

# Obstructive Sleep Apnea (OSA) Challenge

Ron Anafi

Diego Mazzotti

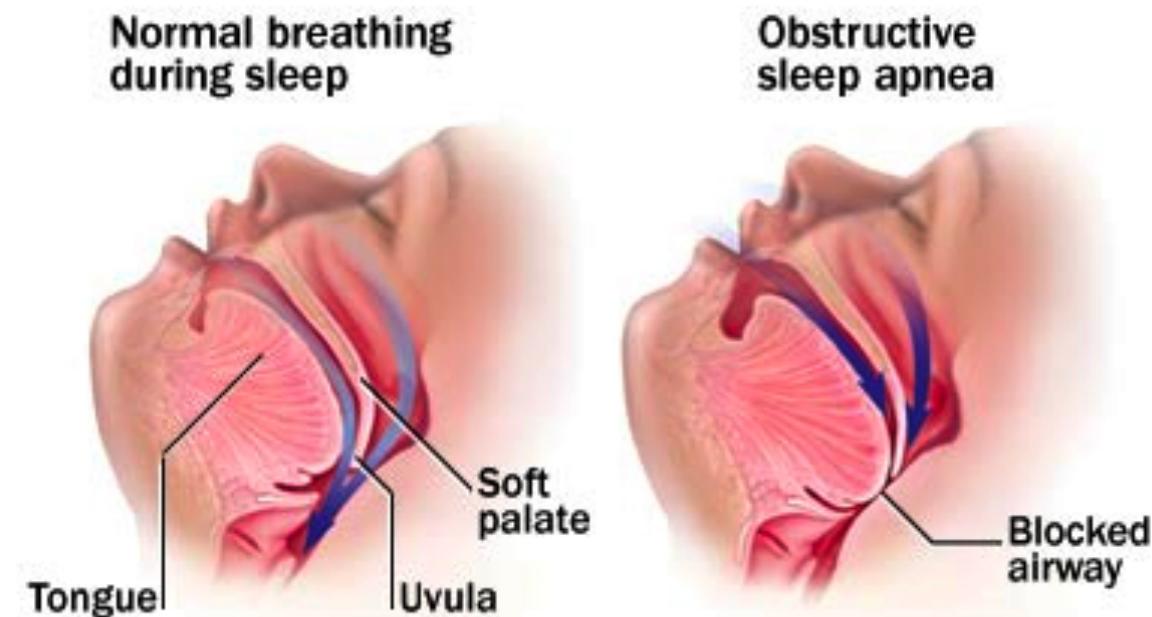
# Outline:

- Obstructive Sleep Apnea (OSA) made simple
  - Why do we care?
  - What is a polysomnogram (sleep study)?
  - How is OSA currently diagnosed/quantified
  - What is the challenge?
- 
- Describe the Sleep Heart Health Study?
  - What data is available?
  - How much detail should we use?
  - How do we access the data/outcomes?

# OSA made simple

- The upper airway is a flexible tube
- When you sleep your muscles relax
- That includes the muscles of your upper airway
- As the muscles relax your upper airway becomes “floppy”
- If it gets floppy enough, it starts to vibrate when you breath and you snore
- If it gets floppier, the airway can close off and you can't get a good breath in
- After a while you will arouse, muscle tone increases, breathing picks back up, and you can return to a deeper sleep
- For some people the cycle can repeat hundreds of times a night

# Obstructive Sleep Apnea



© Mayo Foundation for Medical Education and Research. All rights reserved.

# What does that do to your body?

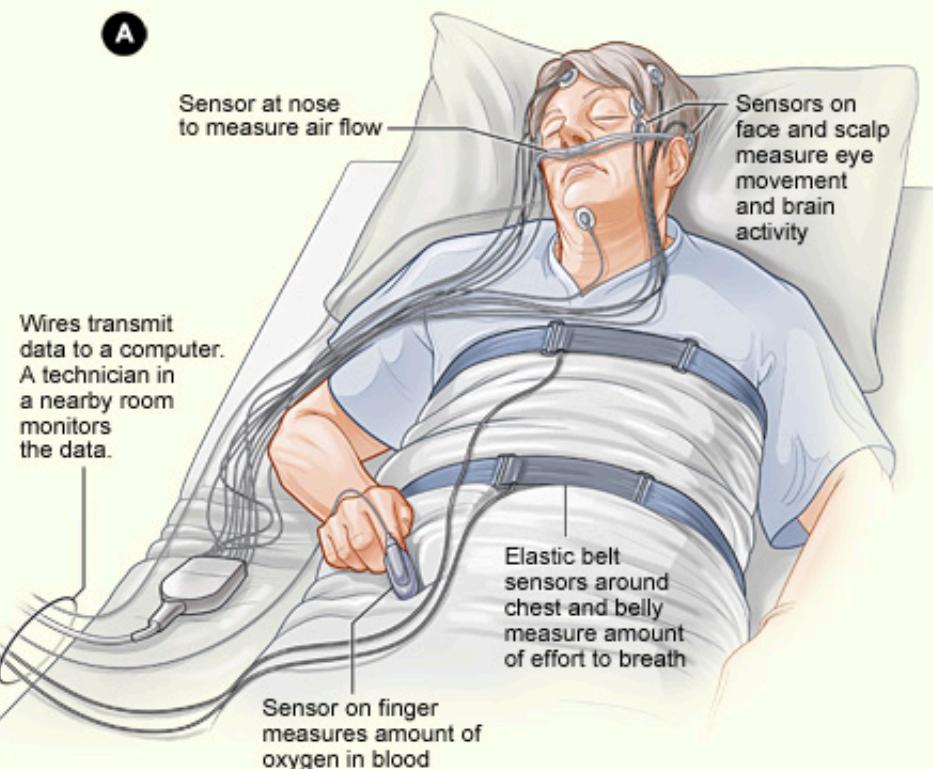
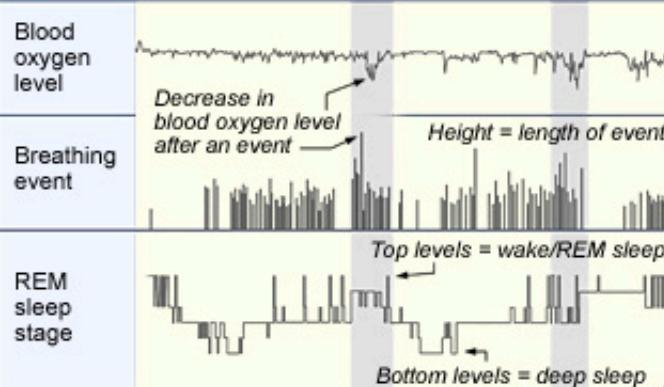
- How would you feel if I woke you up repeatedly throughout the night? (sleepy)
- What would you due to me if I tried to choke you? (fight back)
  - Repeated blood pressure surges
  - Repeated arousals and catecholamine surges (“Adrenaline”)
  - Release of various inflammatory cytokines and clotting factors
  - Intermittent hypoxia (low oxygen)
  - Intermittent hypercapnia (high carbon dioxide)

