Quantifying Leg Movement Activity During Sleep

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KEYWORDS

- Periodic leg movements during sleep • Periodic leg movements during wakefulness
- Alternating leg muscle activation • Hypnagogic foot tremor • High-frequency leg movements
- Excessive fragmentary myoclonus

KEY POINTS

- The recording and scoring of limb movement activity during sleep is an essential component in the characterization of periodic leg movements during sleep.
- Currently, 2 sets of similar (but not identical) rules for recording and scoring periodic leg movements during wakefulness and sleep exist.
- Periodic limb movements are the most frequent type of activity during sleep. However, also other, less frequent limb movement activities can be recorded.
- Digital recording of leg muscle electromyography during a nocturnal polysomnography represents the gold standard method.
- Several elements of the current rules lack an empirical foundation and recent data-driven studies are expected to give the basis for new and improved rules.

INTRODUCTION

The recording and scoring of leg movement activity (LMA) during sleep is an essential component in the characterization of sleep and a required component in the assessment of periodic leg movements (PLMs) during sleep (PLMS). Besides characterizing PLMS, there are several other leg movement (LM) patterns, mostly high-frequency, which can be identified during sleep, such as alternating leg muscle activation (ALMA), hypnagogic foot tremor (HFT), or high-frequency LMs (HFLMs).[1]

Currently, 2 sets of similar (but not identical) rules for recording and scoring PLMS and PLMs during wakefulness (PLMW) exist. These were partly informed by algorithms proposed for the automatic detection of LMs in polysomnographic (PSG) recordings [2] and include mathematically defined parameters such as thresholds, intervals, and amplitude.[3,4] First, in 2006 a task force of the International Restless Legs Syndrome Study Group endorsed by the World Association of Sleep Medicine (WASM/IRLSSG)[5] introduced a major revision of the scoring rules, which were then substantially (but not entirely) adopted by the American Academy of Sleep Medicine (AASM) in 2007,[6] and are being periodically updated.[7] Scoring criteria for LMs other than PLMS are specified in the AASM rules.

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This article reviews the basic recording methods, scoring rules, and computer-based automatic detection programs for LMA during sleep with a focus on PLMS, the most frequent type of LMA during sleep.

BASIC RECORDING METHODS

Electromyography

Surface electromyography (EMG) is the gold standard for recording leg muscle activity during sleep. It is acquired by means of silver-chloride electrodes attached to the inputs of a differential amplifier to obtain a bipolar derivation. It is usually recommended that interelectrode impedance should be at least less than 10 KΩ (but better <5 KΩ).[5] The skin preparation procedure, before electrode placement, is very important and may include shaving any excess hair, cleaning the skin with alcohol pads, and light abrasion. For a better adhesion of the electrodes, the use of collodion is recommended because it is nonconductive; holds through hair (not only on the scalp), oils, and perspiration; and provides high performance for long-term recordings. However, collodion is highly flammable and produces fumes; thus, appropriate air purifier, fume extractor, or ventilation systems should be used. Finally, a conductive paste for long-term recordings must be used to ensure a good electrical contact between the skin and the electrodes.

Surface EMG electrodes should be placed at 2 to 3 cm apart or one-third of the length of the anterior tibialis muscle, whichever is shorter. Electrodes must be located longitudinally on the muscles, symmetrically around the middle. EMG signals must be obtained from both the right and the left leg, and recording the 2 signals in 1 channel is strongly discouraged. Baseline resting EMG amplitude (ie, in the relaxed muscle) should be ±2 to 3 μV (4–6 μV peak-to-peak; WASM/IRLSSG)[5] or 10 μV or less (AASM).[7] The WASM/IRLSSG rules recommend that, before the recording, a calibration should be carried out to obtain from the relaxed anterior tibialis muscles a nonrectified signal no greater than ±5 μV (or 10 μV peak-to-peak, 5 μV for rectified signals) for clinical purposes, and ±3 μV (or 6 μV peak-to-peak, 3 μV for rectified signals).[5]

EMG signals are produced by the muscle situated under the skin and adipose tissue below the electrodes, which are able to record activity of superficial muscle. Muscle size and amount of adipose tissue significantly influence the amplitude of the surface recorded EMG signal. This is the reason why surface EMG signals are considered semiquantitative and calibration of EMG activity is recommended.[5] The amplitude of surface EMG potentials depends also on the distance between the recording electrodes and can range between less than 20 μV and up to several mV, depending on the factors previously listed.

EMG signals are constituted of superimposed motor unit action potentials produced by several motor units, each with a typical repetition rate of firing of about 7 to 20 Hz. Surface EMG records the sum of this activity and produces a signal with a wide spectrum. Thus, the spectral content of the EMG signal requires high sampling rates that should never be lower than 200 Hz; 400 to 500 Hz are usually recommended.[5,7] Band-pass filtering is usually applied, with typical settings at approximately 10 to 100 Hz and with a notch filter at 50 or 60 Hz, depending on the power line frequency.

Actigraphy

Actigraphy refers to devices whose sensors integrate motion amplitude and speed, and whose output is a signal with magnitude and duration, depending on these motion features. This signal is appropriately amplified, filtered, and digitized to be stored in the device memory, most often in terms of movement counts per epoch. The length of the epoch is of crucial importance and can be fixed at 1 minute or can be chosen by the user (from a fixed list of epoch lengths). Epoch length is very important because, in conjunction with the memory capacity of the device, it determines the maximum recording time. Data are stored essentially in 3 different ways by actigraphs. Some of them allow the user to select the preferred mode, whereas others do not. With the time-above-threshold mode, the amount of time per epoch during which activity exceeds the set threshold is stored. The zero-crossing mode assesses the number of times per epoch that the activity signal produced by the accelerometer crosses a threshold set around zero. Finally, with the proportional-integration (or digital) mode, the area under the curve is stored for each epoch. Some devices allow the simultaneous use of multiple modes. There are no conclusive statements in the literature on which is the most accurate among these modes.

Actigraphy is typically worn at the wrist to monitor rest-activity cycles for several days or weeks; however, for the assessment of LMA, actigraphic monitoring of foot movements or LMs has been proposed.[8,9] When used for the assessment of LMA, sampling rate of the actigraphy must be considerably higher: 10 Hz or more.[5] Because it offers the possibility to record multiple nights in a home environment, it has been proposed as a