Sleep Open Source Muscle Activity Analysis System (SOMAS)
User guide

1. Install Matlab Runtime on your Windows PC

If in your Windows PC there is already Matlab Runtime version 25.1 installed, please skip this step. Otherwise, please download and install Matlab Runtime version 25.1 from the link:

https://www.mathworks.com/products/compiler/mcr/index.html

Please note that this file is quite large, therefore its download might require some time. You will download a compressed folder, then please extract its content and run "setup.exe" (Windows). This will require some minutes.

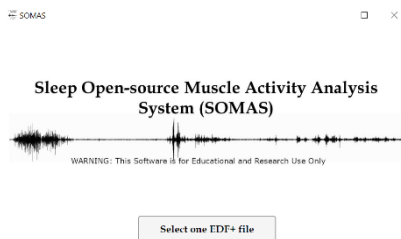### 2. Start the EMG analysis software

Figure 1

Please unzip the folder "SOMAS.zip", then double-click on "SOMAS.exe". After a first window with the logo of SOMAS, the window shown in Figure 1 will appear after some seconds.
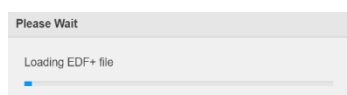
3. Select one EDF+ file

Figure 2

Click on the button "Select one EDF+ file" to select the EDF+ file you want to analyse. After selecting it, the window shown in Figure 2 will appear, showing that the loading is in process. This can take some minutes.

4. Select the analysis window

Once the EDF+ file is uploaded, the window shown in Figure 3 will appear. The top two rows show the recording start time and end time as reported in the EDF+ file.

If you wish to analyse only a specific time window in the recording, please indicate the start time and end time of the window you wish to analyse in the fields "Start Analysis" and "End

Figure 3

Analysis", then click "Next". Please use the format "yyyy-mm-dd HH:MM:SS" to specify the date and times, where yyyy, mm, and dd indicate year, month, and day, respectively, and HH, MM, and SS indicate hours, minutes, and seconds, respectively. By default, the "Start Analysis" and "End Analysis" fields are set equal to the "Start Recording" and "End Recording" fields, respectively. Therefore, if you wish to analyse the whole EDF+ file, simply click on "Next" without changing the content of any field in this window.

5. Optional: Load annotations and channels from a previous file

Figure 4

In the window in Figure 4, please select "Yes" if you wish to use the same selections for annotations and channels as those you used for a previous analysis and saved (see section 8).

6. Specify hypnogram annotations

Figure 5

Please use the window in Figure 5 to select the EDF+ file annotations corresponding to lights off, lights on, wakefulness, stages N1-N3 sleep, and REM sleep from the respective pull-down menus. When the selection is complete, click "Next". If a specific annotation is not available, select "Annotation not available" from the pull-down menu.

Note: the software does not work if annotations of either lights off or lights on are not defined.

7. Main calculation interface

Next, navigate the main calculation interface (Figure 6) to tick the boxes corresponding to the EMG signals you wish to analyse and specify their respective channels and artifact annotations (see step 7.1 below).
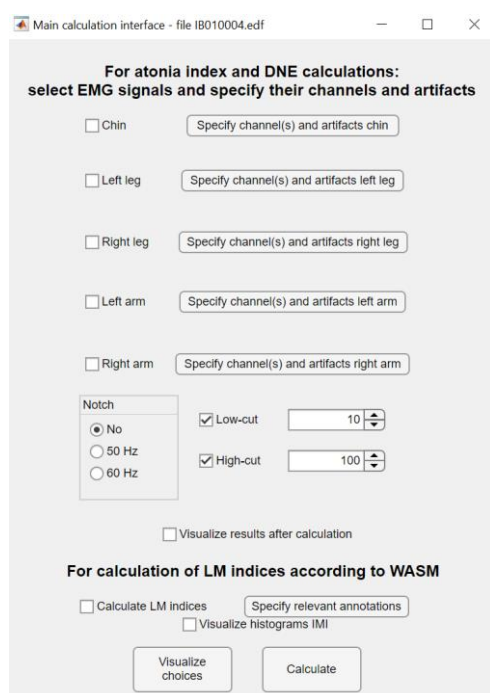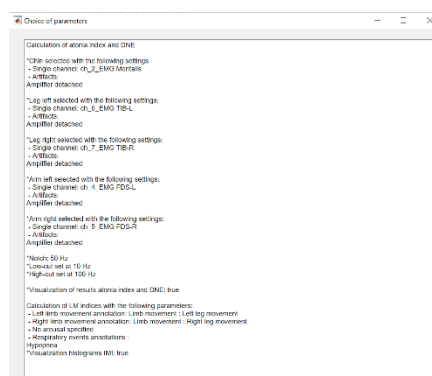
Figure 6

