# Somnofy
## Non-Contact Smart Sleep Monitor

A good night's sleep, nutrition-rich food and regular physical activity are essential for a good life. Sleep quality has worldwide implications on hazard control, human functioning, and biological age — its importance cannot be overstated. Poor sleep has been linked to many of the major healthcare burdens of today's western societies. The methods to collect sleep data have evolved drastically since research first became interested in sleep. From early sleep diaries and personal observation, many researchers today measure sleep with actigraphy and polysomnography. While the latter is regarded the gold standard of sleep research methods, many prefer wearables for their non-intrusiveness, ease-of-use, and scalability.

«Compared to PSG (polysomnography), Somnofy is closer to this gold standard for sleep measurement than any non-contact alternatives.»

– Ståle Pallesen (PhD),  Professor, University of Bergen, Norway

Somnofy is a non-contact high precision sleep assistant made to measure and analyze vital signs, sleep and sleep environment. With its non-contact and non-camera based sensors, it measures movement and  respiratory rate from the human body. Somnofy detects changes in the sleeping environment including  temperature, light, noise and air quality. This combination of data provides a solid foundation for analyzing sleep quality and sleep hygiene. Its high accuracy lends itself to research projects aiming to uncover the effects of different variables on sleep quality.

The development of Somnofy started in 2012. It is based on close collaboration with medical experts and benchmarked with the medical gold standard (PSG - polysomnography). Utilizing the strong correlation between sleep stages, respiration and movement, Somnofy combines these measure points with additional data and performs advanced data science based on machine learning to automatically estimate sleep stages with high precision. A number of published and ongoing studies take advantage of the sleep data quality provided by the non-intrusive nature of Somnofy.

## Subject measures

Respiration rate
Movement/unrest
Sleep (light, deep, REM)

## Environment measures

Air quality
Sound
Light
Temperature

## Bluetooth connect

Heart rate belt*
Pulse oximeter*

*External bluetooth devices can be connected to Somnofy for real-time monitoring and historical data

Choosing Somnofy for your research project is a big step towards larger scale sleep research, or the acknowledgement of the sleep dimension in adjacent research fields such as behavioral psychology, education, human physiology and medicine, psychiatry, aging, and more. Your advantage is a high-quality sleep assessment alternative to polysomnography for a budget similar to actigraphs. Being non-intrusive upon the sleeper, the data collection presents undisturbed sleep patterns in a controlled lab environment — or in the subject's own home.



- Somnofy can be installed by the study participant
- Data is being sent encrypted through WiFi or a preconfigured 4G modem, to the cloud
- A neural network analyzes pre-processed movement data in the cloud
- The analysis result is sent to a smartphone or web-browser for visualization
- Data can be exported for statistical analysis



- Contactless alternative to polysomnography
- Somnofy provides a comfortable, highly accurate measurement of sleep quality.
- No interference through physical contact with the subject normal sleep pattern can be observed without discomfort. Somnofy is a so-called «Nearable».
- Somnofy provides a more natural objective sleep assessment
- Picture shows preparations for a standard polysomnography in the sleep laboratory at Colosseum, Oslo, during our validation study setup.

-  Somnofy makes larger scale sleep research possible
- Up to 100x more overnight sleep assessments per $ spent on data collection compared to PSG
- Non-intrusiveness opens for researching vulnerable populations such as children*, elderly*, and patient groups* (*not independently validated)
- Long-term sleep analysis opens for mapping sleep dependent on seasonal changes, medication, shift work schedules, pre/post child birth, and much more
- Better compliance of the subjects



«Somnofy allowed us to measure sleep in an unobtrusive, valid and highly ecological manner.»
   - Maria Hrozanova (PhD candidate), Centre for Elite Sports Research, NTNU