# Why do we care?

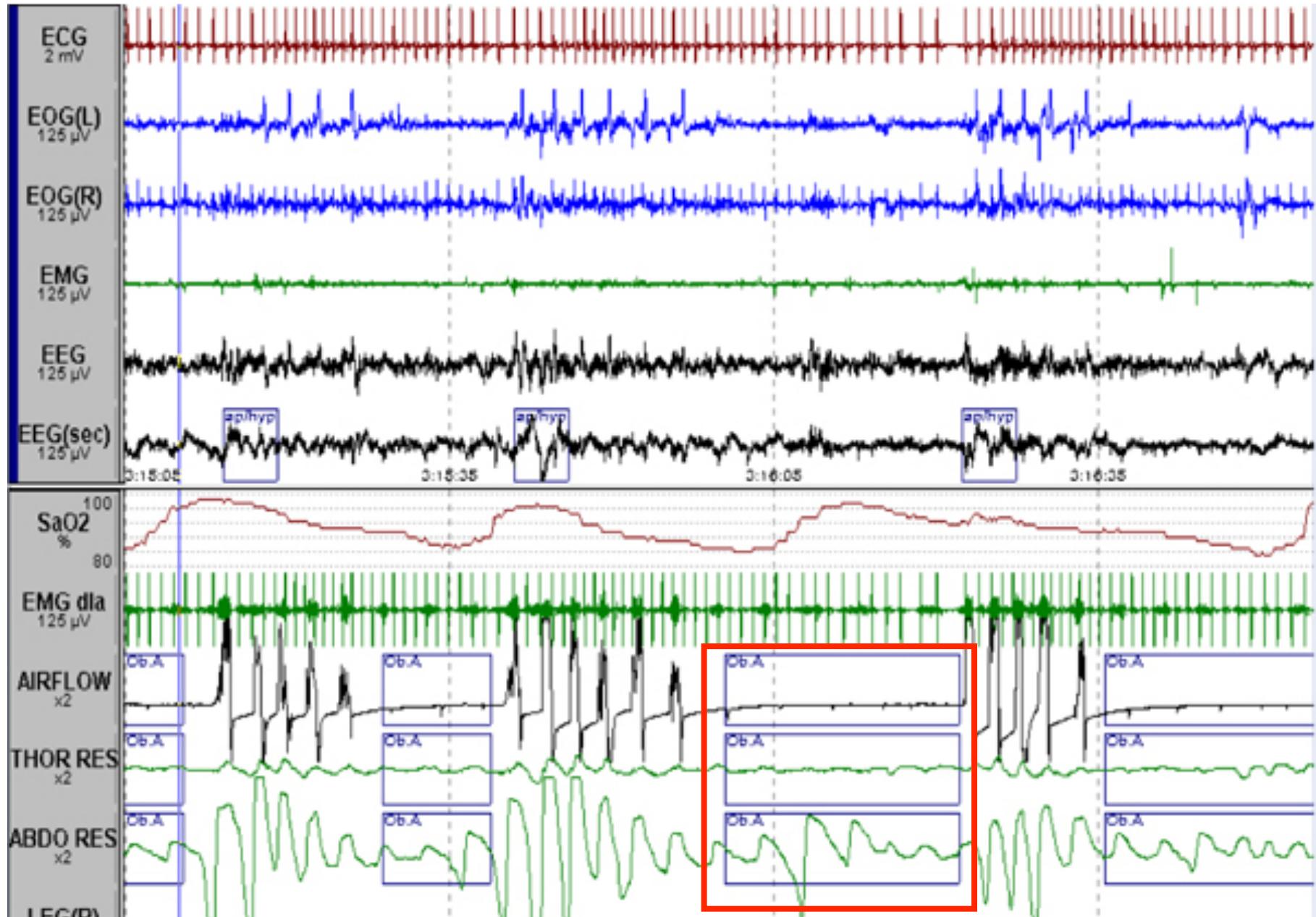
- Prevalent (~10% of the population)
  - Estimates vary from 5-20%
- Immediate Consequences:
  - Sleepiness (and drowsy driving accidents)
- Long-term Consequences:
  - Increased risk of cardiovascular disease (MI, Stroke, Death, etc.)

