

PLM Analysis Noxturnal 6.x

Starting with Noxturnal 6.0, changes were made to the automatic LM / PLMS analysis to meet the AASM 2017 requirements. This support article describes the changes made to the algorithm in Noxturnal 6.0, explains the concordance with AASM 2017, and explains PLM automatic analysis in Noxturnal 6 and higher versions compared to previous Noxturnal versions.

AASM 2017 Scoring LM / PLMS versus Noxturnal 6.x

LM (Leg movement):

Episodes of high muscular activity or kinetic activity and are identified as limb movement (LM) events. LM events should meet the following criteria:

AASM 2017 - Rules	Implementation in Noxturnal
<ul style="list-style-type: none"> Onset: Amplitude of at least 8 microvolts over baseline (fully implemented) End: Amplitude of only 2 microvolts over baseline (fully implemented) 	<div style="border: 1px solid black; padding: 5px;"> <p>Threshold Type: Absolute v</p> <p>Onset Threshold: 8 uV change from background</p> <p>Offset Threshold: 2 uV change from background</p> </div>
<ul style="list-style-type: none"> Duration: 0.5-10 sec in duration (fully implemented) 	<div style="border: 1px solid black; padding: 5px;"> <p>Limb Movement (LM)</p> <p>Minimum Duration: 0.5 seconds</p> <p>Maximum Duration: 10 seconds</p> </div>
	<ul style="list-style-type: none"> If muscle activities meeting the onset/end and duration criteria but are not separated by a minimum of 0.5 sec, they will be joined together as one event. If this adds to a total duration longer than 10 sec → no LM event will be scored. The maximum allowed amplitude should contribute to the elimination of artifact scoring as LM. <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p>Minimum Inter-Movement Interval: 0.5 seconds</p> <p>Maximum Allowed Amplitude: 300 uV</p> </div>
	<ul style="list-style-type: none"> An alternative ruleset according the WASM is available in the settings (and used as default): <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p>Threshold Type: Relative v</p> <p>Onset Threshold: 5 Times background</p> <p>Offset Threshold: 3 Times background</p> </div>

Summary: The limb movement detector detects bursts of muscular activity in the leg EMG channels. In order for a **LM event** to be scored, the bursts must last at least 0.5 seconds (Minimum Duration) and at most 10 seconds (Maximum Duration). Two adjacent bursts must be separated by at least 0.5 seconds (Maximum Inter-Movement Interval). The muscle activity threshold can be chosen as relative or absolute

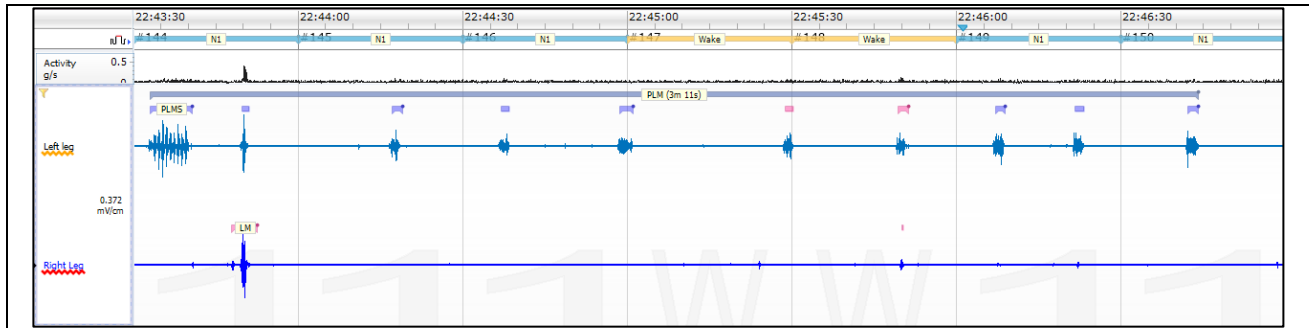
and has two levels for movement onset and offset. These values meet the AASM 2017 requirements and can be seen and modified in the analysis settings.

PLMS (Periodic Leg movement in Sleep)

The PLM algorithm uses LM events that are either scored manually or by the automatic PLM analysis* to identify periodic limb movements.