# Somnofy Web Portal

With your own dedicated login information, you can access your data during the collection phase to check quality and plan a segmental analysis, if warranted. In the below screenshot, an examplary sleep analysis is depicted. Quantitative measures of sleep are presented next to a pie chart giving a quick overview over percentage of time spent in each sleep stage. This overview facilitates both intra- and inter-subject comparisons of sleep measurements. Adjusted to your individual research interest, total sleep time, time spent in deep/REM sleep and many more parameters can be analysed.
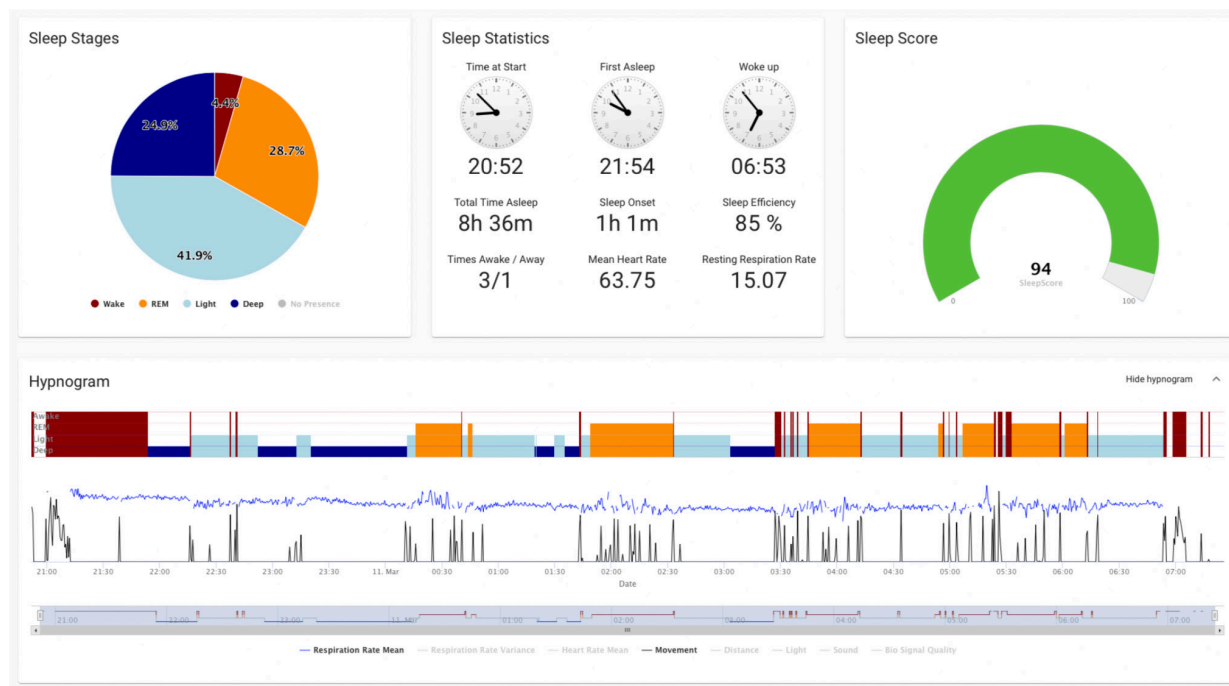