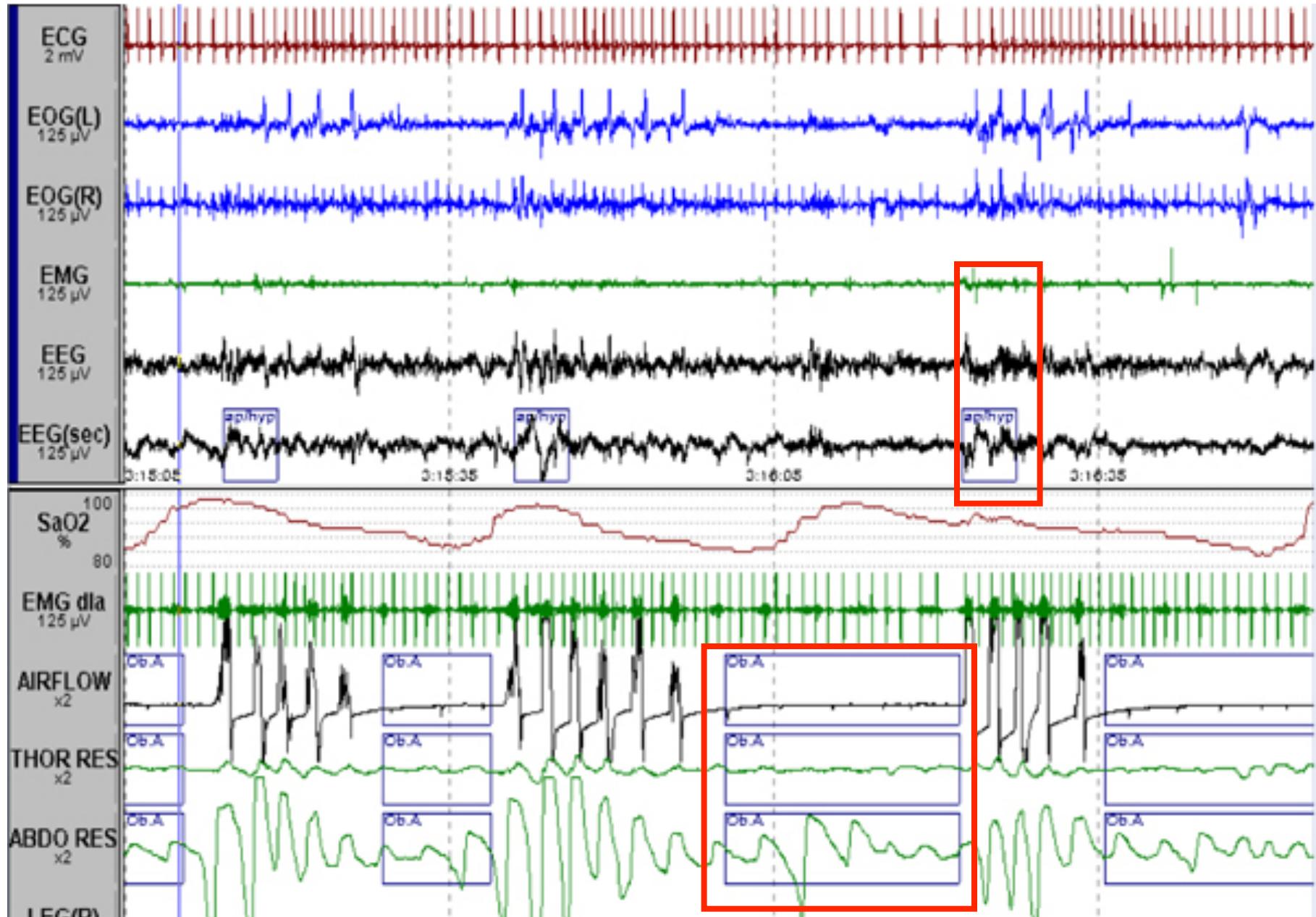
# What is a sleep study?

- EEG (“brain waves”)
- EOG (“eye movements”)
- EMG (“chin muscle tone”)
  - All used to assess sleep stage (Wake, REM, nonREM) and find arousals
- Respiratory Inductance Belts (“chest and abdominal excursion”)
  - Used to assess respiratory effort
- Flow Sensor
  - Measure how much air is really flowing
- Oximetry sensor
  - Measure blood oxygen saturation
- EKG – Measure heart rate/variability.

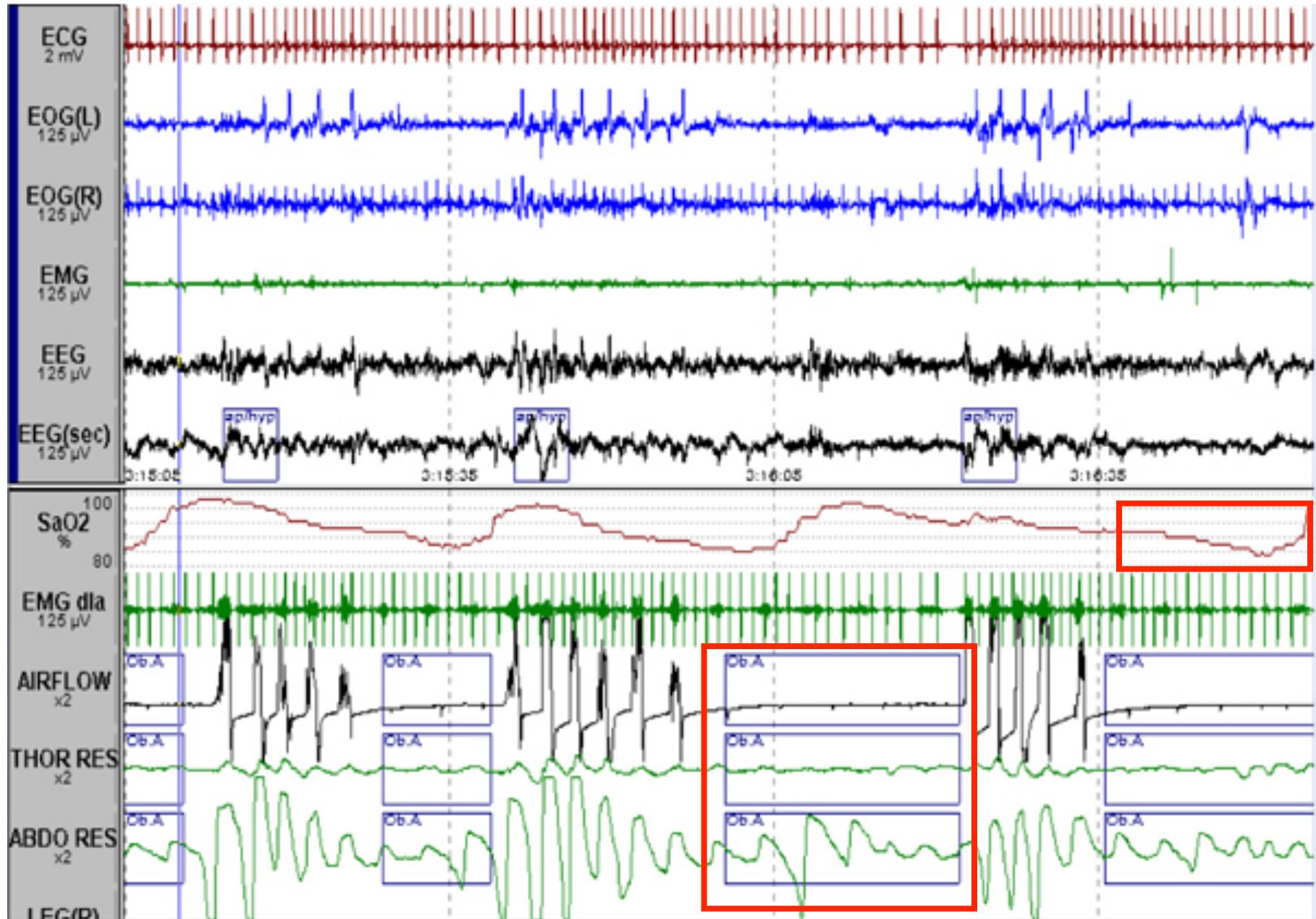
**A****B****Polysomnogram record (over time)**

