Scoring Techniques for Sleep-Related Movements

Ambra Stefani, Birgit Högl, and Raffaele Ferri

Movements during sleep can represent a physiological phenomenon, or be a manifestation of sleep pathology. In fact, abnormal movements during sleep have been observed in almost all major categories of the International Classification of Sleep Disorders (ICSD 3nd Ed. or ICSD-3), namely, in insomnias (e.g., periodic and non-periodic movements in insomnia), sleep-related breathing disorders (major motor activity related to arousals at the end of apnea episodes), hypersomnias (e.g., abnormal motor activity during non-REM and REM sleep in narcolepsy), parasomnias (for many parasomnias, abnormal sleep related movements as part of behaviors are a hallmark), and sleep-related movement disorders (namely restless legs syndrome, periodic limb movement disorder, sleep related rhythmic movement disorder, bruxism, propriospinal myoclonus at sleep onset, among others).

In addition, the ICSD-3 foresees the category "isolated symptoms and normal variants," which contains other sleep-related movements, for which the definite assignment into normal or pathological categories has not yet been made (i.e., sleep starts, hypnagogic foot tremor and alternating leg muscle activation, and excessive fragmentary myoclonus).

This chapter of the Atlas focuses on sleep-related movement disorders and scoring techniques (Figs. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, and 15) [1–7].

A. Stefani (✉) · B. Högl
Sleep Disorders Clinic, Department of Neurology, Medical University of Innsbruck, Innsbruck, Austria
e-mail: ambra.stefani@i-med.ac.at

R. Ferri
Department of Neurology IC, Sleep Research Centre, Oasi Research Institute—IRCCS, Troina, Italy

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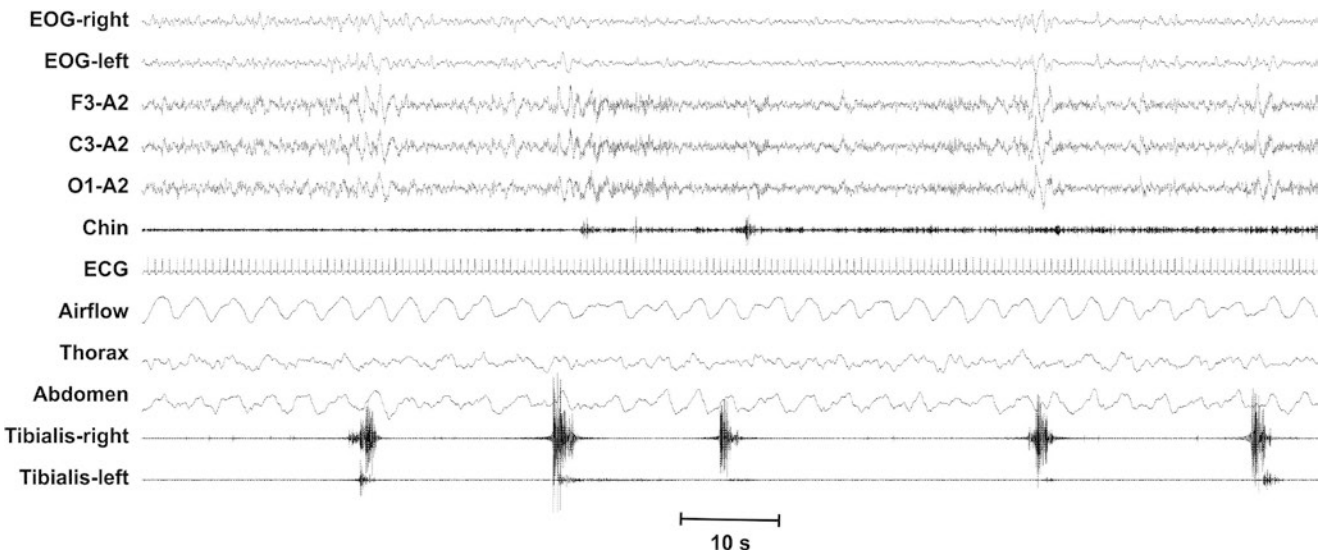

Fig. 1 Periodic leg movements (PLM) are electromyography (EMG) activities in the tibialis anterior muscle lasting 0.5–10 s, separated by 10–90 s (onset-to-onset) and occurring in an uninterrupted series of at least 4. The number of movements presenting these features per hour defines the PLM index. It can be calculated during sleep (PLMS) or during wakefulness (PLMW). Scoring criteria are provided in Ferri et al. 2016 [1]

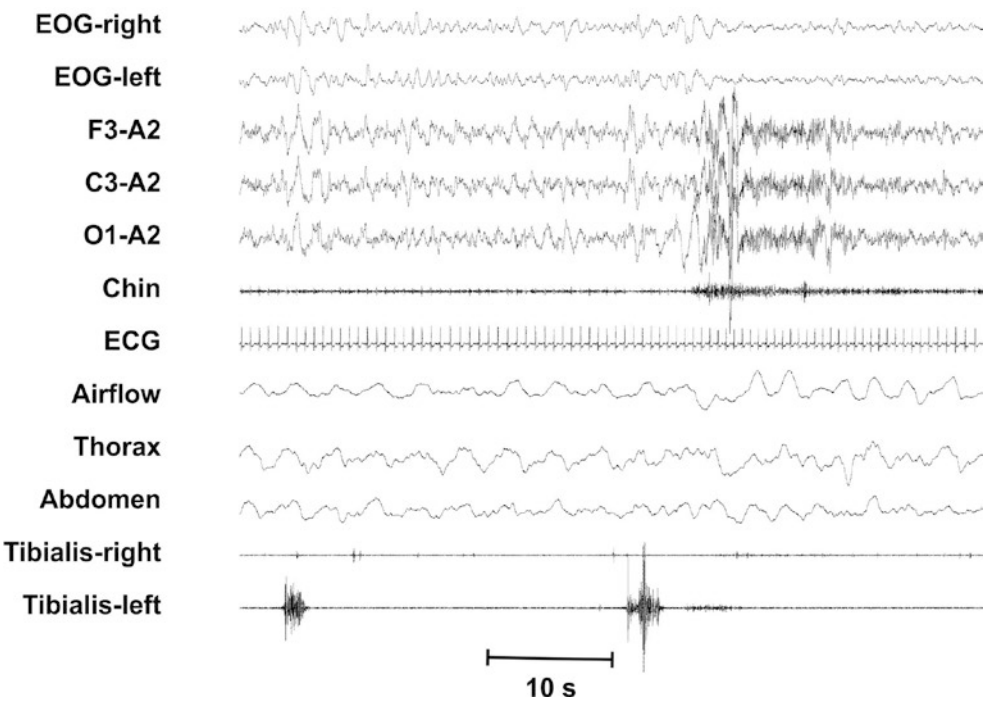

Fig. 2 A leg movement is considered associated with an arousal when there is less than 0.5 s between the end of one event and the onset of the other, regardless of which is first. The PLM/arousal index is the number of PLM events associated with arousal per hour of sleep