# Long Term Trend analysis

Collecting sleep data over longer time periods opens up possibilities for data analysis in an eye-catching and interactive way. The visualizations and graphs in our web-based analysis tool offer selective graphs for different measurement properties, time periods and measurement devices. Plotting average movement data against the average breathing rate per night, for example, can hint at temporary pain or infection events in the current study subject.
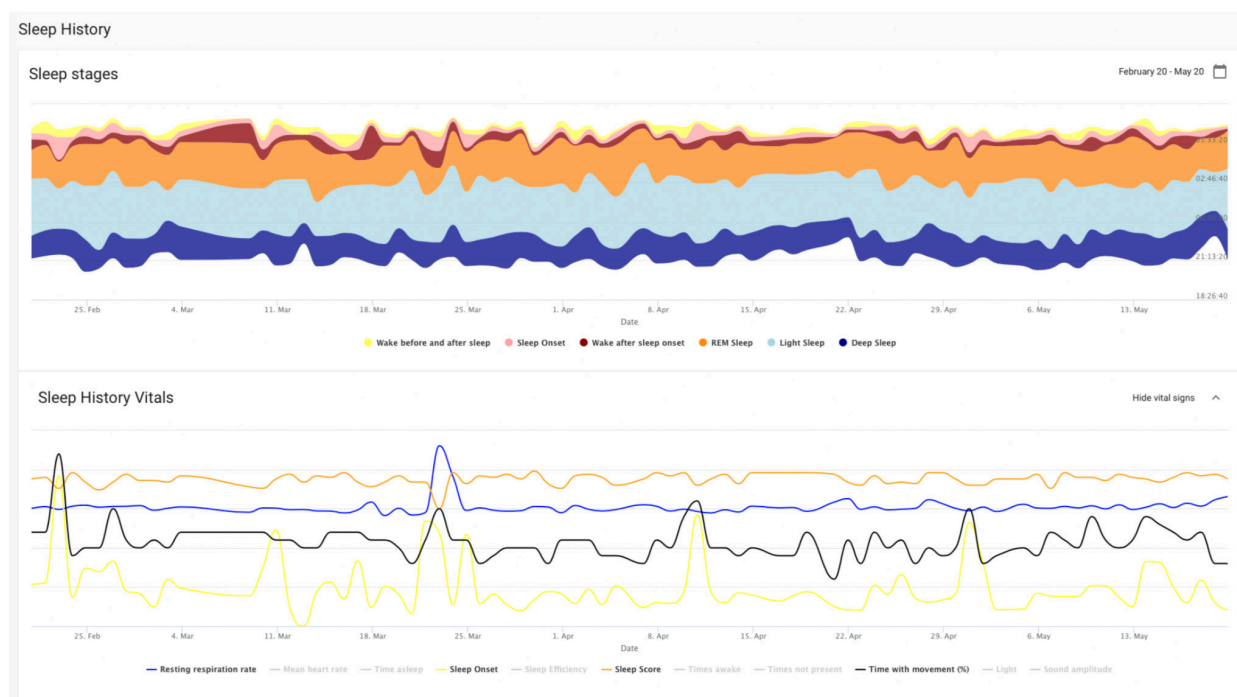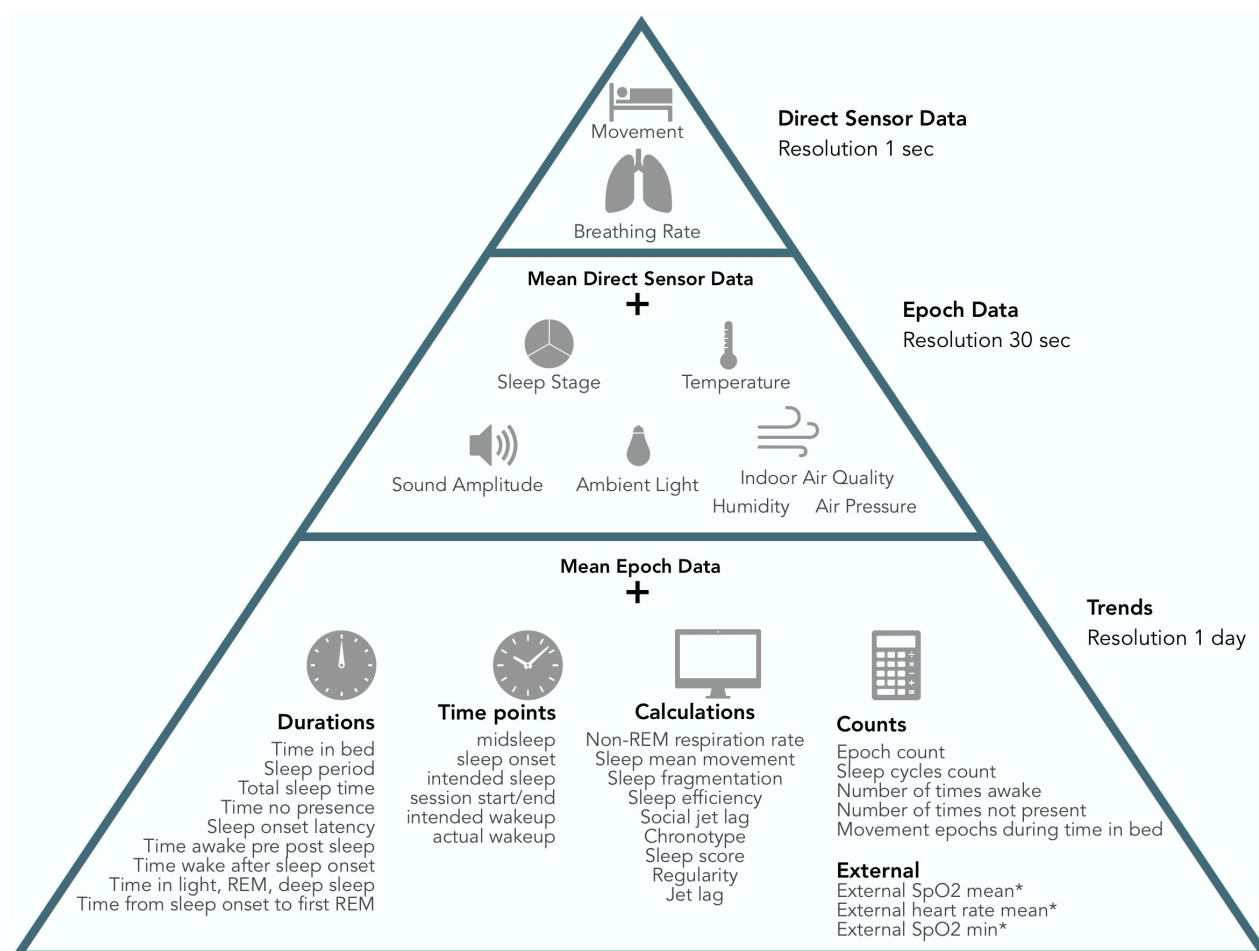
# Somnofy Open API