A “textbook” obstructive apnea



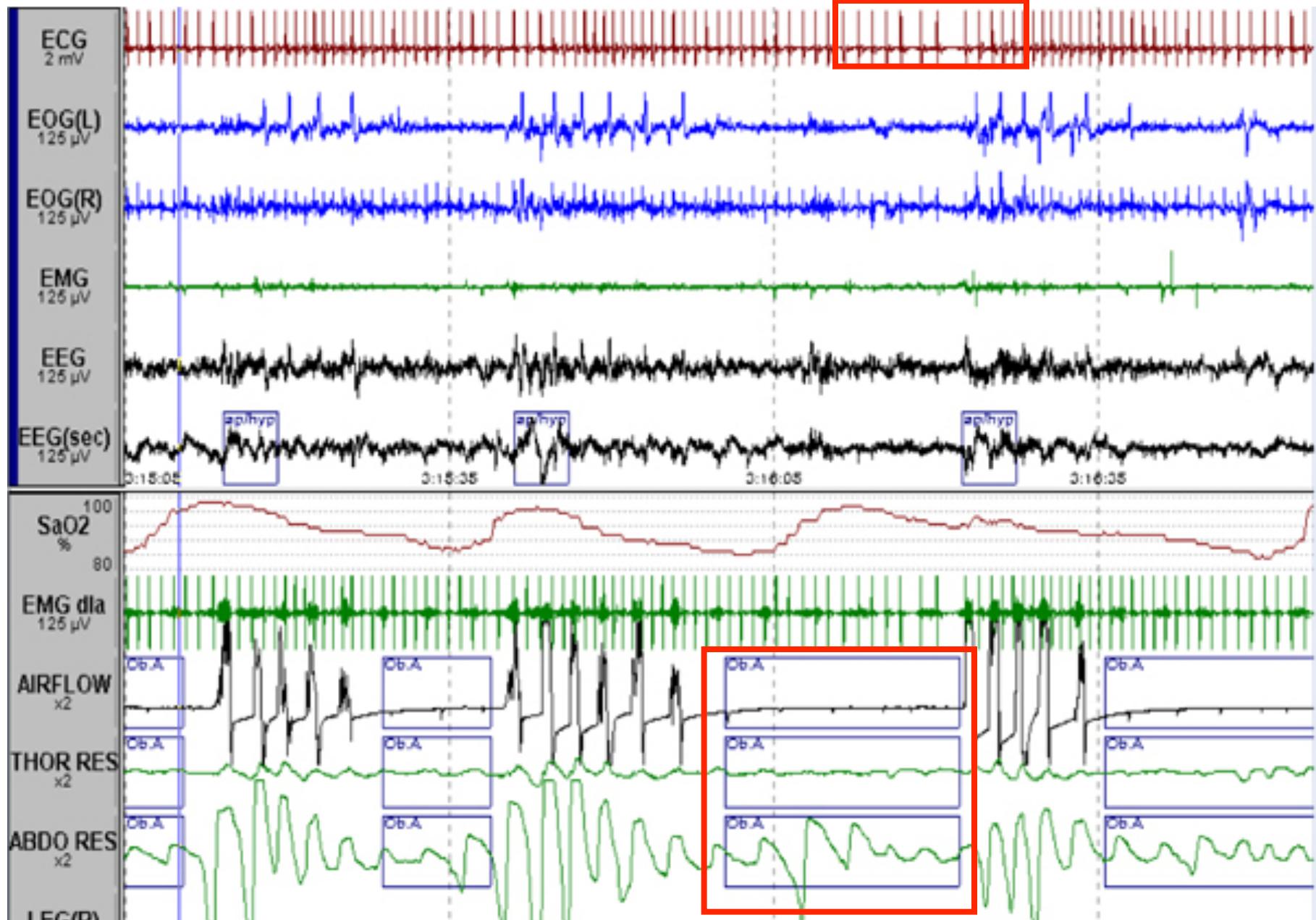


EEG and EMG changes right after event:  
Arousal

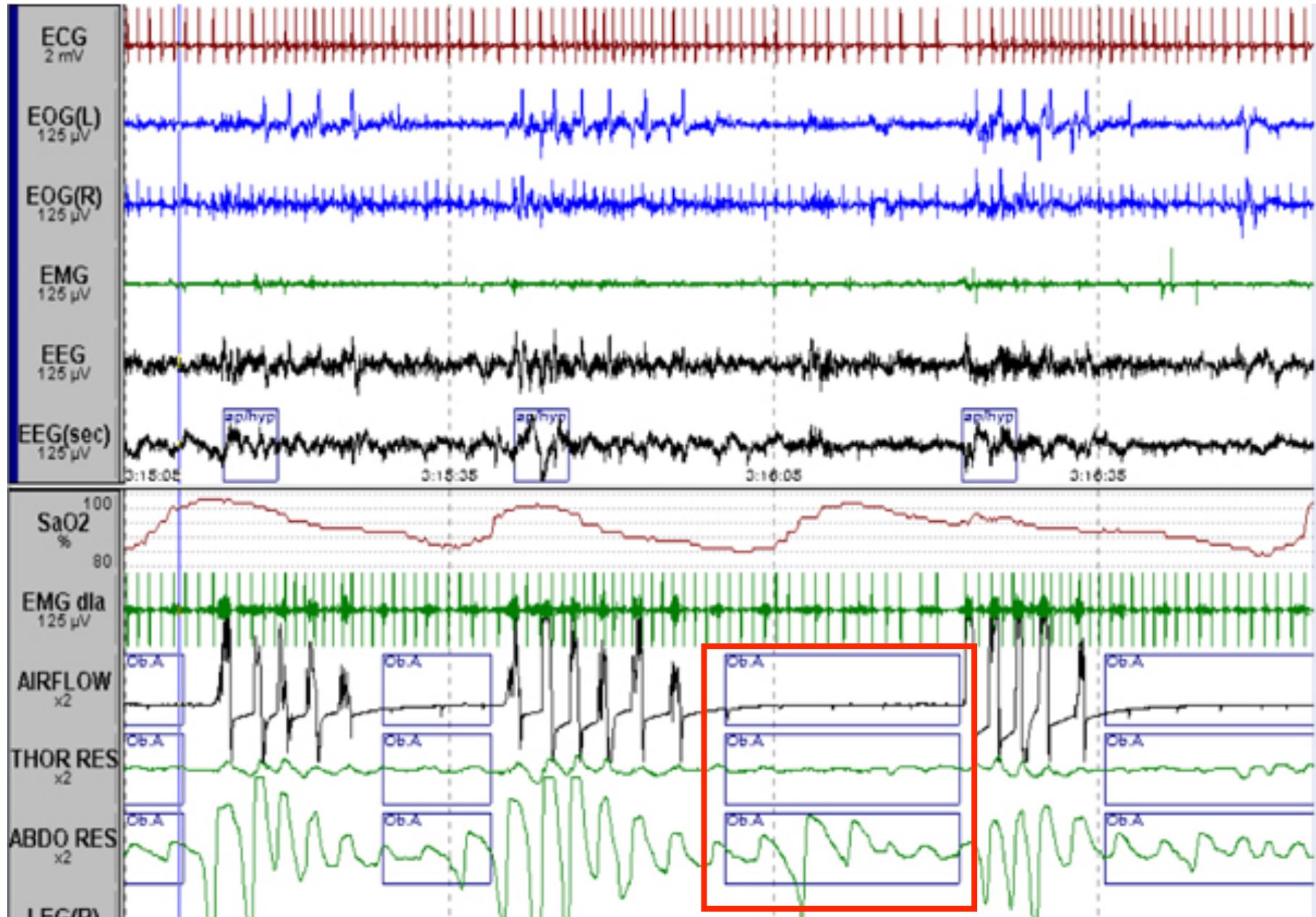


Desaturation often lags further behind breathing changes

This delay reflects a combination of pulmonary reserve and cardiovascular transit time



Heart-rate variability often increases during and after obstructive event  
as a result of autonomic (“fight or flight”) changes



The propensity for obstructive events often depends on other factors  
Including sleep stage

# How do you summarize all that?

- Everybody's breathing changes a bit during sleep -What breathing changes have health consequences?
- How much does airflow need to be reduced for there to be an event?
- Do we need to see a desaturation? How much?
