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An Automatic Algorithm for the Detection of Periodic Leg Movements

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Abstract: *In order to enable automatic detection of periodic leg movements (PLM), an algorithm based on the evaluation criteria of the American Academy of Sleep Medicine (AASM) and the World Association of Sleep Medicine (WASM) has been developed. The algorithm allows a fully automated analysis of leg movements (LM), and includes an optional manual control and correction. The PLM analysis can be done separately for each leg. In another step, the two separate analyses can be merged and unilateral and bilateral PLM events can be determined.*

Keywords: *PLM, PLM analysis, LM, Leg-EMG*

Introduction

Periodic leg movements (PLM) can occur while awake and during sleep. PLMs are short consecutive leg movements (LM), with a typical periodicity of 20 to 40 seconds (s) intervals between single LMs [1]. PLMs can cause blood pressure elevations [2] and untreated patients show a higher prevalence of cardiovascular diseases [3]. PLMs occur in more than 80% of patients suffering from Restless Legs Syndrome (RLS) [4,5]. According to the American Academy of Sleep Medicine (AASM) standard criteria [6], an LM is defined as an increase of ≥ 8 μV from the resting baseline (rb) of the musculus anterior tibialis [6]. This requires an rb ≤ 5 microvolt (μV); typical physiological resting baseline values range from about 1 to about 3.5 μV. The duration of an LM is between 0.5 and 10 s, four or more LMs compose a period and are subsequently called PLMs. The distance between two PLMs has to be between 5 and 90 s.

These criteria for PLMs differ from previous criteria in several points. The most important difference is the introduction of absolute voltage based amplitude criteria for the beginning and the end of a LM. The superseded older criteria relied on relative amplitude criteria: the amplitude of an activity had to exceed 25% of the amplitude achieved during biosignal testing (flexing of toes during wakefulness) [7]. We consider the newer criteria more suitable for automated algorithmic analysis. To our knowledge, there is no published algorithm using these PLM definitions. We therefore developed an algorithm for the automatic detection of PLMs according to AASM criteria [6].

Methods

The algorithm has been tested and validated using > 50 measurements performed in RLS patients according to standard criteria [6] in different sleep disorders centres. These sleep studies were conducted with different polysomnographic (PSG) equipments. All recordings were exported into the European Data Format [8]. If the leg-EMGs were not filtered, high-pass (10 Hz) and low-pass filter (100 Hz) were applied according to AASM criteria [6].

For the automated analysis, leg-EMG signals are rectified. The algorithm then determines the rb of the EMGs. LMs are considered to begin when activations of the leg-EMG exceed the 8 μV onset threshold above rb. LMs end when the activity falls below the offset threshold of 2 μV above rb for at least 0.5 s (Fig. 1). The first step of the automatic analysis is finished with the identification of LMs. These LMs can then be edited by the user and e.g. artefacts can be taken out. The next step is the analysis of periodicity. According to the standards of the World Association of Sleep Medicine (WASM), the Periodicity "can be evaluated in either separate channels, one for each side, or combining the events detected in both sides" [9]. Accordingly, our algorithm performs a periodicity analysis for each leg-EMG and allows a combined analysis.

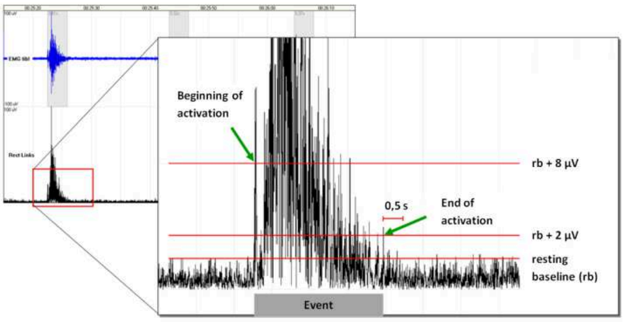

Figure 1: Leg-EMG tracing showing an LM with rb and thresholds for beginning and end of the LM marked.

The distance between two PLMs is calculated from the respective start of PLMs. LMs become PLMs if at least four of them occur in a sequence and each PLM begins 5 to 90 s after the previous PLM. After the separate PLM analysis, the events are collected and classified (left, right, and bilateral). If events are overlapping left and right or the end of the first event and the beginning of the second event are less than 0.5 s apart, they will be classified as a bilateral event.

The results of the finished PLM analysis can now be combined with other results from the evaluation of PSG recordings like time in bed, arousal events, sleep-disordered breathing, sleep stages etc.

Detailed descriptions of the algorithm will be included in the poster presentation.

Results

Our algorithm was used in > 50 recordings from different sleep disorders centres. Compared to a visual analysis, it has proven to be very objective, reliable and has delivered reproducible results. During development and refinement, its results were compared to expert evaluations from board certified sleep specialists and board certified sleep technicians. Results from the final form of the algorithm were considered valid by these specialists.

Detailed results regarding validity of this new algorithm will be included in the poster presentation.

The implementation of our algorithm into study related evaluations has also yielded an unexpected result: a widely used system for PSG recordings showed leg-EMG tracings with unphysiological high rb values of 20 to 30 µV. Assuming correct electrode placement, such baseline values are physically impossible and render an analysis according to AASM criteria impossible. A hardware defect was identified as source of this problem and subsequently corrected.

Discussion

The validation of the algorithm has shown that our automatic algorithm for detection of PLMs works very well. It is efficient, objective and reliable.

Compared to previous purely visual analyses, it requires a better technical quality of PSG recordings. While a trained technician can "ignore" ECG artefacts, floating baseline values and wrong amplitudes of leg-EMGs (especially with relative amplitude criteria for LMs), a computer program applying the algorithm presented here requires technically good recordings with very little artifacts.

The AASM criteria for PLMs do not tolerate bad signal quality especially if they are implemented into an automatic analysis as the one presented here for the first time.

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