Please indicate whether you wish to apply a notch filter to EMG signals to attenuate AC power interference. The software employs a second-order IIR notch digital filter with a quality factor of 30, applied in the forward and reverse directions to achieve zero phase distortion. The options are no notch filter or 50/60 Hz notch filter depending on the AC frequency in the area where the recordings were performed.

If you wish to apply also low-cut and high-cut filters please tick the corresponding boxes and indicate the corresponding cut frequencies (default values are 10 Hz and 100 Hz, respectively). The software employs 6-pole Butterworth filters applied in the forward and reverse directions to achieve zero phase distortion. The selections concerning notch, low-cut, and high-cut filters will apply to all the EMG signals selected in the main calculation interface.

Figure 7

If you wish to plot the results of the atonia index and DNE calculations, please tick the box labelled as "Visualize results after calculation".

If you wish to calculate leg movement (LM) indices, please tick the corresponding box and then specify the relevant annotations (see step 7.2 below). If you wish to plot the computed inter-movement interval (IMI) histograms, please tick the box labelled "Visualize histograms IMI". You may review your parameter selection clicking on "Visualize choices" (as shown in Figure 7).

Finally, when you are done with the different selections of the main calculation interface, please click "Calculate".

7.1. Specify channels and artifacts

As you click "Specify channel(s) and artifacts chin" in the main calculation interface (Figure 6, see step 7 above), another window (Figure 8) will open and let you specify whether the chin EMG channel in the EDF+ file is already differentiated (option "Single channel") or needs to be
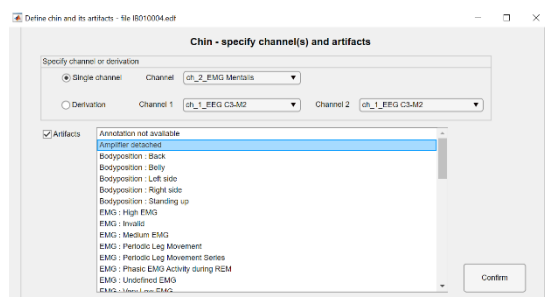
Figure 8

computed as the difference between two EDF+ channels (option "Derivation"). Once you make this selection, please choose the corresponding channel(s) from the respective pull-down menus. If chin EMG signal artifacts are reported as annotations in the EDF+ file and you wish to exclude them from the analysis, please tick the box labelled "Artifacts" and select the

corresponding artifact annotations from the menu to the right of the box (please keep the Ctrl key pressed to select more than one annotation).

Once you conclude the channel specification and the selection of artifact annotations, if any, please click "Confirm".

Repeat step 7.1 for the other EMG channels you wish to analyse (options are left and right legs and left and right arms, selected from the main calculation interface).