- Do we need to see an arousal?
- Are EKG changes important?
- Are particular EEG patterns/frequencies meaningful?
- Does the stage of sleep where the event happens matter?
- How about the time course/sequence of these events?

# Experts sat in a room in Chicago and came to a simple consensus

- Apnea: >90% Reduction in airflow for >10 seconds
- Hypopnea: >50% Reduction in airflow for >10 s with an observable consequence
  - >4% reduction in oxygen saturation OR an EEG arousal
- AHI (Apnea Hypopnea Index):
  - (#Apneas+ #Hypopneas)/(sleep duration in hours)

**Consensus definitions were not data driven**

**The absolute cutoffs have actually shifted over the years**

**All the other information in the study is effectively ignored**

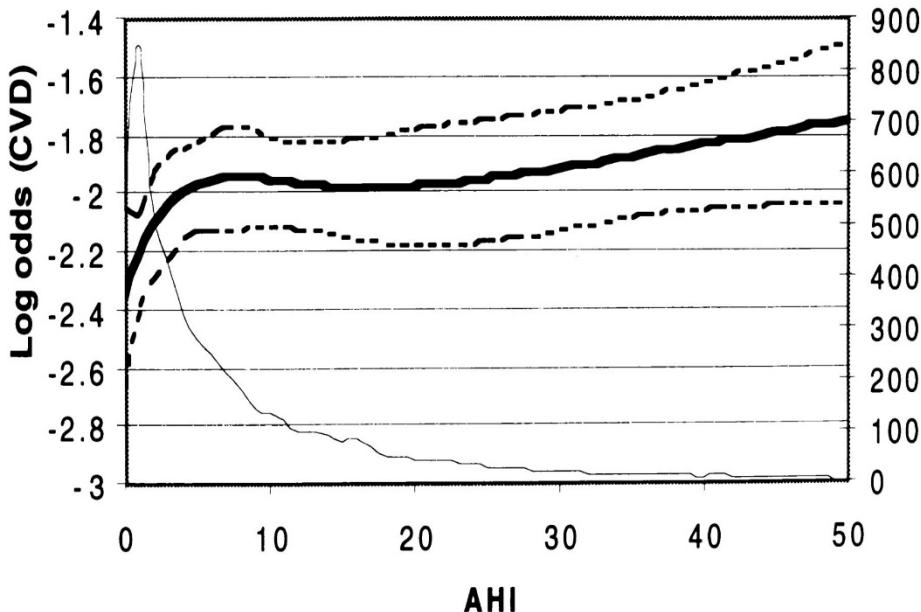
# Apnea Hypopnea Index (AHI)

