movements, although high-amplitude EMG potentials may be associated with a K-complex or even with transient EEG arousal. There are no ocular or autonomic accompaniments. Depending on the digitalization rates, digital systems may record less fragmentary

myoclonus than earlier paper records. No laboratory tests other than polysomnography (optimally with multiple EMG leads) have improved the assessment of EFM.

### *Differential Diagnosis*

**Periodic limb movements.** EFM generally has a maximum burst duration of only 150 milliseconds and does not recur periodically. In contrast, PLMS are characterized by a longer burst duration (typically 0.5 to 10 seconds) and a long period between bursts (5-90 seconds).

**Physiological phasic REM twitches.** EFM, which occurs in NREM, must also be differentiated from normal phasic REM twitches, which have a similar burst duration but are limited to the REM state and tend to occur in clusters within an epoch. EFM bursts tend not to cluster within a particular epoch.

**Larger body movements** across the large joints are not a feature of excessive fragmentary myoclonus. Such movements suggest other disorders.

Further investigation is necessary to determine whether EFM occurs as a consequence of sleep disruption or whether it is an independent cause of sleep disruption and daytime symptoms in its own right. It must also be determined whether any physiological differences distinguish fragmentary myoclonus seen in many normal individuals from EFM. It is unknown whether some additional pathophysiological element is required to increase fragmentary myoclonus into an abnormal range. The current threshold for the diagnosis of EFM should be further investigated because the scoring criteria lack specificity. The apparent strong predominance in males also remains unexplained.

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## Hypnagogic Foot Tremor and Alternating Leg Muscle Activation

Hypnagogic foot tremor (HFT) is a rhythmic movement of the feet or toes during the transition between wake and sleep or during light NREM sleep (stages N1 and N2). Foot movements may be reported directly by the patient or by an observer. On occasion, the movement has not been observed, but HFT is seen as an incidental finding on sleep study conducted for other indications. HFT may be a relatively common and normal finding. Affected individuals move the feet or the toes rhythmically for seconds to minutes during drowsy wakefulness or lighter stages of sleep. However, it can be pathologically exaggerated in some patients.

Alternating leg muscle activation (ALMA) consists of brief activation of the anterior tibialis in one leg alternating with similar activation in the other leg during sleep or arousals from sleep. The movements may be reported directly by the patient or observed by others. There is frequently no reported movement, but alternating leg muscle activation is recorded as an incidental finding on polysomnography. The movements most commonly occur during the transition between wake and sleep or during light sleep. Frequency of muscle activations, length of activations, and occurrence primarily with arousals suggest that ALMA may be similar to HFT or represent an EMG manifestation of some episodes of HFT. The original case series that described ALMA did not link it with movement of the lower extremity, but a subsequent report did. HFT and ALMA have been reported as occurring coincidentally in the same individual.

HFT and ALMA are described together in this section because the similarity in a number of their features suggests they may not be fully independent entities. However, there is insufficient evidence to resolve this question. It has also been proposed that HFT and ALMA represent a variant of rhythmic movement disorder in which movements are confined to the legs, and an older population is affected. The degree to which these movements are quasi-voluntary remains to be determined because some are suppressible. Since reports of these movements have arisen mainly from reviews of sleep center records, their manifestation in the general population is unknown. In addition, the associated factors described below may be due to biased sampling caused by a skewing of the population toward those with sleep disorders, especially respiratory disorders. The degree to which HFT and ALMA have clinical significance remains uncertain. Potential differences between HFT and ALMA include the presence of clear movement in HFT as opposed to some uncertainty whether ALMA must involve movement. In contrast to HFT, ALMA alternates between sides, occurs in any sleep stage, can occur without arousal, and is associated with the use of antidepressants.

Associated features of HFT and ALMA are similar. Most cases of HFT have been reported in persons with other sleep disorders, such as RLS or SRBDs. ALMA has been identified mainly in patients with SRBD or PLMs. Seventy-five percent of patients with ALMA in the original series used antidepressant medication.

In that study, patients with ALMA complained of sleepiness, insomnia, or restlessness of the legs. Still, only one reported patient had more specific complaints of sudden nocturnal muscle contractions in his legs and a sensation that his legs were vibrating. A separately reported case of a patient with ALMA documented the absence of any SRBD, PLMs, or use of antidepressant medication. This patient reported frequent and easily provoked awakenings and excessive daytime sleepiness. The ALMA and symptoms responded to treatment with pramipexole.

The single series in which HFT was studied found that it occurs in 7.5% of patients in whom a polysomnogram was performed for other reasons. Affected individuals range from 14 to 72 years, with a majority in the middle-age range (40 to 65 years). Men and women are equally affected. The frequency of these movements may be increased in individuals with disorders such as RLS or SRBD, but it can occur in individuals with otherwise normal sleep. The prevalence of the condition in the general population and its frequency in affected individuals remains uncertain.