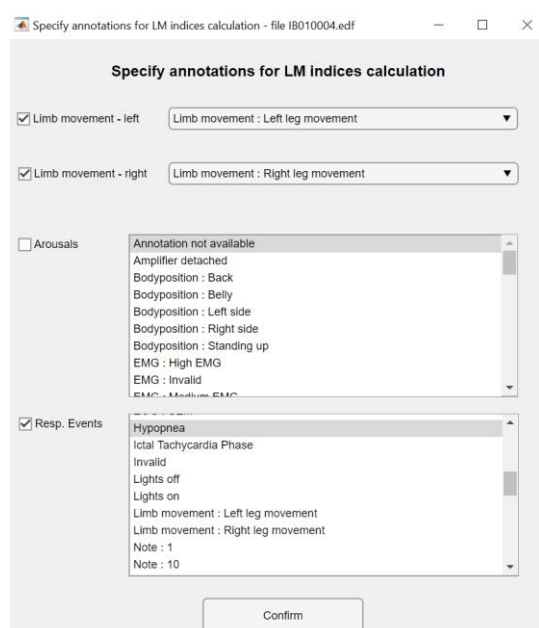### 7.2 Specify annotations for calculation of LM indices

Figure 9

If you wish to calculate LM indexes according to the World Association of Sleep Medicine (WASM) 2016 criteria (DOI: 10.1016/j.sleep.2016.10.010), please tick the box "Calculate LM indices" and click "Specify relevant annotations" in the main calculation interface (Figure 6). Another window will open, as shown in Figure 9. This new window will let you specify annotations in the EDF+ file corresponding to left and right leg movements, arousals, and respiratory events. Please tick the corresponding boxes and select the relevant annotations from the menus. Press the Ctrl key to select multiple annotations for any specific category. Please click "Confirm" when you complete the selections.

8. Optional: Save the selected annotations and channels for future use on another file
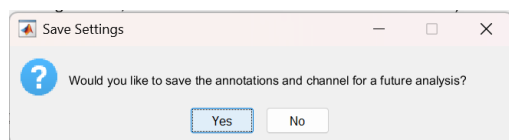
Figure 10

Please select "Yes" in the window shown in Figure 10 if you wish to save your selections of annotations and channels for future use on another file. These can be loaded in the step described in section 5 and will allow you to save time when analysing a new EDF+ file, which was recorded and analysed with exactly the same settings as for the current EDF+ file.

9. Select save directory

A system window will open to let you select the directory in which you wish to save the results of the EMG calculations.

10. Optional: check the log file

The software saves a log file documenting all the selections you made. The log file is a .txt file with a filename reporting the date and time of analysis in the form "YYYYMMDD,'T',HHMMSS_logFile.txt". Please note the log file is saved in the same directory as the SOMAS.exe file, which may be different from the directory selected in step 9 above.

11. Results: Sleep macrostructure parameters

The software saves in the directory selected at step 9 a comma-separated .csv file including indexes of sleep architecture according to the recommendations of the American Academy of Sleep Medicine (AASM) Manual for the Scoring of Sleep and Associated Events. The file name includes the name of the EDF+ file and the string "_sleep_macrostructure".

Specifically, the .csv file includes **lights out** (off) and **lights on** clock time, **total recording time** between lights off and lights on, and **total sleep time** (TST, i.e., total time spent in stages N1, N2, N3, and R (REM)). **Sleep period time** (SPT), corresponding to the time between sleep onset and the last sleep epoch, is also reported. **Sleep onset** corresponds to sleep latency, i.e., the time from lights out to the first epoch of any sleep. **Sleep efficiency** is the ratio of TST to total recording time, in percentage. The **wakefulness after sleep onset** (WASO) is the difference between total recording time and the sum of sleep latency and TST. The **time spent in wakefulness** (Wake) during the SPT, both in absolute values and as a percentage of SPT.

The **time spent in stages N1, N2, N3, and R** is reported in absolute values and as percentage of TST and of SPT. The **onset of stages N1, N2, N3, and R** is also reported as the time from lights out to the first epoch of the corresponding sleep stage. **REM latency** is the time between sleep onset and the first epoch of stage R (REM) sleep.