AASM 2017 – Rules	Implementation in Noxturnal
<ul style="list-style-type: none"> A minimum of 4 LM events which are separated each by a minimum of 5 but not more than 90 seconds qualifies for these LM to be scored as PLMS. (fully implemented) 	<div> <p>Periodic Limb Movement in Sleep (PLMS)</p> <p>Minimum Number of LMs: <input type="text" value="4"/></p> <p>Minimum Interval Between LM Onsets: <input type="text" value="5"/> seconds</p> <p>Maximum Interval Between LM Onsets: <input type="text" value="90"/> seconds</p> </div> <div> </div>
<ul style="list-style-type: none"> LM and Respiratory Events: LM / PLMS should not be scored if they occur during a period from 0.5 seconds preceding- to 0.5 seconds following an apnea, hypopnea, or RERA events. (fully implemented option) 	<p>For scoring PLMS (from LM) following options apply:</p> <div> <p>Exclude LM events:</p> <ul style="list-style-type: none"> <input checked="" type="checkbox"/> starting in an epoch classified as wake <input checked="" type="checkbox"/> starting in a movement event <input checked="" type="checkbox"/> starting close to or in an apnea, hypopnea or RERA event <p>Minimum Inter-Onset Interval: <input type="text" value="0.5"/> seconds</p> </div> <p>With these settings there are no PLMS scored / reported according to the AASM rules. If (single) LM are of additional interest the AASM rules can be applied to the reported variables.</p>
<ul style="list-style-type: none"> LM starting during wake. LM starting in an epoch classified as wake should not be changed to PLMS. Short periods of wake (< 90 s) that include LMs do not prevent LMs preceding and following the period of wake from being included as PLMS in a PLM event. 	<div> <p>Exclude LM events:</p> <ul style="list-style-type: none"> <input checked="" type="checkbox"/> starting in an epoch classified as wake <input checked="" type="checkbox"/> starting in a movement event <input checked="" type="checkbox"/> starting close to or in an apnea, hypopnea or RERA event <p>Minimum Inter-Onset Interval: <input type="text" value="0.5"/> seconds</p> </div>

LM / PLMS and Wake rule implementation example of Noxturnal:



- LM and Movement: The Onset and Offset Thresholds for scoring LMs only apply for a resting EMG signal ($\pm 5 \mu\text{V}$). (fully implemented option)

Exclude LM events:

- starting in an epoch classified as wake
- starting in a movement event
- starting close to or in an apnea, hypopnea or RERA event

Minimum Inter-Onset Interval: seconds

In assumption that activity over the resting EMG threshold will be scored by Noxturnal as a Movement event the AASM rule for LM and Movement is a fully implemented option.

- LM /PLMS in both legs: if movement in both legs occur at the same time OR if it occurs WITHIN 5 seconds of each other, it is counted as ONE EVENT (fully implemented for event reporting, not implemented for visualization)

Periodic Limb Movement in Sleep (PLMS)

Minimum Number of LMs:

Minimum Interval Between LM Onsets: seconds

Maximum Interval Between LM Onsets: seconds

Combine LM events from all channels into one PLMS scoring

Note: Only the leading LM event in an overlap (or one following the other) movements within both legs will be visually represented as PLMS and counted. This allows clear identification which PLMS are counted and contribute to PLMS reporting.

Periodic Leg movement (in Sleep) Series

The periods of PLMS events are called Periodic Leg movement (in Sleep) Series.

Noxturnal: Periodic Leg movement (in Sleep) Series are marked by a PLM event that starts with the first and ends with the last PLMS event of the series.

The PLMS index is displayed as a number with a colored background depending on severity in the Recording Result tab in Noxturnal for each study. The severity scale is set after the AASM classification criteria.



Summary: The PLM algorithm uses LM events that are either scored manually or by the automatic PLM analysis* to identify periodic limb movements. If at least 4 LM events occur (Minimum Number of LMs), separated by at least 5 seconds (Minimum Interval Between LM Onset) and at most 90 seconds (Maximum Interval Between LM Onset), the LM events are changed to **PLMS events**. The LM events from the two leg channels are combined into one scoring for identifying PLMS. In addition, the PLM series are scored as **PLM events**.

* If LM events are scored both automatically and manually (or removed manually), it is needed to run the 'Update PLM tool' for the total amount of LM to be included in the PLM algorithm.

Nocturnal 6 PLMS standard reporting

Nomenclature of Nocturnal events

- LM: Limb movements (which are also candidates for periodic limb movements in Sleep (PLMS))
- PLMS: LM events that qualify as PLM are changed to PLMS events
- PLM: Series of PLMS events.

Nocturnal 6 reporting is focused on PLMS and PLMS series. There is no standard reporting of separate LM events. For any LM reporting, a custom report needs to be set up. Previously created custom reports for LM need to be adjusted according to the new logic for LM to PLMS event conversion as well as the new automated scoring of PLMS series (PLM).