In the initial series reporting ALMA, the disorder occurred in 1.1% of unselected studies from a sleep disorder center. Patients with ALMA were primarily male (M/F ratio 11:5) and ranged in age from 12 to 70 years, with most aged 35 to 55 years (mean age 41 years). Therefore, the age ranges of both conditions are similar, with both males and females affected. These distributions may be due to the incidental discovery of both entities during routine sleep studies for other sleep complaints.

No predisposing factors are identified for HFT. Antidepressant use may increase the risk for ALMA.

Polysomnography in patients with HFT demonstrates a pattern of brief, repeated activation of the anterior tibialis in one leg. The minimum frequency is 0.3 Hz; the maximum is 4.0 Hz. Multiple leg activations in a single leg occur in a train of at least four movements. EMG recordings of the foot or leg muscles or video recordings of movement may show trains of recurrent 1-Hz to 2-Hz EMG potentials or movements. Typical associated EMG bursts are 300 to 700 milliseconds in duration, and the usual duration of trains is 10 to 15 seconds, although longer bursts and trains have been reported. In morbid conditions, trains may persist much longer. Events are recorded at the transition into sleep and during stages N1 and N2 sleep. Distribution over the night has not been fully investigated. Persistent HFT has been described in about half of the individuals who have had multiple studies. Alternation between legs has not been described, but its potential occurrence is suggested in two published studies of HFT.

In ALMA, polysomnography demonstrates a pattern of brief, repeated activation of the anterior tibialis in one leg alternating with similar activation in the other leg. At a minimum, a single leg muscle activation in one leg is followed sequentially by a similar single activation in the other leg, reactivation in the original leg, and then reactivation in the alternate leg, with some continued alternation beyond this minimal sequence in most instances. The minimum frequency of alternating EMG bursts is 0.5 Hz, and the maximum frequency is 3.0 Hz.

ALMA can be demonstrated by polysomnography if the surface EMG is recorded independently from both right and left anterior tibialis muscles. A sequence of ALMA may begin with one to several lengthy

activations (one to two seconds) in one or both legs. Some patients show unilateral activity at times. ALMA usually closely precedes or follows an arousal or awakening and gradually diminishes as sleep returns. However, ALMA can also emerge without arousals from any sleep stage. Proclivity for any specific portion of the nocturnal sleep cycle has not been identified. Leg muscle activations during REM sleep are often briefer and somewhat less regular than in NREM sleep. Sequences of ALMA sometimes recur at intervals similar to those of PLMs. Extensor forearm EMG study may suggest alternating muscle activity in the upper extremities, though it is less prominent than activation in the legs. ALMA shows some night-to-night consistency. Repeat studies are likely to show persistent ALMA. The number of sequences recorded, on average, and the timing of ALMA with respect to arousals tends to remain constant.

The specific polysomnographic criteria for HFT during sleep and ALMA are defined in the latest version of the AASM Manual for the Scoring of Sleep and Associated Events.

Presentation of HFT or ALMA with other concurrent sleep disorders is common.

### *Differential Diagnosis*

**Periodic limb movement disorder (especially the polyclonic form), propriospinal myoclonus at sleep onset, and sleep-related rhythmic movement disorder;** HFT and ALMA should be distinguished from these other sleep-onset movements:

**Other movement disorders** that should be distinguished from HFT and ALMA include *dyskinetic movements* of the foot, such as *painful legs and moving toes*; *tremors or rhythmic movements* of other causes (Parkinson's disease, clonus); and *neuroleptic-induced akathisia*. None of these conditions involves regular alternation between sides, as seen in ALMA, or an association with the use of antidepressant medication.

**High-frequency leg movements (HFLM)** have also been described as repetitive anterior tibialis, polysomnographic activation phenomenon, possibly showing some association with RLS and potential overlap with HFT and ALMA. In contrast to HFT, however, HFLMs occur in all sleep stages and are primarily unilateral rather than bilateral. In contrast to ALMA, HFLMs are mostly unilateral rather than alternating and often show longer sequences than those reported for ALMA. Reported cases of HFLMs may be more common than ALMA, a possible subtype of HFLMs in which leg alternation occurs.

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## Sleep Starts (Hypnic Jerks)

Sleep starts, also known as hypnic jerks, are sudden, brief, simultaneous contractions of the body or one or more body segments occurring at sleep onset. Sleep starts usually consist of a single contraction that often affects the body asymmetrically. The jerks may either be spontaneous or induced by stimuli. The motor activity is often associated with a sensory component, which may be somesthetic, often an impression of falling. Less commonly, pain or tingling; auditory stimuli (e.g., banging, snapping, crackling noises), or visual stimuli (e.g., flashing lights, hypnagogic dreams, or hallucinations) may provoke sleep starts. A sharp cry may occur. The patient may not recall a jerk that a bed partner noted if the sleep start does not cause awakening. Multiple jerks occasionally occur in succession, usually early in the sleep period. When sleep starts or hypnic jerks are frequent, intense, or repetitive, they may lead to sleep-onset insomnia.