12. Results: Sleep Atonia Index

The software saves a comma-separated .csv file including the sleep atonia index results in the directory selected at step 9. The file name includes the name of the EDF+ file and the string "_atonia_index". Atonia index results are reported for each EMG channel selected at step 7 according to the following published references:

DOI 10.1111/j.1365-2869.2008.00631.x
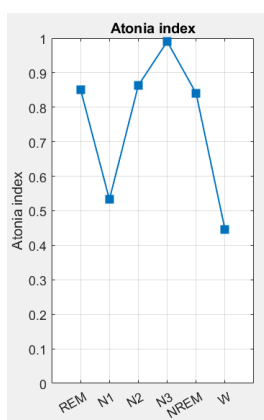
DOI 10.1016/j.sleep.2010.06.003

Figure 11

REM indicates REM sleep. N1, N2, and N3 are the corresponding sleep stages. NREM indicates the average atonia index during all non-REM sleep epochs, regardless of the stage. W indicates wakefulness. The mean atonia index for left and right legs EMG channels and for left and rights arms EMG channels are included if appropriate based on EMG channel selection in step 7. The file also reports the duration of recordings in wakefulness and in stages N1, N2, N3, and R on which the atonia index calculation was based, subtracting the durations of any artefacts selected in step 7.1. If the box "Visualize results after calculation" was ticked in step 7, the atonia index results are also shown in the left panels of corresponding figures, as shown in Figure 11.

13. Results: Distributions of normalized EMG values (DNE)

The software saves a comma-separated .csv file including the results of the analysis of distributions of normalized EMG values (DNE) in the directory selected at step 9. The file name includes the name of the EDF+ file and the string "_DNE". Results are reported for each EMG channel selected at step 7 according to the following published reference:
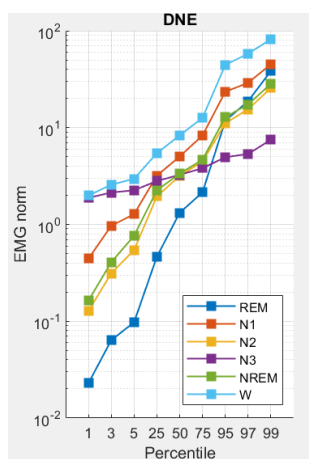
DOI 10.1093/sleep/zsx029

Figure 12

The 1st, 3rd, 5th, 25th (i.e., first quartile), 50th (i.e., median), 75th (i.e., third quartile), 95th, 97th, and 99th DNE percentiles (perc) are reported. The mean DNE centiles for left and right legs EMG channels and for left and rights arms EMG channels are also included if appropriate based on EMG channel selection in step 7. The 0.5th and 99.5th centiles of the rectified and averaged EMG values over the whole recording time are also reported for signal quality assessment. REM indicates REM sleep. N1, N2, and N3 are the corresponding sleep stages. NREM indicates the average DNE percentiles during all non-REM sleep epochs, regardless of the stage. W indicates wakefulness. The duration of recordings in wakefulness and in stages N1, N2, N3, and R on which the DNE computation was based, subtracting the durations of any artefacts selected in step 7.1, is the same as that used for the atonia index computation and reported in step 12. If the box "Visualize results after calculation" was ticked in step 7, the DNE results are also shown in the right panels of corresponding figures, as shown in Figure 12.

14. Results: calculation of LM indices

The software saves three comma-separated .csv files including the results of the analysis of leg movement (LM) indices in the directory selected at step 9 according to the consensus criteria of the World Association of Sleep Medicine (WASM) published in
DOI 10.1016/j.sleep.2016.10.010

14.1. Raw LM data

The file name includes the name of the EDF+ file and the string "_LM_raw". The file is a table where for each LM, the following information is reported:
- Epoch: the number of the 30-s epoch from the start of the EDF+ file where the LM starts. Note that the first epoch is labelled as 1.
- Stage: the sleep stage of the epoch (i.e., either Wake, N1, N2, N3 or REM sleep).
- Start and End: corresponding times of onset and offset of the LM from the start of the EDF+ file, expressed in seconds.
- Duration: duration of the LM, expressed in seconds.
- Mov type: the type of LM, i.e. left LM, right LM or bilateral LM.