Accessing your data after successful collection is convenient and adapted to your needs. Our open API standard makes it possible to extract data continuously or at one timepoint for individual statistical analysis. All visualizations in the Web API can be also be downloaded in a standard table format (.xml, .csv).

The resolution degree is presented in the graphic below. Starting at the top of the below pyramid, **Direct Sensor Data** is being collected at 1Hz and is subject to our algorithmic calculations which are performed in the cloud (upon special request, direct sensor data can be extracted at 17Hz).

A sleep session analysis comprises average **Direct Sensor Data** plus the additional parameters mentioned in the central tier of the figure with **Epoch Data** available at a 30s resolution.

The variables available for long term sleep analysis (**Trends**) include one data point per sleep session. **Trends** include average epoch data plus additional variables listed in the bottom tier of the pyramid.



**Direct Sensor Data**
Resolution 1 sec

Movement
Breathing Rate

**Mean Direct Sensor Data**
**+**

**Epoch Data**
Resolution 30 sec

Sleep Stage
Temperature
Sound Amplitude
Ambient Light
Indoor Air Quality
Humidity
Air Pressure

**Mean Epoch Data**
**+**

**Trends**
Resolution 1 day

**Durations**
Time in bed
Sleep period
Total sleep time
Time no presence
Sleep onset latency
Time awake pre post sleep
Time wake after sleep onset
Time in light, REM, deep sleep
Time from sleep onset to first REM

**Time points**
midsleep
sleep onset
intended sleep
session start/end
intended wakeup
actual wakeup

**Calculations**
Non-REM respiration rate
Sleep mean movement
Sleep fragmentation
Sleep efficiency
Social jet lag
Chronotype
Sleep score
Regularity
Jet lag