- AHI 0 - 5 events/hour: Normal
- AHI 5 - 15 events/hour: Mild sleep apnea
- AHI 15 - 30 events/hour: Moderate sleep apnea
- AHI > 30 events/hour: Severe sleep apnea

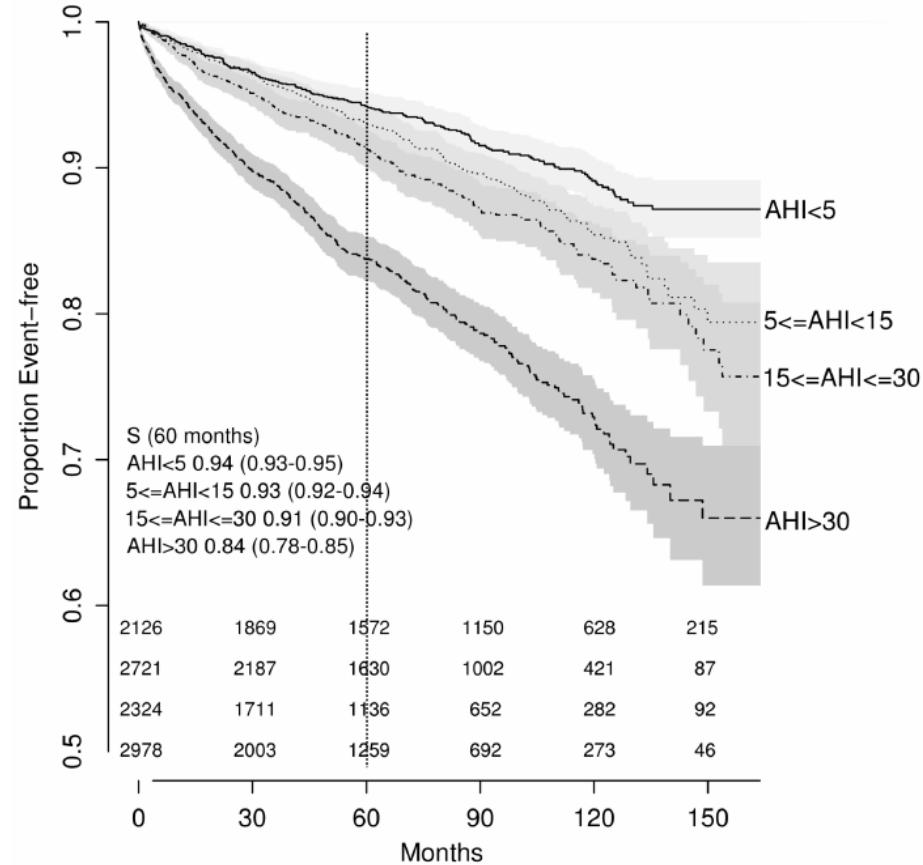
**Doctors diagnose (and recommend to treat) OSA almost exclusively from this one number**

# AHI predicts future cardiovascular events (but its not perfect...)

A



Shahar et al. AJRCCM 200!



Kendzerska et al. PLoS Medicine 2014

The relationship with subjective sleepiness is weaker

# Proposed challenge:

- Derive new diagnostic criteria for Obstructive Sleep Apnea (machine learning classifier) *that better predicts the subsequent development of new cardiovascular events*
- Derive new diagnostic criteria for Obstructive Sleep Apnea (machine learning classifier) *that better predict the patient's subjective sleepiness*

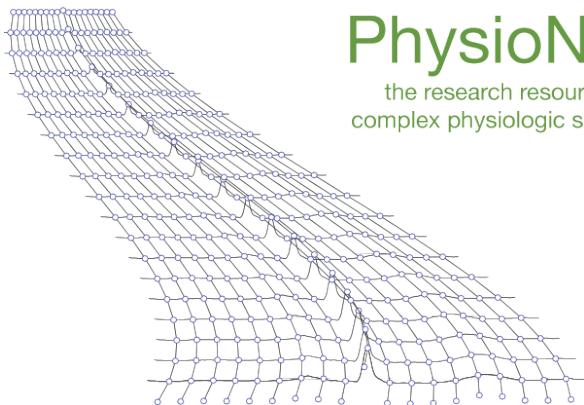
# Explaining the data

Diego Mazzotti

# National Sleep Research Resource

Free research data and tools.

- <https://sleepdata.org/>
- Data access and aggregation resource for Sleep Research
- Maintained by the National Heart, Lung, and Blood Institute, NIH

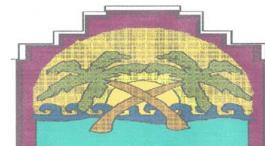


**PhysioNet**  
the research resource for  
complex physiologic signals



# National Sleep Research Resource

- 11 sleep-related datasets: polysomnography, actigraphy, sleep questionnaires, clinical data, etc.



Cleveland Children's  
Sleep and Health Study



# Sleep Heart Health Study



- NIH funded study to learn the cardiovascular consequences of sleep-disordered breathing in adults (over 40 years old)
- A polysomnography is obtained at baseline along with demographic information, questionnaires and known comorbidities.
- Cardiovascular outcomes are tracked at the initial visit and followed up to 13 years
- Baseline and outcome data is available for **5,082 subjects**
- **More info:** <https://sleepdata.org/datasets/shhs>