- Sequence: ordinal number of the periodic leg movement (PLM) sequences during the recording. LM belonging to the same PLM sequence are labelled with the same PLM sequence number. LM not part of a sequence are labelled with a not-a-number ("#NUM!"/NaN) value.
- IMI: inter-movement interval (onset of the previous LM to onset of the current LM), expressed in seconds.
- Isolated: a binary variable (yes = 1, no = 0) specifying if the current LM is isolated, i.e. LM with IMI > 90 s or with 10 s <= IMI <= 90 s but not satisfying criteria for PLM.
- Short-interval: a binary variable (yes = 1, no= 0), specifying if the current LM is a short-interval LM, i.e. a LM with IMI < 10 s.
- CLM: a binary variable (1 = yes, 0 = no), specifying the LM is a CLM.
- AssociatedArousal and AssociatedRespiration: association of leg movements to arousals or respiratory, events, respectively (binary variables, 1 = yes/0 = no). If no annotations were specified for arousals and respiratory events, the respective columns are labelled with not-a-number ("#NUM!"/NaN) values.

14.2. WASM LM indices

The file name includes the name of the EDF+ file and the string "_LM_indices_WASM". This file contains the results of LM indices according to the consensus criteria of the WASM. The symbols match the ones defined in DOI 10.1016/j.sleep.2016.10.010. The following values are reported:

- PLMS/hr and PLMW/hr: periodic leg movements during sleep and during wakefulness, respectively, per hour of sleep and wakefulness, respectively. Data are reported also separately for left, right, and bilateral leg movements. NR: non-REM sleep; R: REM sleep; hr: hour.
- PLMSa: PLMS associated with arousals (the result is not a number ("#NUM!"/NaN) if no annotation corresponding to arousals was available or selected in step 7.2.
- PLMSnr (note capitalization and lack of underscore symbol): non-respiratory PLMS.
- PLMnr_NR and PLMSnr_R (note capitalization): non-respiratory periodic leg movements during non-REM sleep and REM sleep, respectively. The result is not a number ("#NUM!"/NaN) if no annotation corresponding to respiratory events was available or selected in step 7.2.
- PLMnr_a: non-respiratory periodic leg movements during sleep associated with arousal.
- CLM: candidate leg movements (other acronym specifications as above).

- CLMSr/hr, CLMr_NR and CLMr_R: candidate leg movements associated with respiratory events during whole sleep, non-REM sleep and REM sleep, respectively. The result is not a number ("#NUM!"/NaN) if no annotation corresponding to respiratory events was available or selected in step 7.2.
- shortIMImov: short-interval LM (see definition at step 14.1; other acronym specifications as above).
- isolatedLM: isolated LM (see definition at step 14.1; other acronym specifications as above).
- avgdur: average duration (other acronym specifications as above).
- Periodicity index: the number of PLM expressed as a percentage of the number of CLM.
- Average and std log IMI: average and standard deviation of the e-base logarithm of the IMI (times between the onset of successive CLM) during sleep, with IMI 10 s <= IMI <90 s.
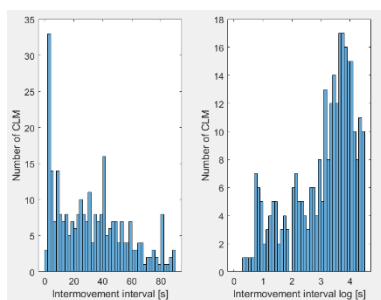
14.3. IMI histograms

Figure 13

The file names include the name of the EDF+ file and the strings "-IMI" and "-IMI_LOG". The files report inter-movement interval (IMI) histograms with 45 bins, computed on raw IMI values and on the e-base logarithm of IMI values, respectively. CLM indicates candidate leg movements. If the box "Visualize results after calculation" was ticked in step 7, the IMI and IMI_LOG histograms are also shown in a corresponding figure (as shown in Figure 13).