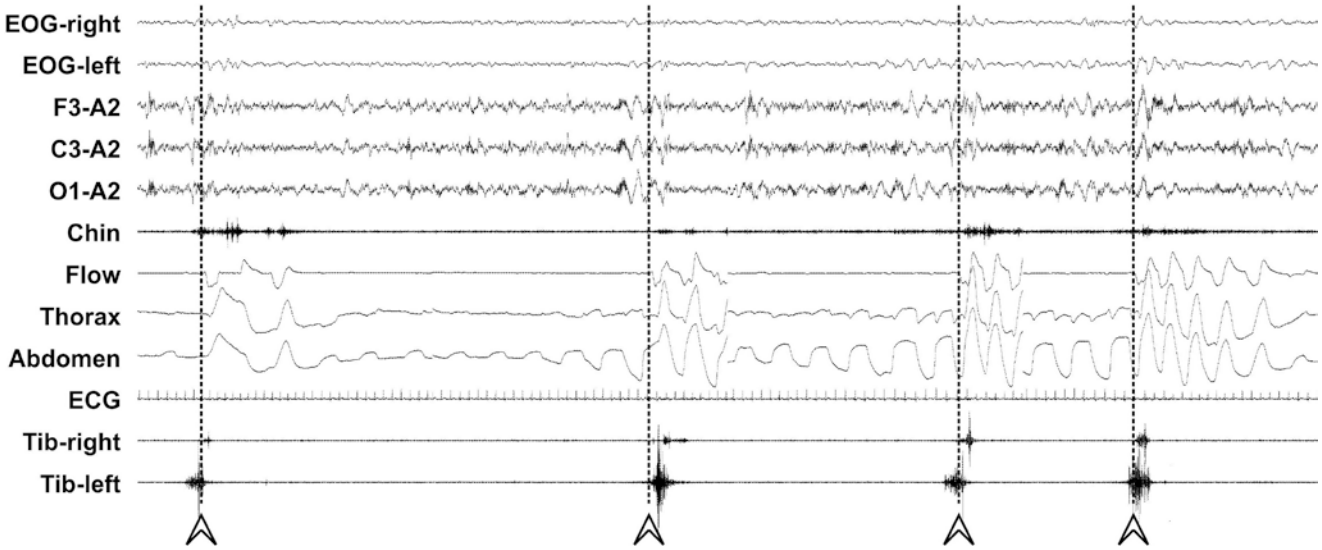

Fig. 3 A leg movement is associated with the ending of an apnea/hypopnea event when they have some part overlapping within an interval of 2.0 s before to 10.25 s after the end of a respiratory event (World Association of Sleep Medicine, WASM, criteria [1]) or when they overlap or the offset of the earlier event precedes the onset of the other by less than 0.5 s, regardless of which is first (American Academy of Sleep Medicine, AASM, criteria [2]); these leg movements can be excluded from the computation of PLM-related parameters. Arrowheads and dashed lines indicate the resumption of breathing after apnea episodes

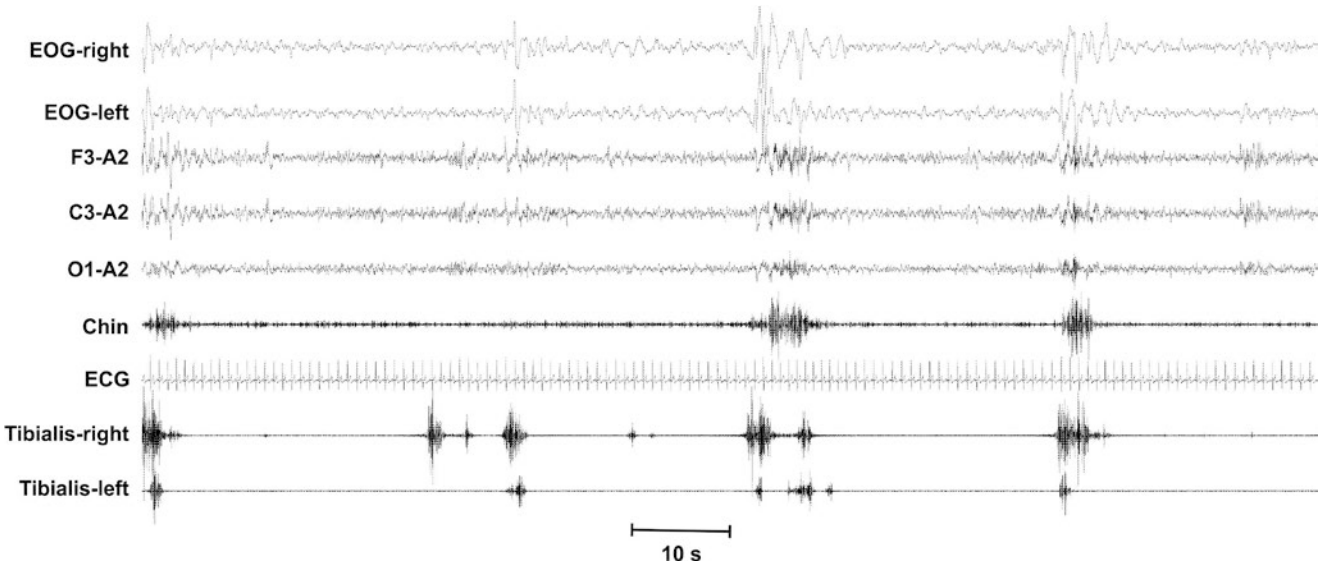

Fig. 4 The leg motor activity during sleep contains also irregular short-interval movements interrupting the regular periodic sequences and ending a PLM sequence. Also, long-interval movements (>90 s) are present that do not belong to the periodic activity. The degree of periodicity can be measured by means of the Periodicity index = number of movements in sequences of at least 4 separated by 10–90 s divided by the total number of movements including those with intervals <10 s and >90 s. Note that, differently from the computation of the PLM index, for this analysis also intervals <5 s are counted