Purely sensory sleep starts are subjective, localized sensory impressions that occur at sleep onset and are not associated with motor activity. Exploding head syndrome may be a type of sensory sleep start. The term “Intensified sleep starts” has been applied to both the motor and purely sensory forms when a complaint of difficulty falling asleep as a result of the starts is present.

A prevalence of 60% to 70% has been reported, but with a highly sporadic occurrence. Sleep starts affect all ages and both sexes.

Excessive caffeine or other stimulant intake, prior intense physical work or exercise, sleep deprivation, and emotional stress can increase the frequency and severity of sleep starts. Frequent sleep starts may occur more commonly in patients with parkinsonism than in the general population.

Sleep starts are a universal component of the sleep-onset process, although they are often not recalled. Hypnic jerks may occur at any age as a subjective complaint; however, they are usually encountered in adulthood. The course is usually benign. Intensified sleep starts may lead to avoidance/delay of sleep, a fear of falling asleep, and chronic anxiety. As a result, acute and chronic sleep deprivation may occur. Sleep-onset insomnia may result from repeated awakenings induced by the starts or anxiety about falling asleep. Injury, such as bruising a foot against a bedstead or kicking a sleeping companion, may occasionally occur.

The physiological mechanisms underlying sleep starts are uncertain. No pathologic finding has been described except for a single case of auditory sleep starts associated with a brainstem lesion. Sleep starts are hypothetically caused by sudden descending volleys originating in the brainstem reticular formation, activated by system instability at the transition between wake and sleep. However, the similarity between sleep starts and the startle response has led some to postulate that sensory processing abnormalities are primary, with secondary motor manifestations involving the reticulospinal tract. Sleep starts are a prominent symptom in hereditary hyperekplexia, some cases of which are caused by mutations in the glycine receptor. It has also been postulated that sleep starts are a response to hypnagogic imagery.

Polysomnographic monitoring shows that hypnic jerks occur during transitions from wakefulness to sleep, mainly at the beginning of the sleep episode. Superficial EMG recordings of the involved muscles show brief (generally 50-millisecond to 250-millisecond) high-amplitude potentials, either singly or in succession. The EEG typically shows drowsiness or stage N1 sleep patterns, sometimes with a negative-vertex sharp wave occurring at the time of the jerk. Autonomic activation, including tachycardia, tachypnea, irregular breathing, and sudomotor activation may follow an intense jerk. After the start, a brief arousal or a return to sustained wakefulness may occur. Physical and neurological examinations and routine laboratory tests are otherwise normal. Although polysomnography is not necessary for diagnosis in most individuals, it may be indicated in occasional cases with complaints of insomnia and frequent movements.

### *Differential Diagnosis*

Hypnic jerks must be differentiated from numerous physiological or pathologic movements that occur at sleep onset or during sleep.

**Normal body movements** are complex, with postural body shifts usually at the transition between one sleep stage and another

**Physiological partial hypnic myoclonus** consists of small, isolated contractions of a muscle or part thereof, occurring sporadically in distal muscles and resembling fasciculation potentials. The contractions are particularly evident during stage N1 and REM sleep.

**Fragmentary myoclonus** consists of profuse, brief, small-amplitude muscle twitches in an asynchronous, symmetrical, and bilateral manner, especially in distal muscles. Fragmentary myoclonus occurs at sleep onset as well as within all sleep stages. Contrary to the massive jerks of the sleep starts or hypnic jerks, the small muscle twitches of physiological partial hypnic myoclonus and fragmentary myoclonus often represent only an EMG finding and are not associated with overt movements at the joints.

**Benign sleep myoclonus of infancy** consists of myoclonic jerks at the elbow, fingers, toes, and face during sleep in infants.

**Propriospinal myoclonus at sleep onset (PSM)** is characterized by jerks, usually spontaneous, but sometimes evoked, arising in spinal innervated axial muscles of the trunk, neck, or abdomen, and then propagated at slow velocity to more rostral and caudal muscles. PSM is present during relaxed wakefulness and disappears with sleep onset or mental activation. PSM is usually a chronic condition associated with sleep-onset insomnia.

**Hyperekplexia syndrome** is typified by excessive startling and hypnic jerks, in which stimuli readily elicit generalized myoclonus during either wakefulness or sleep. The major form of this condition is also characterized by stiffness and falls.

**Brief epileptic myoclonus** is differentiated from sleep starts by coexistent EEG discharge, other features of epileptic seizures, and the occurrence of the myoclonus in both wakefulness and sleep rather than only at sleep onset.

**Periodic limb movement disorder and restless legs syndrome**, the muscle contractions of *PLMD* are much longer in duration, involve mainly the feet and lower legs, show periodicity, and occur within sleep. *RLS* consists of slower and repetitive semi-voluntary movements at sleep onset, associated with deep, unpleasant, and sometimes unbearable sensations, temporarily relieved by getting up and exercising.

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