**Counts**
Epoch count
Sleep cycles count
Number of times awake
Number of times not present
Movement epochs during time in bed

**External**
External SpO2 mean*
External heart rate mean*
External SpO2 min*

*Somnofy connects to external sensors to collect additional data. Somnofy reads data from heart rate belts (e.g. Polar H10) and pulse oximeters (e.g. Nonin 3150). Somnofy is CE and FCC approved. WiFi and Bluetooth connected. Somnofy products and services are not medical devices, and are not intended to dignose, treat, cure or prevent any disease.

# Analytics & PowerBI

The Web API automatically displays a selection of the collected sleep data each night and offers a comprehensive overview that is easy to learn to interpret.

In addition to the available web portal, we are happy to provide you with our latest platform-based analytics tool built with PowerBI. Your access to our platform enables you to correlate different data types and sources to find connections previously difficult to un-ravel. The analysis platform puts you in a position of absolute control over your study cohort with the full overview over current and previous trends across different segments of your population.

## Selection of research projects using Somnofy

Since the inception of Somnofy, research groups around elite sports and sleep research have shown interest in our then novel technology. The product description you are holding in your hands right now is the result of years of collaboration between Norway's foremost sleep researchers and our engineers to offer the most convenient tool for large scale sleep research.

Our close connection to various university institutions, medical doctors and other healthcare researchers has provided us with the certainty of building a product that adds value to the laborious and exact work of researchers in many fields. Consult the below (non-exhaustive) list of research projects centered around data collection performed at least partly with the help of Somnofy.

| Project | Goal | Description |
|---|---|---|
| Norwegian Olympic Committee | Identify the role of sleep in elite sports performance, restitution, and stress | Follow up professional sports teams and individuals both in training and competition. Effects on sleep locally and traveling in changing sleep and training environments. Skiing, soccer, biathlon, triathlon, chess, e-sports, and para-sports. |
| Young Sleepers | Determine correlations btw. personality and sleep in 14-15 year olds | Non-intrusive monitoring of sleep in middle-school students (14-15 yrs.). Somnofy deployed together with pre and post questionnaires with a psychological dimension. Correlating sleep habits with personal insight and psychological maturity. |
| The HUNT study | Map sleep in an elderly population | A population subset of elderly people (age 70+ yrs) perform a two week cross-sectional sleep study comparing different methods of data acquisition: Somnofy, actigraphy, tri-axis accelerometer, sleep diary, and a subjective sleep quality questionnaire. |
| Sleep Apnea | Screening of at-risk patients for sleep apnea | Validation of Somnofy continuous sleep measurements as a screeening aid for the general practitioner prior to a costly sleep apnea test. |
| Narcotics rehabilitation | Monitor sleep quality during «cold turkey» period | Observing total sleep time, respiration rate and calmness/agitation during sleep. Big chance for relapse when sleep quality declines during initial «sober-period». |
| Sleep Course | Helping overweight insomniacs | Follow up course participants before and after a standardized course with the goal to teach basic sleep hygiene tips. Participants partake remotely in their home sleep environment. |

## Have a research-related question?

Being equipped with senior as well as junior researchers on our team, we can consult with you to find research topics, discuss potential projects or help you find a way to utilize Somnofy to add maximal value to your specific research project. Our team comprises medical doctors, data scientists (PhD), researchers, engineers (MSc), and an exercise physiologist (MSc). The experience we have gathered in the above detailed research projects may prove valuable for your planning phase.