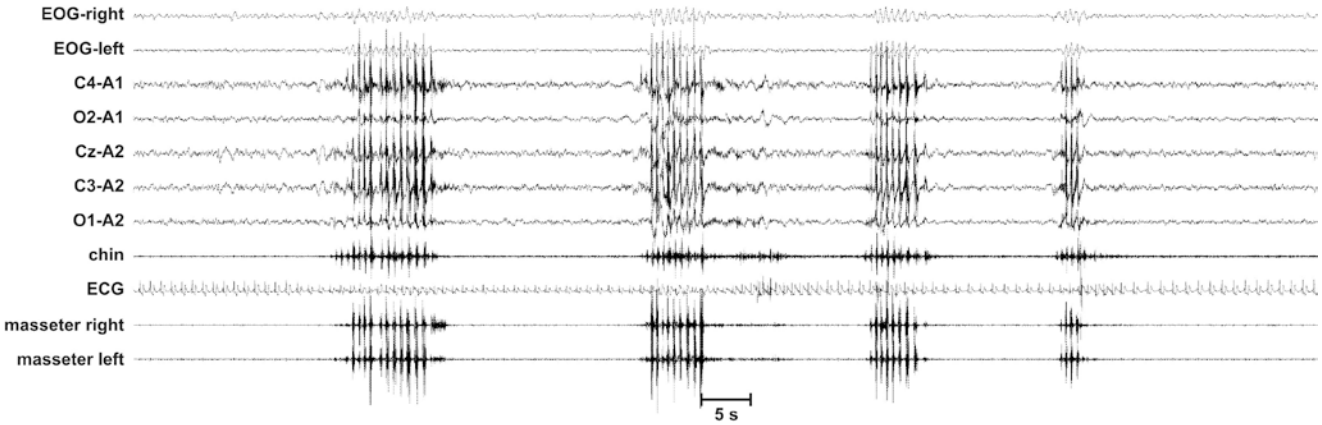

Fig. 5 Polysomnographic recording of a sequence of "rhythmic masticatory muscle activity" (RMMA: at least 3 rhythmic phasic contractions at a frequency of 1 Hz, lasting between 0.25–2 s) episodes in one subject with sleep bruxism (SB). An episode of SB may consist of RMMA, tonic (sustained contraction for more than 2 s) or mixed phasic-tonic masticatory muscle activities, associated with tooth grinding sound during sleep. Contractions shorter than 0.25 s are scored as myoclonus. Each SB episode has to be separated by a period of at least 3 s of stable background EMG to be scored as a new SB episode. SB can be scored reliably by audio-video recording in combination with polysomnography (PSG), with a minimum of 2 audible tooth grinding episodes per night, in the absence of epilepsy. The diagnosis of SB requires the presence of at least 4 episodes of SB per hour of sleep or at least 25 individual masticatory muscle bursts per hour of sleep, accompanied by at least 2 audible episodes of tooth-grinding noise. For the scoring of SB, the recommended chin EMG electrodes have been indicated to be sufficient, but additional masseter and/or temporal EMG can be helpful, in accordance with the discretion of the investigator or clinician

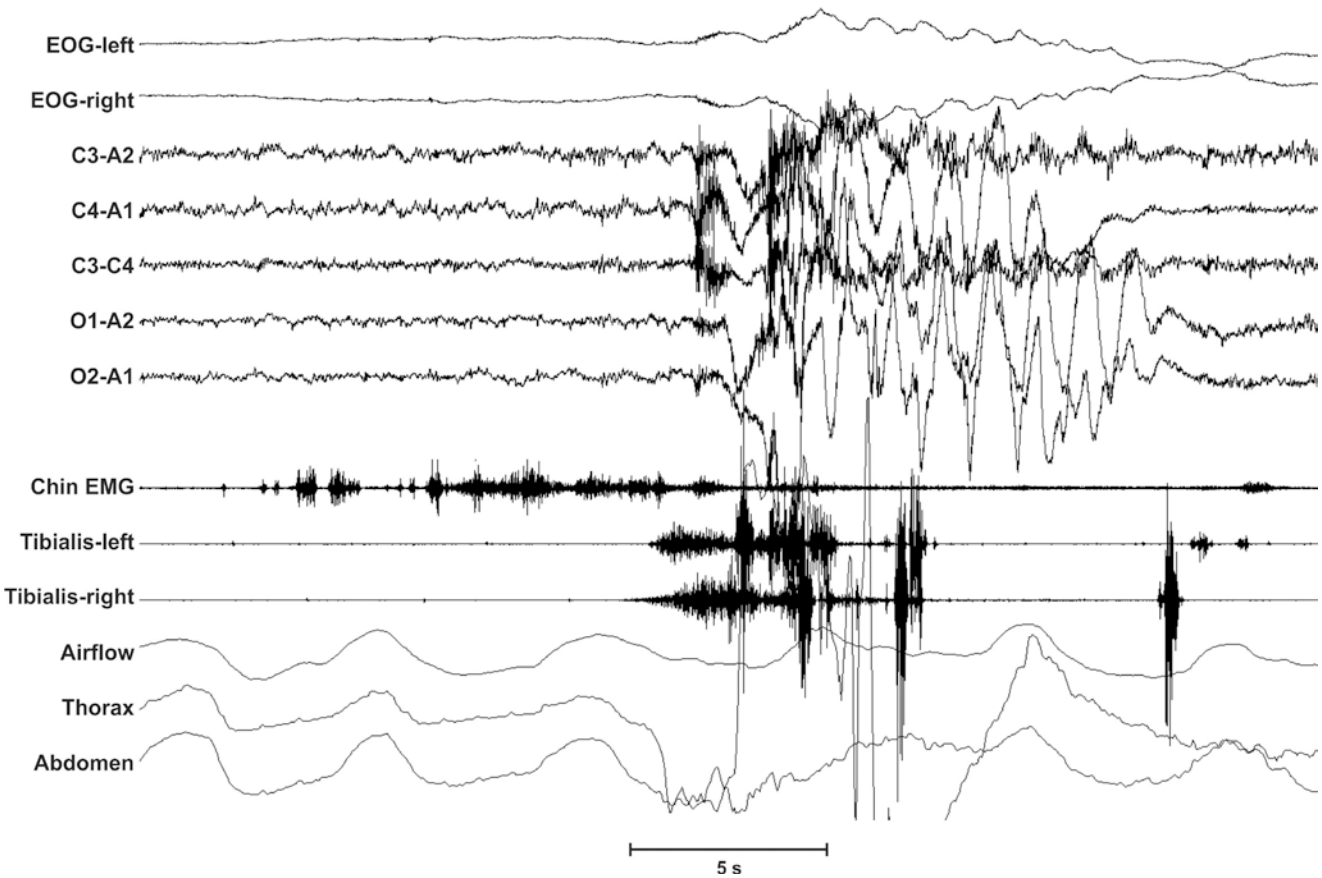

Fig. 6 Polysomnographic recording of a rhythmic movement disorder episode. Rhythmic movement disorder consists of repetitive, stereotyped, and rhythmic motor behaviors, such as head banging, head rolling, body rocking, and body rolling. As the movements involve large muscle groups, often the polysomnographic recording shows mainly movement artifacts. The behavior arises during wakefulness or during superficial sleep stages, rarely also in REM sleep around arousals, for instance respiratory arousals. If possible, the frequency of the repetitive movements should be reported (usually between 0.5–2 Hz), as well as the duration of the episode, and it should be indicated during which sleep stage or W it arises, and/or if it is associated with an arousal

