Findings on sleep apnea and detection

What is sleep apnea?

Sleep apnea is a sleep disorder that causes interrupted or shallow breathing while sleeping. It occurs when the muscles at the back of the throat fail to keep the airway open, resulting in apneas, or brief pauses in breathing. Sleep apnea can lead to daytime fatigue, increased risk of heart problems, and other health complications if left untreated.

Few ways of detections

1. **Tracheal Sound Analysis for Detection of Sleep Disordered Breathing**

The apnea-hypopnea index (AHI) calculates the number of breathing pauses (apneas) and/or partial respiratory flow decreases (hypopneas) lasting more than 10 seconds per hour of sleep. The AHI is the primary criterion for determining the severity of obstructive sleep apnea (OSA). Apneas are defined as a pause or at least 90% reduction in airflow, whereas hypopneas are defined as at least 30% reduction in airflow combined with more than 3% oxygen desaturation and/or arousal. The American Academy of Sleep Medicine (AASM) advises using an oronasal thermal airflow sensor as the first-choice sensor for apnea diagnosis and a nasal pressure transducer for hypopnea detection.**[1]**

Sensors used in the above methods are listed as :

- **Oronasal thermal airflow sensors (Therm)** estimate airflow and detect mouth breathing by measuring the temperature difference between exhaled and ambient air. The use of temperature as a surrogate for measuring airflow is an adequate method for detecting apneas because it detects both nose and oral airflow. However, despite their high sensitivity, these sensors only monitor airflow indirectly and do not offer quantitative measurements of airflow for hypopnea identification.

- **Nasal pressure transducers (NP)** are sensors capable of detecting pressure changes during inspiration and expiration. This semi-quantitative measurement of airflow pressure gives details on airflow such as the presence of flattening of the inspiratory part of the signal in case of increased upper airway (UA) resistance and also allows better evaluation of hypopneas than thermistors.

- Flow derived from **respiratory inductive plethysmography (RIP flow)** from the thorax and abdominal belt signals has been proposed as an alternative signal for scoring apneas and hypopneas if the thermistor signal fails or is unreliable

- **Tracheal sounds, recorded at the sternal notch,** reflect the superficial vibrations of the body set in motion by pressure fluctuations . Placed on the sternal notch, the TS sensors can detect these vibrations and thus measure tracheal flow sound as well as snoring.

2. Portable Monitors for Obstructive Sleep Apnea

The patient is given a portable sleep monitoring equipment with multiple sensors to track various physiological indicators while sleeping. Sensors placed on the body and connected to a monitoring device may be used in the configuration.

The patient wears the portable monitor while sleeping in their usual sleep environment. The device continuously records the data from the various sensors throughout the night. Once the sleep study is completed, the data recorded by the portable monitor is analyzed. Sleep specialists or healthcare professionals review the data to identify sleep patterns, the frequency of breathing disruptions, and other relevant information.

Based on the data analysis, healthcare professionals can determine whether the patient has sleep apnea and, if so, the severity of the condition. They will also be able to distinguish between obstructive sleep apnea (OSA) and central sleep apnea.

The portable monitor may include sensors such as:

Pulse oximetry sensor: Measures blood oxygen levels.

Respiratory effort belts: Detect chest and abdominal movements.

Nasal airflow sensor: Tracks breathing patterns.

Actigraphy sensor: Monitors overall sleep-wake patterns.

Position sensor: Detects sleeping positions.

Though it has some **limitations..**

- The current consensus recommendations are that portable monitors can be used as an alternative to polysomnography for the diagnosis of OSA if used in conjunction with a comprehensive clinical sleep assessment.
- Portable monitoring should not be used in those with significant comorbid medical conditions (eg, congestive heart failure) or in those who may have other sleep-related problems (eg, circadian rhythm disorders).
- The recording montage needs to include at the least airflow and oxyhemoglobin saturation. The monitor should be applied by a trained technician or the patient must be instructed in the correct application of the device and its associated sensors.**[2]**

3. **Polysomnography(PSG)**

Polysomnography (PSG) is a complete sleep examination that is used to diagnose sleep disorders such as obstructive sleep apnea (OSA). It is widely regarded as the gold standard for assessing sleep-related breathing problems and provides thorough information on a person's sleep architecture and physiological changes while sleeping.

How and where?

A patient spends the night in a sleep lab or specialist sleep center for a PSG for obstructive sleep apnea. Multiple sensors and electrodes attached to various regions of the body are used in the study to measure several physiological indicators at the same time.