# Sleep Heart Health Study

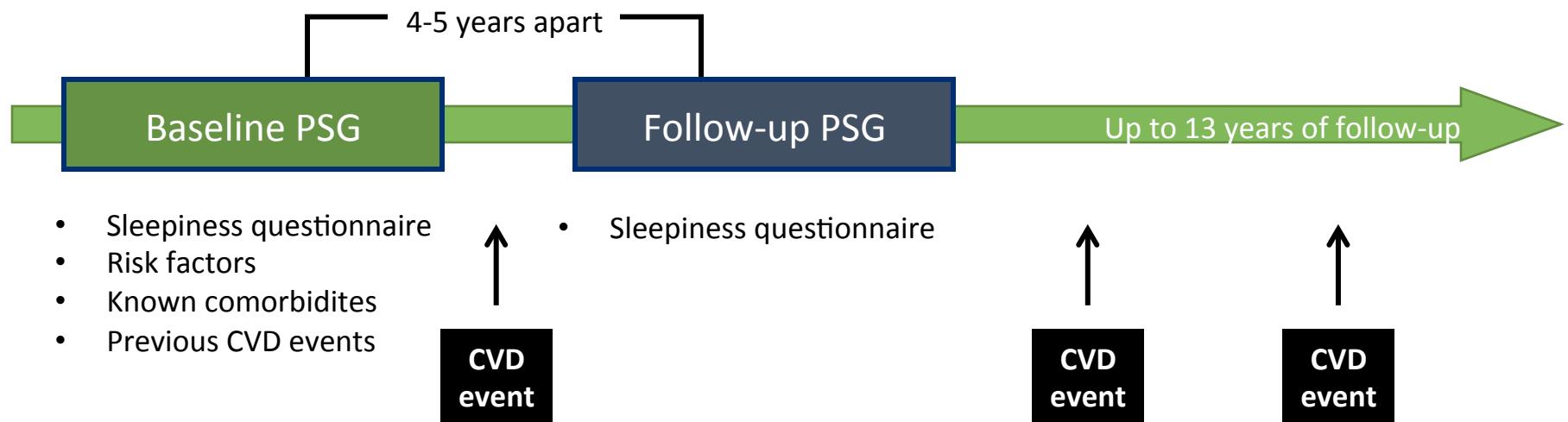


- Polysomnography (PSG, “Sleep Study”): overnight continuous, time series recordings of several physiological signals
  - Pulse oximetry
  - Nasal/oral airflow
  - Body Position
  - 2 electroencephalogram (EEG) channels
  - Bilateral electrooculogram (EOG)
  - Chin electromyogram (EMG)
  - Electrocardiogram (ECG)

# Conventional PSG metrics

- Related to **sleep**
  - Time and % spent on different sleep stages and awake
  - Number of EEG arousals
- Related to **disordered breathing**
  - Apnea-Hypopnea Index (AHI): Number of apnea and hypopnea events per hour of sleep
  - Other indexes by types of apnea (e.g. central, obstructive)
- Related to **blood oxygenation**
  - Oxygen desaturation indexes: number of desaturation events (e.g.  $\text{SpO}_2 < 3$  or 4%)
- Related to **heart rate**
  - Heart-rate variability metrics
- Combinations of the above and many others

# Can we predict future outcomes using data from the sleep study?

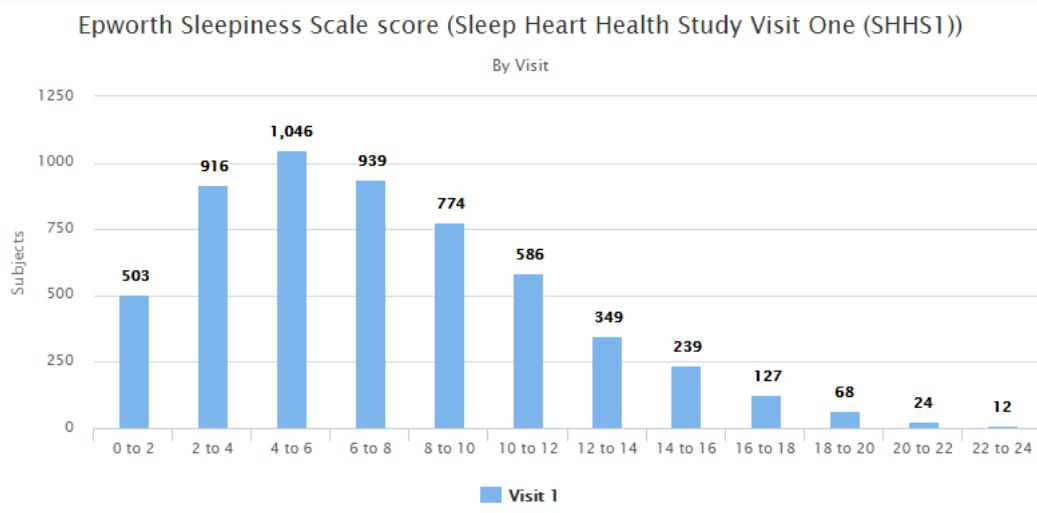
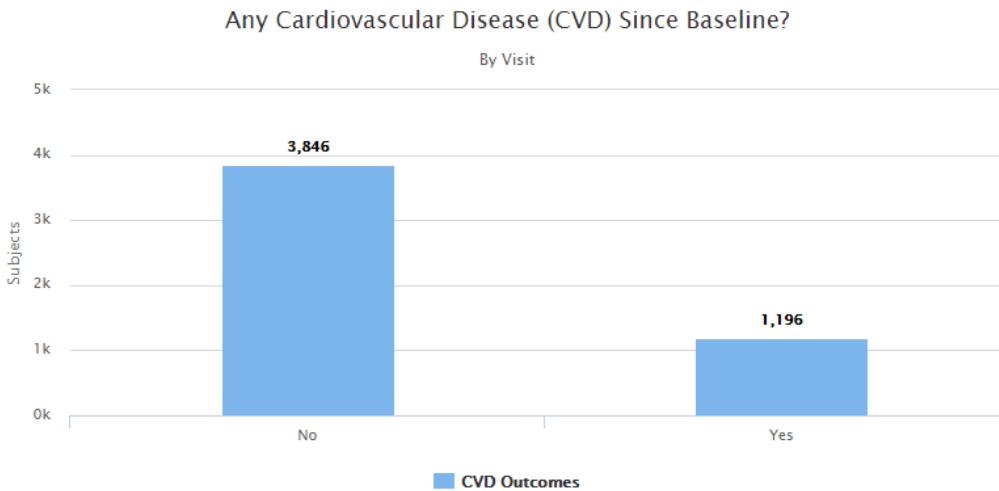