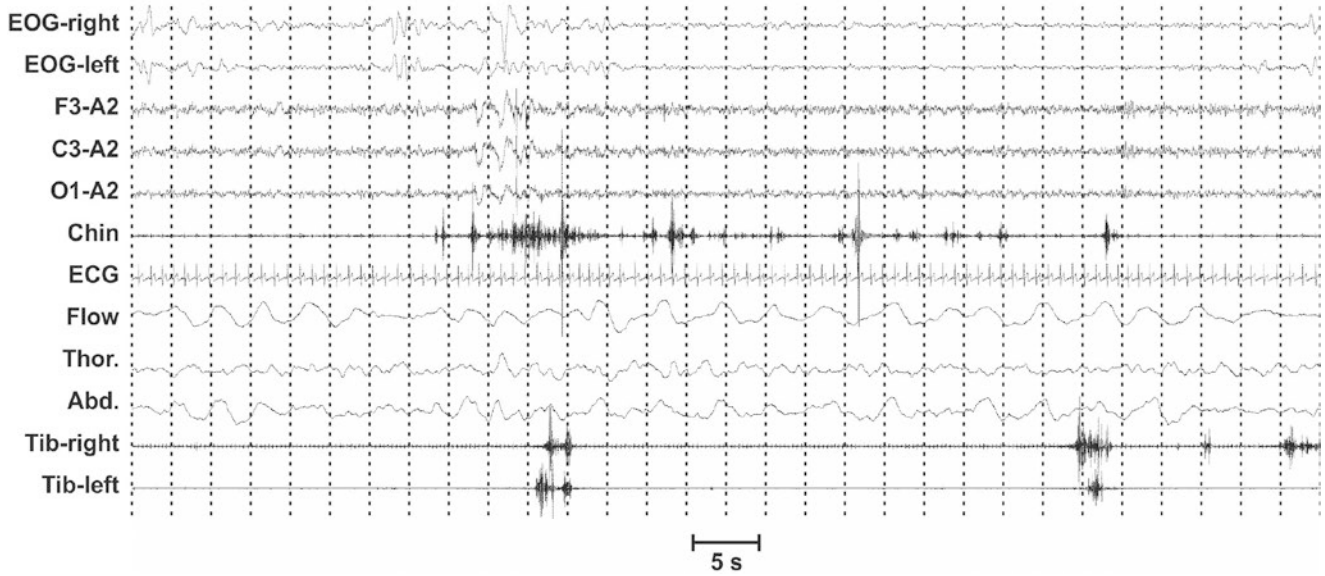

Fig. 7 Excessive transient (phasic) chin EMG activity bursts (0.1–5 s in duration and at least 4 times as high in amplitude as the background EMG activity) and PLMS (tibialis anterior EMG channels) in a PSG recording of one patient with REM sleep behavior disorder (RBD). The phasic chin EMG activity can be quantified by subdividing REM sleep into 3-s miniepochs [3] and counting those including phasic bursts as defined above, and then dividing this number for the total number of REM sleep mini-epochs. In this example, 13 miniepochs out of 30 (43.3%) included phasic chin EMG activity

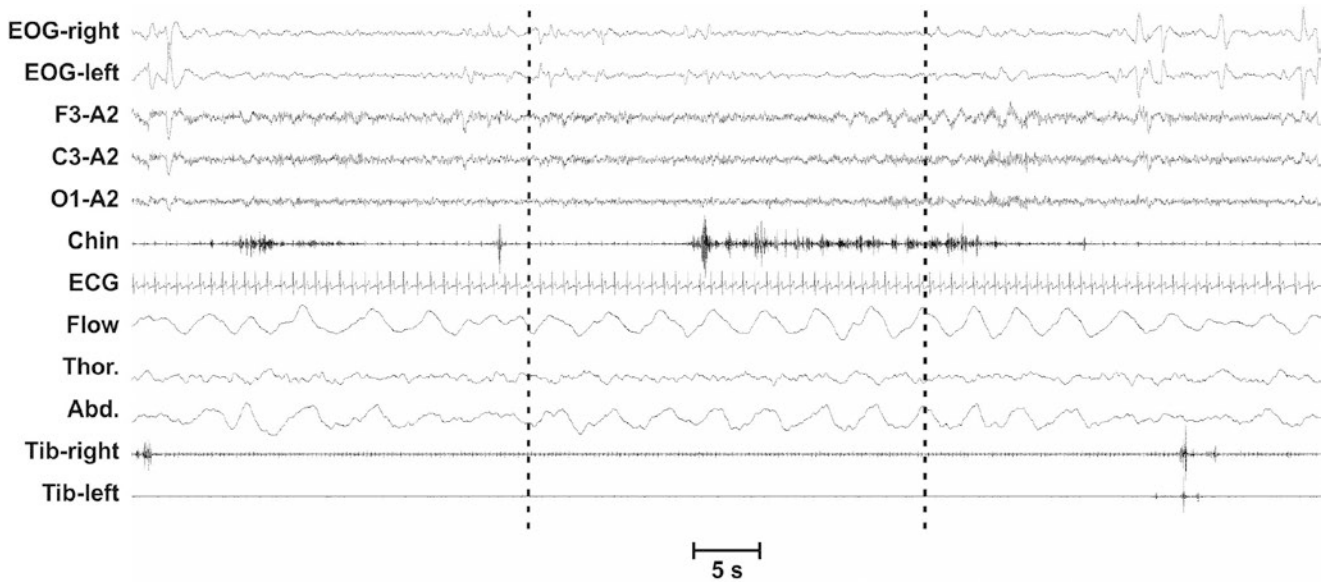

Fig. 8 Excessive tonic chin EMG activity (at least 50% of the duration of the epoch having a chin EMG amplitude greater than the minimum amplitude than in NREM) in the middle 30-second epoch in a PSG recording of a patient with REM sleep behavior disorder. For "any" muscle activity (tonic, phasic and/or anything in between) when using 3-s miniepochs, the proposed cutoff with 100% specificity for RBD is 18.2, and 14.5 when analyzing based on 30-s epochs [4]