Analysis

Throughout the night, the PSG monitors the patient's sleep cycles, breathing patterns, muscle activity, heart rate, and oxygen levels. This data is then analyzed by sleep specialists, who can identify sleep apnea events, including apneas (complete cessation of breathing) and hypopneas (shallow breathing episodes). They can also determine the severity of sleep apnea and assess its impact on sleep quality and overall health.

Sensors in use :

- **Electroencephalography (EEG):** Measures brain activity and helps identify different sleep stages (e.g., REM sleep, NREM sleep).
- **Electrooculography (EOG):** Records eye movements to identify rapid eye movement (REM) sleep.
- **Electromyography (EMG):** Monitors muscle activity, including chin and leg muscles, to identify muscle tone changes during sleep.

- **Electrocardiography (ECG or EKG):** Records heart activity and detects any irregularities or disturbances during sleep.
-
- **Respiratory Effort Sensors:** Measure chest and abdominal movements, providing information about breathing effort.
- **Pulse Oximetry:** Measures blood oxygen levels, which can help identify episodes of oxygen desaturation during sleep.
- **Nasal and Oral Airflow Sensors:** Track breathing patterns through the nose and mouth.
- **Snoring Microphone:** Detects and records snoring sounds during sleep.

4. Obstructive Sleep Apnea Syndrome Screening Through Wrist-Worn Smartbands

Medical-grade wearable devices have recently sparked the interest of researchers, and several studies have examined the usefulness of algorithms trained on data acquired by these devices for OSAS screening and detection. Wearables are outfitted with various sensors, such as accelerometers and photoplethysmography, which allow for the collection of physiological data such as tri-axial wrist movement and cardiorespiratory related parameters. Among the wearables explored is reflecting photoplethysmography, the data from which was utilized to train an ML-algorithm with a 61% correlation to the PSG reference. A deep learning algorithm based on tracheal-placed accelerometers achieved 81% sensitivity, 87% specificity, and 84% accuracy, respectively. Both photoplethysmographic sensors mounted on the nasal septum and ECG wearing belts were employed in similar techniques.

An alternative approach to medical-grade devices could instead take advantage of the widespread distribution of biometric sensors in the consumer market. More specifically, consumer wrist-worn smartbands are considered affordable and minimally invasive, capable of continuously collecting physiological data, such as heart rate (HR) and sleep parameters.29 Fitbit Inc. devices, such as Fitbit ChargeHRTM, Fitbit Charge 2TM and Fitbit AltaHRTM, are amid the most studied commercial smartbands. Their accelerometric and HR measures have been validated in literature both during sleep and wakefulness, showing higher sensor accuracy during sleep.Their unobtrusiveness, their easy accessibility and reliability makes these devices compatible with a population-based screening test.**[3]**

EXPLORING SOME MORE WEARABLE SENSORS FOR OSA DETECTION PURPOSES IN COLLABORATION WITH MACHINE LEARNING CLASSIFIERS

1. The reference standard method of polysomnography (PSG) or other diagnostic techniques like cardiorespiratory monitoring (CRM) can be used to evaluate OSAS. Both PSG and CRM are mentioned in the clinical guidelines of the American Academy of Sleep Research (AASM) and the European Respiratory Society, respectively, although they are rather invasive, pricey, and time-consuming when it comes to the process of rating sleep episodes.Therefore, using PSG or CRM for general population screening is not viable due to budget limitations. It is critical to look into more convenient instruments to screen the general population for OSAS because various studies suggest that OSAS goes mainly undetected and is not identified in up to 90% of patients. Single-lead electrocardiography(ECG) could potentially lessen the PSG and CRM's intrusiveness. Two electrodes are applied to the skin in order to collect data on the electrical activity of the heart as well as the condition of the autonomic nervous system, which is known to be disturbed by OSAS occurrences.**[4][5]** Recent research using single-lead ECG signals to train deep neural networks showed promising results: Yang et al. achieved a sensitivity of 87.1% with a deep learning algorithm capable of extracting from the single-lead ECG cardiopulmonary features. Feng et al. reached a sensitivity of 86.1% relative to the gold standard. Similar conclusions were achieved by other studies**[6–9]**. A single-lead ECG approach is a promising alternative to PSG and CRM, but it cannot be used to conduct a large-scale screening in a population that is not aware of OSAS. Instead, a single-lead ECG test must be administered by a healthcare professional after developing a suspicion of OSAS.

2. One of the possible ways ECG signals can be collected remotely is through new age sensors like Movisen's EcgMove 4. Through the parallel recording of the ECG and Activity Signals (ECG, 3D Accelerometer, Gyroscope, Barometric Air Pressure, and Temperature), the **EcgMove 4** offers a rich treasure trove of data for the detailed analysis of the functioning of the heart, the autonomic nervous system, and additionally behaviour and activity. Whilst recording the raw data stream, the sensor can also analyze certain parameters live on the sensor and transmit the results via Bluetooth smart interface, e.g. to a smartphone.