Nocturnal default PLM / PLMS reporting:

PLMS (Periodic Limb Movements in Sleep)	Count	Index	Duration		
			Average	Min	Max
PLMS:	657	94.9 /h	2.7 s	0.5 s	7.7 s
PLM during Wake:	0	0 /h	s	s	s
PLMS in N1:	5	85.7 /h	3 s	2.2 s	4 s
PLMS in N2:	562	99.8 /h	2.8 s	0.5 s	6.1 s
PLMS in N3:	24	102.9 /h	2.8 s	0.8 s	5.7 s
PLMS in REM:	66	66 /h	1.8 s	0.5 s	7.7 s
PLMS Supine:	196	68.4 /h	2.9 s	0.5 s	7.7 s
PLMS Non-supine:	461	113.6 /h	2.6 s	0.5 s	4.4 s
PLMS Arousals:	139	20.1 /h			
PLM Series:	20	2.9 /h	786.3 s	84.5 s	3810.8 s

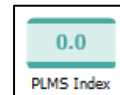
Differences between Noxturnal 5.x and 6. potential x with respect to LM / PLMS representation

The main changes between the PLM algorithm in Noxturnal 5.1.3 and Noxturnal 6.x are the following:

- The PLM analysis was upgraded to **meet AASM 2017** requirements.
- **ECG artifact filter** is automatically applied to the signal prior to event detection, which contributes largely to artefact rejection due to heart signal interference.
- **Improved event presentation**: Events that are contributing to the PLMS count have changed from previous Noxturnal 5.x version and got their own event type (PLMS) and event (e.g. color) settings. The PLMS is a new event type which did not exist in Noxturnal 5.x.
- **Recording Result page**: Only the PLMS index is displayed (no LM Index).


Updating a scoring from 5.1.3 to 6.x with regards to LM / PLMS

- As Noxturnal 5.1.3 did not use the PLMS event as the base for the PLMS Index it will display “0” when opening up studies from 5.1.3 in Noxturnal 6.x
- Similarly, the report table will not be able to display PLMS events related data.
- To update PLMS / LM data either a new PLM analysis or the “Update PLM” tool has to be run.



Options to customize / enable reporting LM outside of PLMS series

Below is an example of an optional report variable which can have even more but also less conditions:

 Edit Report Field

Name:

Category:

Number of events

Number of [LM](#) events in [Sleep](#)
that start in [N1 or N2 or N3 or NREM or REM](#) events
that does NOT overlap [PLM](#) events
that are NOT near [Apnea or Hypopnea or RERA](#) events which start [0.5](#) seconds before and up to [0.5](#) seconds after

Note: if an LM occurs overlapping in both legs, it will be reported as one single event in the report variable.

Noxturnal 5.1.3 and Noxturnal 6 – Automatic Arousal Association

The Arousal Tool in Noxturnal can be used to automatically associate arousals with other events incl. PLMS and LM.

Arousal Tool

Settings

Associates arousals into subtypes related to events. The Arousal Tool prioritizes respiratory arousals over other types of arousals, then PLM arousals, then LM arousals and finally spontaneous arousals.

- Respiratory Arousal**
Each arousal occurring simultaneously or followed by an apnea or hypopnea event by <5 sec will be marked as a respiratory arousal.
- PLM Arousal**
Each arousal occurring simultaneously, preceding or following PLMS event with <0.5 sec will be marked as PLM arousal.
- LM Arousal**
Each arousal occurring simultaneously, preceding or following LM event with <0.5 sec will be marked as LM arousal.
- Spontaneous Arousal**
All non-designated arousal events will be marked as spontaneous arousal.

Default PLM Analysis Settings in Noxturnal 6.x

1 Protocol Properties

Name:
Category:
Description:
 Fail protocol if any detector fails

2 Position

General Properties | Input Signals
Minimum Position Duration: seconds
Minimum Upright Angle: °

3 Limb Movements

General Properties | Input Signals

Limb Movement (LM)
Minimum Duration: seconds Threshold Type:
Maximum Duration: seconds Onset Threshold: Times background
Minimum Inter-Movement Interval: seconds Offset Threshold: Times background
Maximum Allowed Amplitude: uV

Periodic Limb Movement in Sleep (PLMS)
Minimum Number of LMs:
Minimum Interval Between LM Onsets: seconds
Maximum Interval Between LM Onsets: seconds
 Combine LM events from all channels into one PLMS scoring
Exclude LM events:
 starting in an epoch classified as wake
 starting in a movement event
 starting close to or in an apnea, hypopnea or RERA event
Minimum Inter-Onset Interval: seconds

LM Detection

PLM algorithm and exclusion of LM events

4 Activity

General Properties | Input Signals

Amplitude
Amplitude threshold: g/s

Activity Event Properties
Minimum Duration: seconds
Join Interval: seconds

Criteria for scoring Movement events