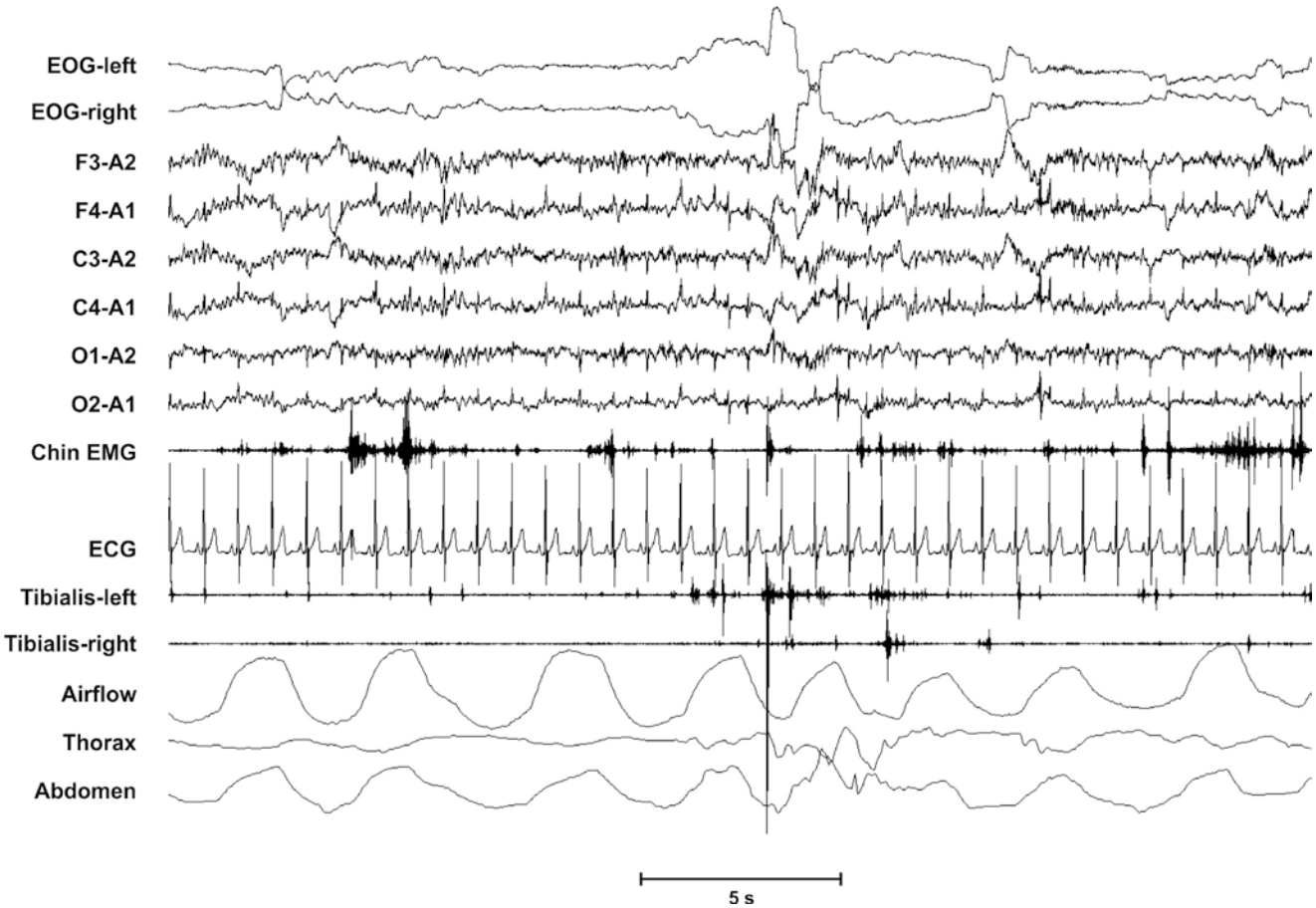

Fig. 9 This figure gives an example of tonic and phasic muscle activity in the chin and phasic activity in the tibialis anterior muscles. Quantification of any muscle activity in the chin (irrespective if it is tonic or phasic) plus quantification of phasic muscle activity in two upper extremity muscles has a very high sensitivity and specificity for RBD (and has therefore been proposed as the preferred minimal muscle combination for diagnosis of RBD by the SINBAR group [4, 5]). To achieve a 100% specificity for RBD, a cutoff of 31.9% for any chin and phasic extensor digitorum superficialis has been proposed when calculating quantification based on 3-s miniepochs, and 27.2% when using 30 s epochs [5]. However, many laboratories only record EMG from chin and tibialis anterior muscles. Here the proposed cutoff for diagnosis of RBD is 46.6% for 3 s mini-epochs (any chin plus phasic tibial anterior from both sides), and 42.5% for 30 s epochs, but area under the curve for the combination chin-tibialis anterior muscle is slightly lower

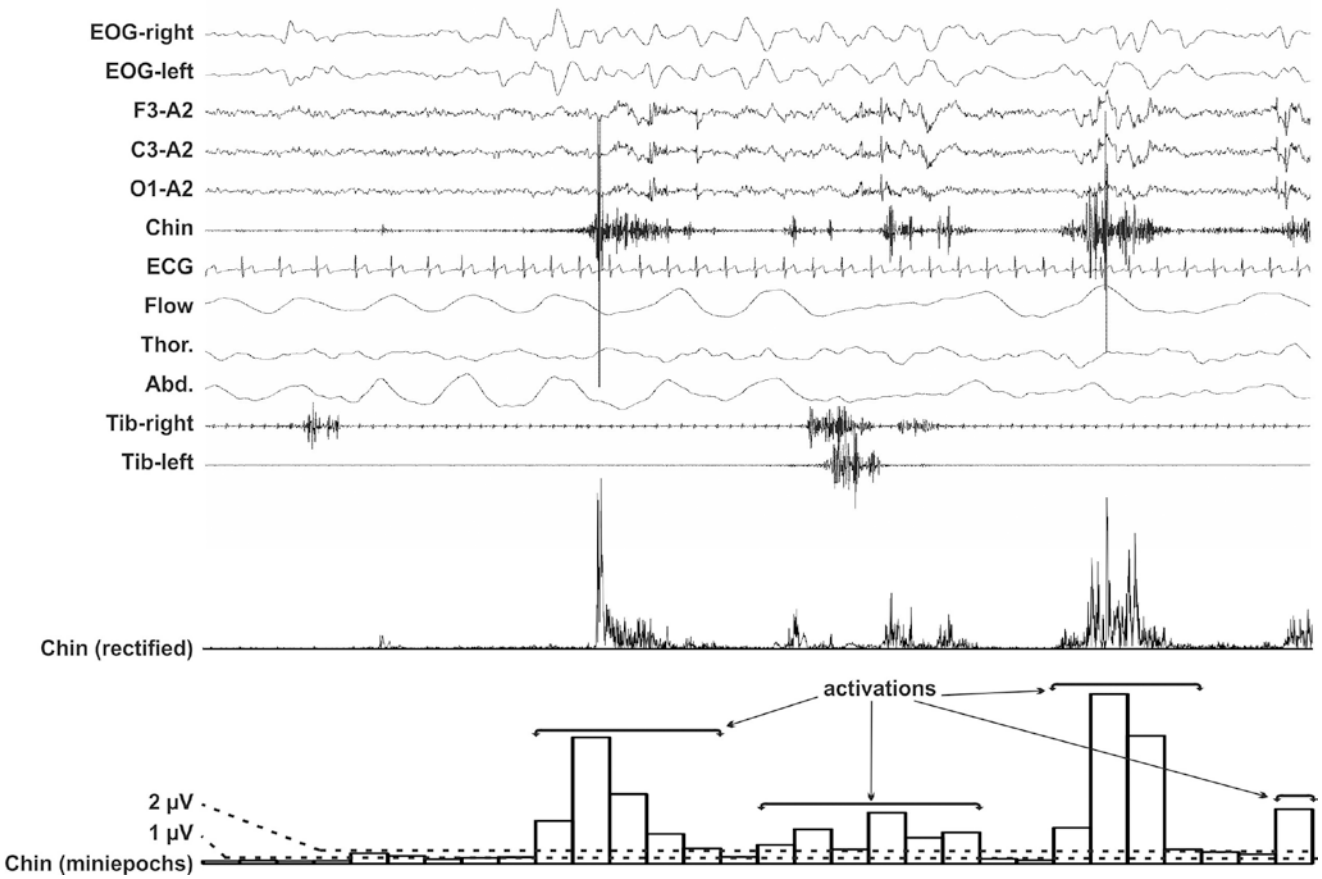

Fig. 10 Example of the calculation of the Atonia Index on one PSG REM sleep epoch of a patients with REM sleep behavior disorder. The chin EMG signal is first rectified, then its average amplitude for 1-s miniepochs is calculated. Activations are defined as single or sequences of consecutive miniepochs exceeding the threshold of 2 μV (16 miniepochs in this example); the Atonia index is computed as the ratio of the number of miniepochs exceeding the threshold of 2 μV to the total number of miniepochs, excluding those with average amplitude >1 ≤ 2 μV (5 miniepochs in this example). Thus, in this example, Atonia index = 16/25 = 0.64. Total REM sleep Atonia index >0.9 denotes normal atonia; Atonia index ≥0.8 ≤0.9 indicates a mild/moderate atonia reduction, and Atonia index <0.8 indicates clearly reduced atonia [6]