## List of published studies using Somnofy

- Toften, Ståle & Pallesen, Ståle & Hrozanova, Maria & Moen, Frode & Grønli, Janne: "Validation of sleep stage classification using non-contact radar technology and machine learning (Somnofy®)", available online 6 March 2020, epub ahead of print, Sleep Medicine. DOI: 10.1016/j.sleep.2020.02.022
- Hrozanova, Maria & Klöckner, Christian & Sandbakk, Oyvind & Pallesen, Ståle & Moen, Frode. (2020). Reciprocal Associations Between Sleep, Mental Strain, and Training Load in Junior Endurance Athletes and the Role of Poor Subjective Sleep Quality. Frontiers in Psychology. 11. 1-14. 10.3389/fpsyg.2020.545581.
- Moen, Frode & Olsen, Maja & Hrozanova, Maria. (2020). Associations Between Sleep Patterns and Performance Development Among Norwegian Chess Players. Frontiers in Psychology. 11. 1855. 10.3389/fpsyg.2020.01855.

Somnofy is validated against PSG

ELSEVIER

Original Article

# Validation of sleep stage classification using non-contact radar technology and machine learning (Somnofy®)

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## ARTICLE INFO

## ABSTRACT

Objective: To validate automatic sleep stage classification using deep neural networks on sleep assessed by radar technology in the commercially available sleep assistant Somnofy® against polysomnography (PSG).
Methods: Seventy-one nights of overnight sleep in healthy individuals were assessed by both PSG and Somnofy at two different institutions. The Somnofy unit was placed in two different locations per room (nightstand and wall). The sleep algorithm was validated against PSG using a 25-fold cross validation technique, and performance was compared to the inter-rater reliability between the PSG sleep scored by two independent sleep specialists.
Results: Epoch-by-epoch analyses showed a sensitivity (accuracy to detect sleep) and specificity (accuracy to detect wake) for Somnofy of 0.97 and 0.72 respectively, compared to 0.99 and 0.85 for the PSG scorers. The sleep stage differentiation for Somnofy was 0.75 for N1/N2, 0.74 for N3 and 0.78 for R, whilst PSG scorers ranged between 0.83 and 0.96. The intraclass correlation coefficient revealed excellent and good reliability for total sleep time and sleep efficiency, while sleep onset and R latency had poor agreement. Somnofy underestimated total wake time by 5 min and N1/N2 by 3 min. N3 was overestimated by 4 min and R by 3 min. Results were independent of institution and sensor location.
Conclusion: Somnofy showed a high accuracy staging sleep in healthy individuals and has potential to assess sleep quality and quantity in a sample of healthy, mostly young adults. More research is needed to examine performance in children, older individuals and those with sleep disorders.

The validation study that proves the accuracy of Somnofy has been published in «Sleep Medicine» in 2020. Somnofy is a novel non-contact bedside sleep assistant that monitors vital signs fully automated during sleep. Somnofy reaches substantial agreement with PSG on staging sleep (κ = .63) [1]. Somnofy may thus be considered a valid tool for furthering the sleep field in specific research questions and areas previously impractical to study.

[1] Ståle Toften, Ståle Pallesen, Maria Hrozanova, Frode Moen, Janne Grønli: "Validation of sleep stage classification using non-contact radar technology and machine learning (Somnofy®)", available online 6 March 2020, epub ahead of print, Sleep Medicine. DOI: 10.1016/j.sleep.2020.02.022



The figure to the right shows the distribution of epoch-by-epoch agreement between manual polysomnography on the y-axis and Somnofy on the x-axis on scoring deep sleep (N3), light sleep (N1/N2), REM (R), and wake (W). The more the two sleep scoring systems agree, the darker the shade of blue. Clearly visible, the agreement of Somnofy against the medical gold standard of sleep research is substantial. Another way of comparing the sleep staging agreement is by stating Cohen's kappa κ = .63. Somnofy scored sleep vs wake robustly with 0.97 of true sleep epochs scored as sleep, and 0.72 of true wake epochs scored as awake.

The challenge for non-intrusive sleep tracking devices is to reliably detect wakefulness. To our knowledge, Somnofy shows the highest specificity compared to other non-EEG systems, including other contactless monitoring devices that use technology based on passive infrared, sonography, actigraphy or pressure sensation.