The sensor is optimized for use in scientific studies and interactive ambulatory assessment. The new attachment systems offer you great flexibility in use and a high wearing comfort for the study participant, with the choice of adhesive electrodes or our acclaimed dry electrode textile chest belt. This leads to improved compliance, higher data volume and quality, and thus reduces the effort of carrying out a study and reduces costs.

Combined with our Analysis-Software DataAnalyzer allows the simple calculation of parameters such as Heart Frequency, Heart Rate Variability, Activity Class, Steps, Energy Expenditure and Metabolic Equivalent of Task (MET).

3. In the article **[10]** where Georgia Institute of Technology, group of researchers have developed wearables with two sensors for forehead and chin. With a thickness of that of a bandage this can be used to transmit brain, eye and muscle activity over Bluetooth connectivity. They found that the device had an accuracy rate of 88.52 percent.
4. Our health information from the many supported platforms is housed in the Health Connect program, which functions as a single repository.It acts as a hub where data from many platforms for fitness and health congregates. Following that, the user can choose how supported services should access this data. This is great for syncing wearables and fitness trackers that some providers do not support, as well as services that are not natively supported.A lot of apps can connect with each other or this feature can greatly aid in the development of new apps by just allowing data synchronization with health connect.

Oura and **Sleep as Android** are applications focused on sleep that this offers.

By leveraging every signal from the Oura Ring (movement, temperature, heart rate, and HRV), **Oura's research scientists were able to develop a new sleep staging algorithm that achieves 79% agreement with gold-standard polysomnography (PSG)** for 4-stage sleep classification (wake, light, deep, and rapid eye movement (REM) sleep).

Oura's new sleep staging algorithm was developed using advanced machine learning techniques and one of the largest wearable sleep datasets collected to date. **This one-of-a-kind dataset includes diverse participants across multiple continents and sleep laboratories**, demonstrating the power of using all of the signals of the Oura Ring to maximize accuracy.

Oura Ring monitors body signals, like heart rate, movement, and body temperature trends, to determine when one has fallen asleep and which sleep stage they're in. This is possible because each sleep stage (awake, light sleep, REM, and deep sleep) is characterized by distinct biosignals.

The following attributes are tracked by Oura application in order to predict and suggest on any Sleep disorders.S

- **Sleep Patterns**: The app tracks your sleep duration, sleep stages (light, deep, REM), and sleep efficiency. It provides insights into the quality of your sleep.

- **Sleep Score**: Oura calculates a sleep score that takes into account various sleep-related metrics to provide an overall assessment of your sleep quality.
- **Resting Heart Rate**: The app monitors your resting heart rate over time, which can serve as an indicator of your cardiovascular health and recovery.
- **Heart Rate Variability (HRV)**: Oura measures HRV, which is the variation in time between successive heartbeats. It's often used as an indicator of stress levels and recovery.
- **Body Temperature**: The app tracks your body temperature, which can provide insights into your body's circadian rhythm and overall health.
- **Activity Tracking**: Oura may monitor your daily activity, steps taken, and calories burned. While not its primary focus, it provides a basic overview of your movement.
- **Readiness Score**: Oura calculates a readiness score that considers factors like sleep quality, recovery, and HRV to help you gauge your overall readiness for the day's activities.
- **Guided Interventions**: The app offers personalized recommendations and interventions to improve sleep quality, recovery, and overall well-being.

REFERENCES

[1] https://link.springer.com/article/10.1007/s11818-019-0200-1
[2] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3566993/
[3] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9124490/
[4]https://pubmed.ncbi.nlm.nih.gov/15471971/
[5]https://pubmed.ncbi.nlm.nih.gov/15994124/
[6]Shen Q, Qin H, Wei K, Liu G. Multiscale deep neural network for obstructive sleep apnea detection using RR interval from single-lead ECG signal. IEEE Trans Instrum Meas. 2021;70:1–13.
[7] Gupta K, Bajaj V, Ansari IA. OSACN-Net: automated classification of sleep apnea using deep learning model and smoothed Gabor spectrograms of ECG signal. IEEE Trans Instrum Meas. 2021;71:1.
[8]Liu HQ. A dual-model deep learning method for sleep apnea detection based on representation learning and temporal dependence. Neurocomputing. 2022;473:24–36. doi: 10.1016/j.neucom.2021.12.001
[9]https://pubmed.ncbi.nlm.nih.gov/34896885/
[10] https://mhealthintelligence.com/news/georgia-researchers-develop-wearable-device-to-detect-sleep-apnea