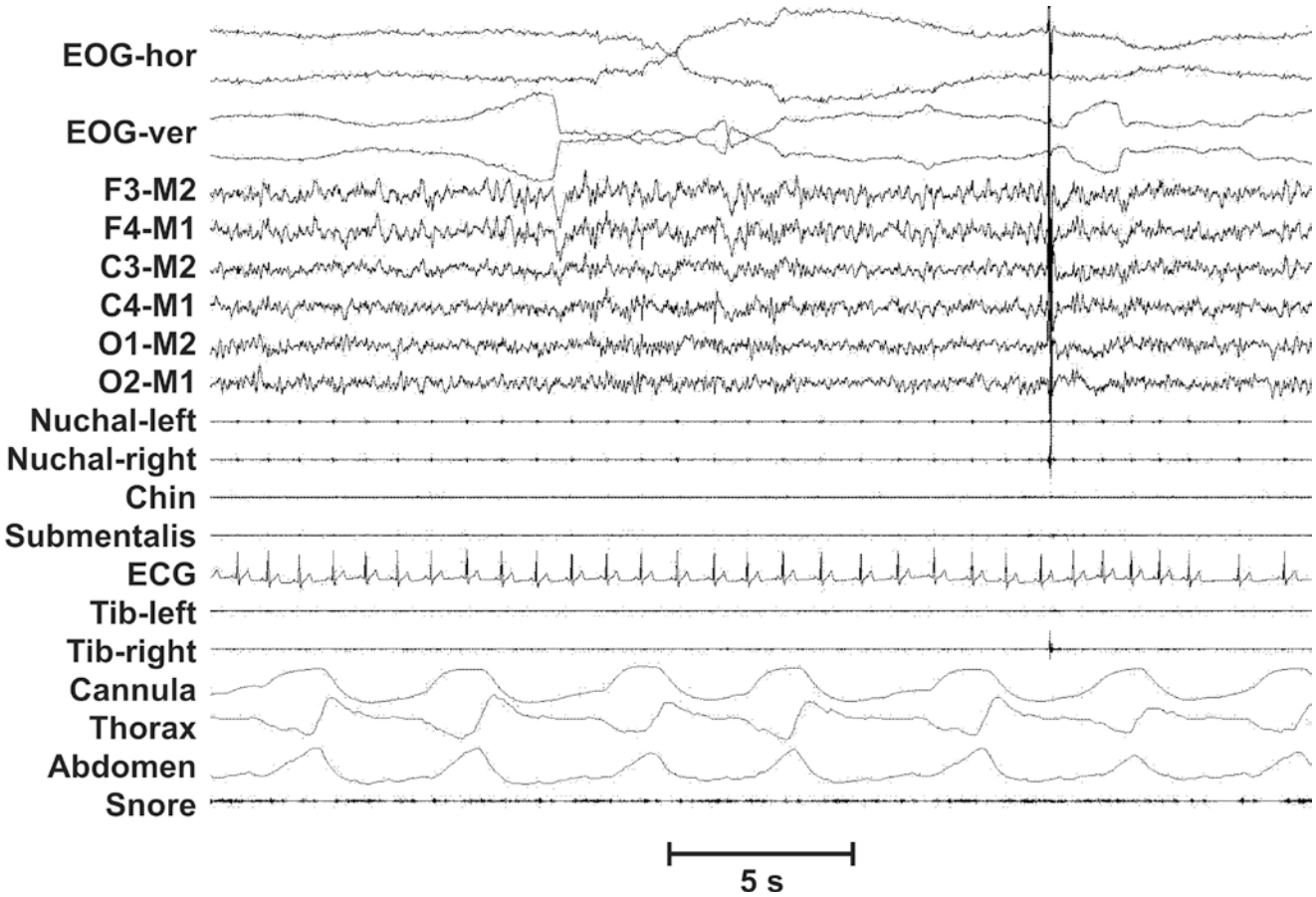

Fig. 11 Polysomnographic recording of neck myoclonus (head jerk), characterized by a movement associated with a short stripe-shaped movement-induced artifact over the EEG leads during REM sleep

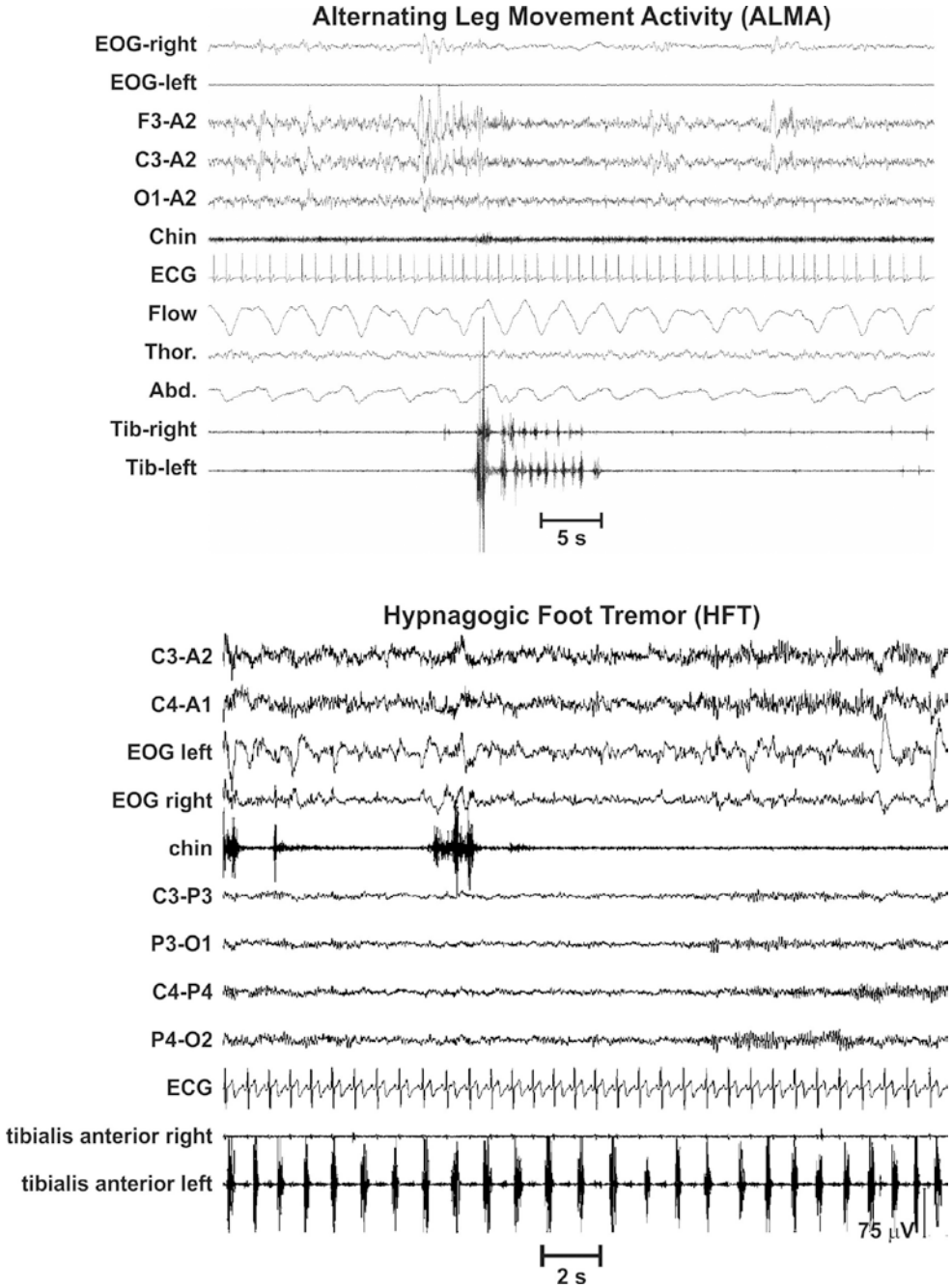

Fig. 12 Top panel: polysomnographic recording of alternating leg muscle activation (ALMA) during sleep, a quickly alternating pattern of anterior tibialis activation occurring at a frequency of approximately 1–2 Hz, lasting between 0.1 and 0.5 s each, organized in sequences of alternating activations lasting up to 20–30 s. Bottom panel: Hypnagogic Foot Tremor (HFT), at the transition between wake and sleep or during light sleep PSG recordings show the presence of recurrent EMG potentials or foot movements typically at 1–2 Hz (range 0.5–3 Hz), in one or both feet. The EMG bursts are longer than those of myoclonus (>250 ms), they last usually less than 1 s and are organized in trains lasting 10 or more seconds

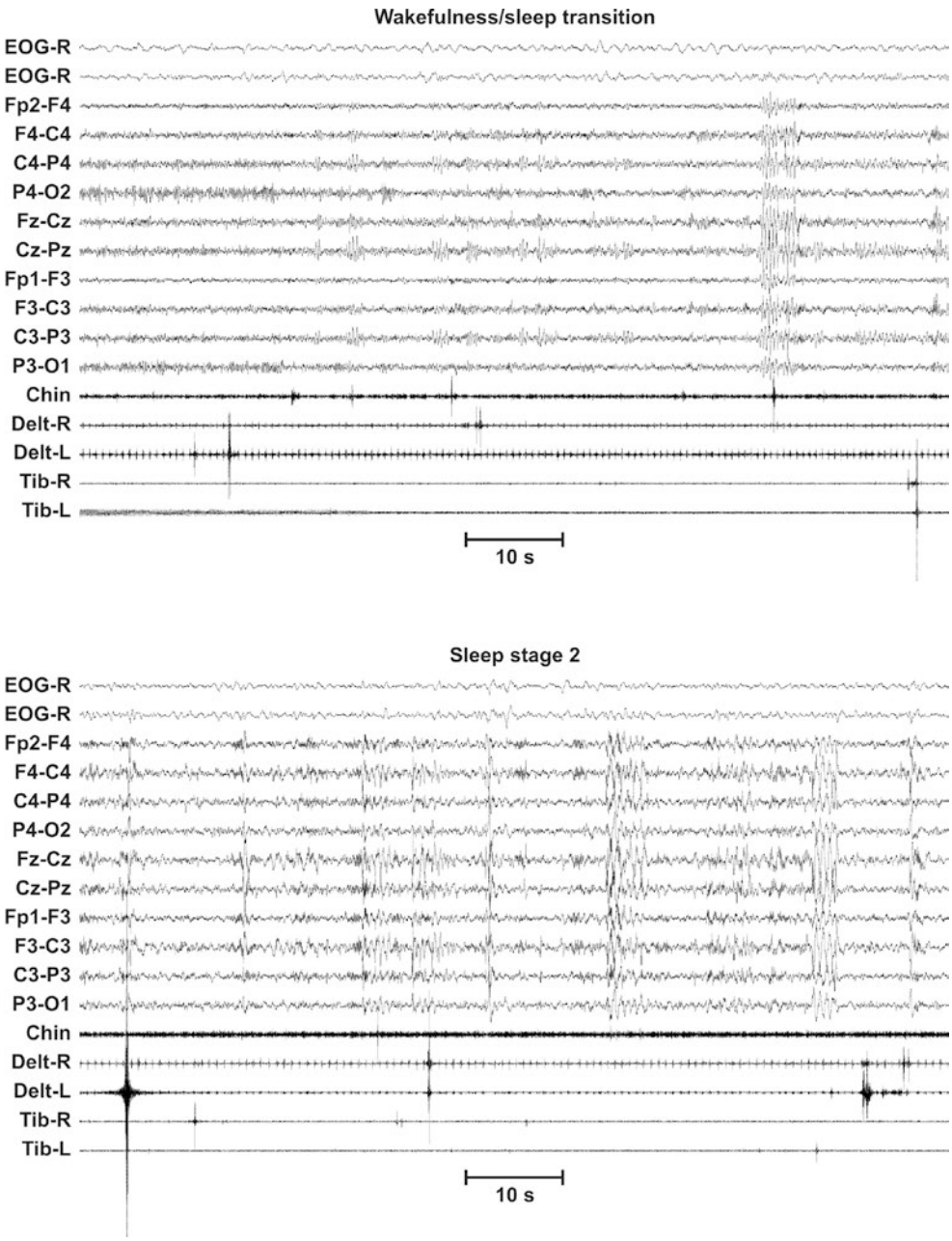

Fig. 13 Excessive fragmentary myoclonus (EFM) at the wakefulness/sleep transition and during sleep stage two. EFM is characterized at PSG by recurrent and persistent, very brief (75–150 ms) EMG potentials in various muscles, occurring asynchronously and asymmetrically, in a sustained manner, without clustering. More than 5 potentials per minute should be sustained for at least 20 min of stage N2 or slow-wave sleep. EFM can be quantified by means of the myoclonus index that is defined as the number of 3-s mini-epochs containing at least one fragmentary myoclonus potential fulfilling the criteria, counted for each 30-s epoch and resulting in a number between 0 and 10

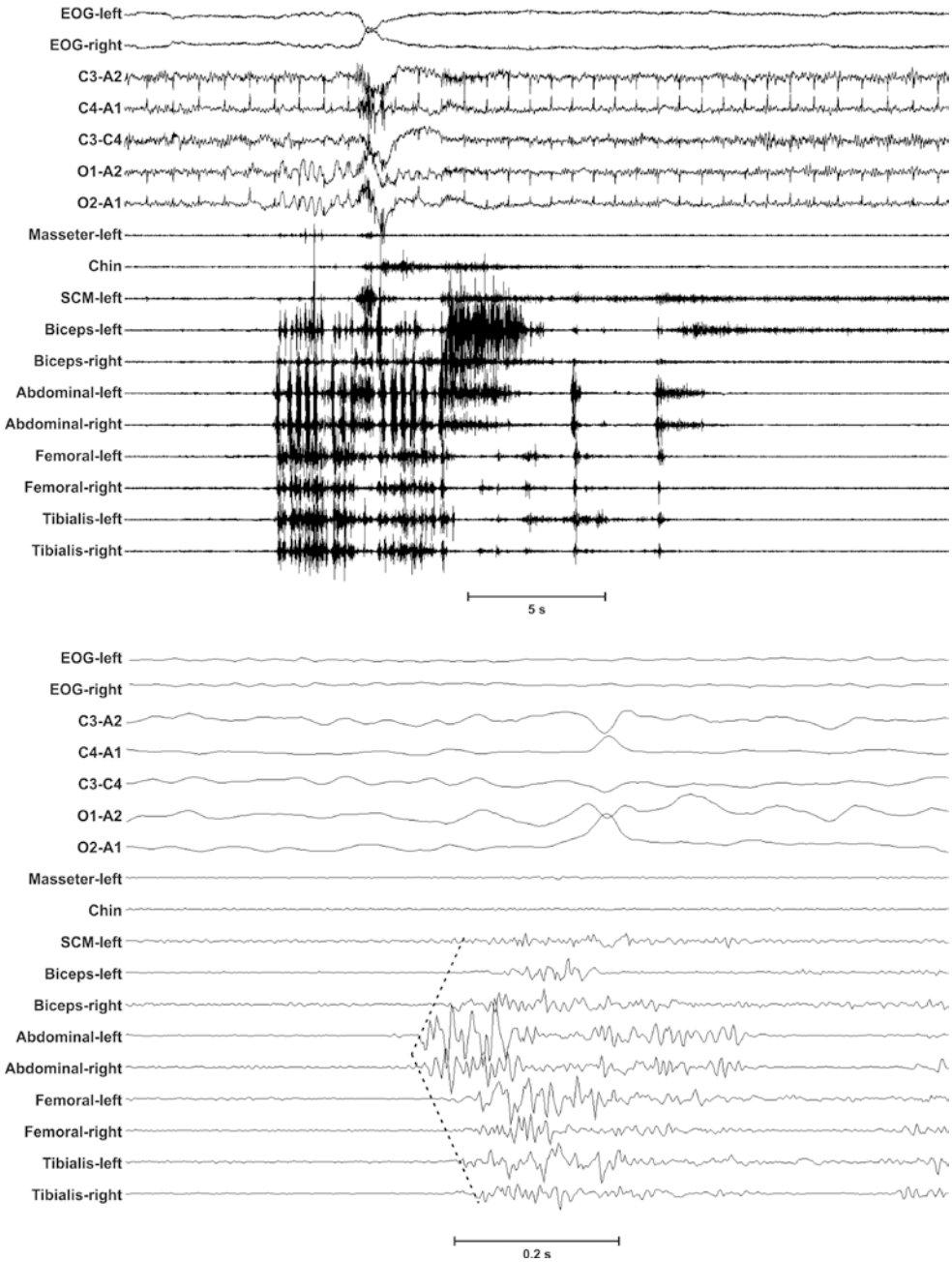

Fig. 14 Spreading of muscle activation, rostrally and caudally, starting from abdominal muscles in one patient with propriospinal myoclonus (PSM). PMS is characterized by generalized and symmetric jerks that arise during the transition between wakefulness and sleep, from axial muscles of the abdomen, thorax or neck, and spread rostrally and caudally to the other myotomes by means of slow propriospinal polysynaptic pathways. No quantitative PSG features have been described and its description is basically qualitative

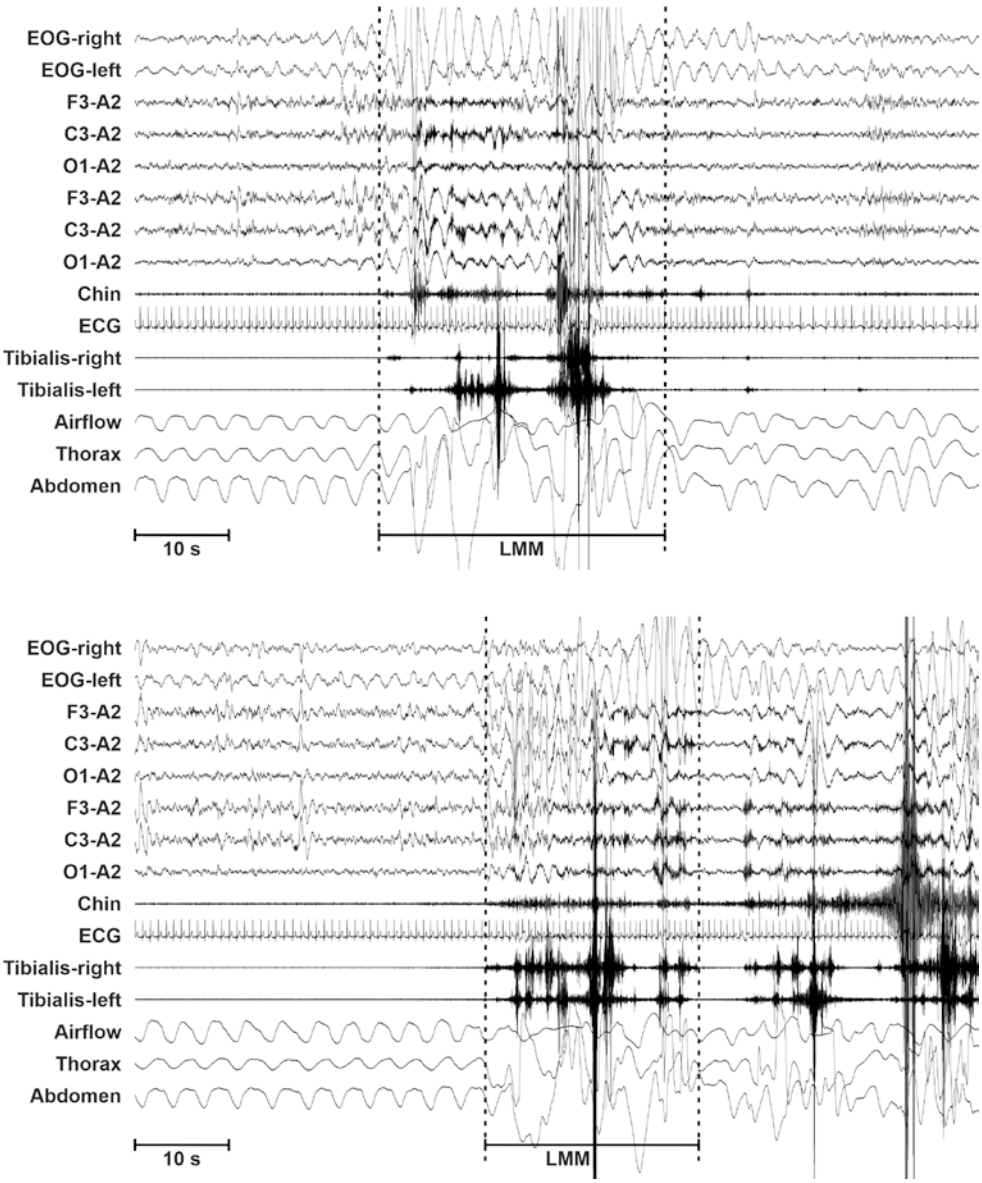

Fig. 15 A large muscle group movement (LMM) is defined as a temporally overlapping increase in EMG activity and/or movement artifact in any combination of at least two recommended channels, with an amplitude at least twice the background, with a duration of 3–30 s for children and 3–45 s for adults. Criteria for scoring of LMM have been developed by a taskforce of the International Restless Legs Syndrome Study Group [7]. Top panel: LMM starting in stage N2 with EMG activity in all recorded muscles (chin and tibialis anterior bilaterally), and movement artefacts in the EOG, EEG, ECG, and respiratory channels. The LMM is followed by sleep stage N2. Bottom panel: LMM starting in stage N3, associated with awakening. EMG activity is present in all recorded muscles and movement artifacts are visible in the EOG, EEG, ECG, and respiratory channels. An LMM and an awakening are considered associated with each other when they occur simultaneously or when the awakening occurs while the movement lasts or within 0.5 s from its end

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