CVD: cardiovascular event detected from medical record (e.g. myocardial infarction, stroke, congestive heart failure)

12-lead ECG: more detailed electrocardiogram – can detect other events (e.g. atrial fibrillation)

# Outcomes

- 1) Presence of incident Cardiovascular Disease since baseline (**yes/no**)
- MI
  - Stroke
  - Congestive Heart Failure
  - Coronary Heart Disease
  - Fatal events



## 2) Sleepiness (0-24)

- Epworth Sleepiness Scale (ESS), a self-reported sleepiness scale that indicates the subjective likelihood of fall asleep in different scenarios

# Predictors

- Conventional PSG metrics
- Sleep stage and respiratory event annotations
- Any other feature extracted from raw signal data
- Other CVD risk factors (extra)
  - Sex, age, body mass index, blood lab tests, lung function, medications
- Questionnaires about health, lifestyle, etc. (extra)

# Predictor datasets

- Three difference sources:
  - **EASY**: Subject summary data
    - .csv format, 1 row per subject
  - **MODERATE**: 30-s epochs of event annotations during the PSG
    - .csv format, each subject represented by X rows, where X is the number of epochs in their sleep study
  - **HARD**: Raw signal file
    - European Data Format (.edf), a standardized format that stores physiological signal time series data
    - Can be exported and converted to .csv, but converted file is very large (~300MB per subject)
    - Requires signal processing skills

# Predictor datasets

- EASY: Subject summary data

nsrrid	stdydtqa	slp_lat	slp_rdi	slp_time	time_bed	slp_eff	WASO	timest1p	timest2p	times34p	timeremp
200001	0		375.5	375.5	440.5		65	6.25832	60.8522	19.3076	13.5819
200002	0		182	182	225		43	0.82418	65.6593	16.7582	16.7582
200003	0		358.5	358.5	431.5		73	4.88145	40.3068	42.8173	11.9944
200004	0	14	301	301	358.5	83.9609	43.5	2.99003	29.402	52.3256	15.2824
200005	0	6.5	370	370	477	77.5681	100.5	5.67568	68.6487	13.3784	12.2973
200006	0		387	387	469.5		82.5	6.20155	68.3463	5.03876	20.4134
200007	0	44.5	332.5	332.5	418.5	79.4504	41.5				
200008	0		335		479.5		103	2.23881	53.8806	31.791	12.0896
200009	0	20	351.5	351.5	424	82.9009	52.5	5.40541	42.3898	33.5704	18.6344
200010	0	24	415.5		507	81.9527	67.5	1.20337	58.9651	19.6149	20.2166
200011	0	6.5	371.5	371.5	399	93.1078	21	2.28802	44.8183	43.3378	9.55586
200012	0		311.5	311.5	412		100.5	7.54414	52.9695	26.9663	12.5201

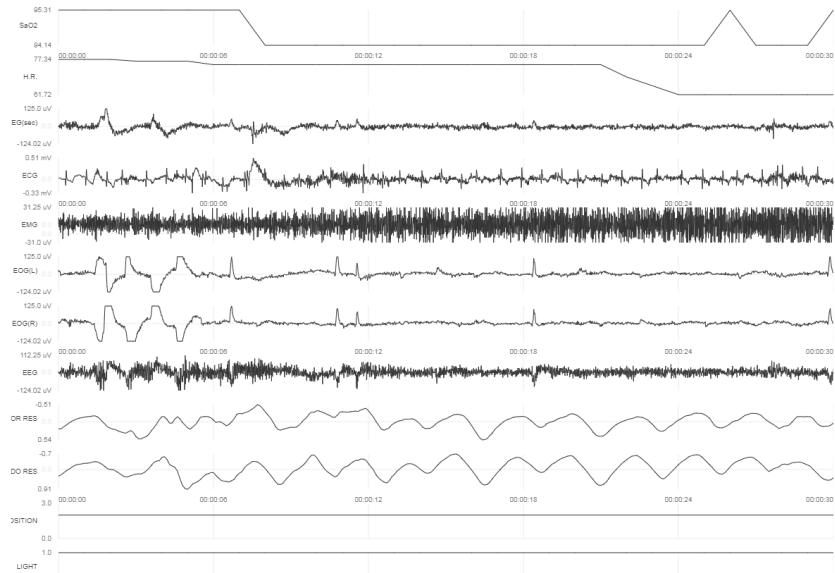
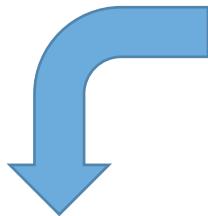
# Predictor datasets

- **MODERATE:** 30-s epochs of event annotations during the PSG
  - Stored in .XML, script to convert to .csv is provided

ptpid	epoch	EpochStartTime	SleepStage	Name	Start	Duration	Input	LowestSpO2	Desaturation
shhs1-200001-profusion.xml	257	7680	5	Hypopnea	7680.3	37.9	AIRFLOW	NA	NA
shhs1-200001-profusion.xml	258	7710	5	SpO2 desaturation	7710.3	37.9	SAO2	88	4
shhs1-200001-profusion.xml	259	7740	5	Hypopnea	7747.8	25.9	AIRFLOW	NA	NA
shhs1-200001-profusion.xml	260	7770	5	SpO2 desaturation	7777.8	25.9	SAO2	88	4
shhs1-200001-profusion.xml	260	7770	5	Hypopnea	7788.3	30.9	AIRFLOW	NA	NA
shhs1-200001-profusion.xml	261	7800	5	SpO2 desaturation	7818.3	30.9	SAO2	88	2
shhs1-200001-profusion.xml	262	7830	5	Hypopnea	7837	34	AIRFLOW	NA	NA
shhs1-200001-profusion.xml	263	7860	5	SpO2 desaturation	7867	34	SAO2	87	3
shhs1-200001-profusion.xml	263	7860	5	Arousal ()	7877	6.7	EMG	NA	NA
shhs1-200001-profusion.xml	264	7890	5	Hypopnea	7899.4	31.6	AIRFLOW	NA	NA
shhs1-200001-profusion.xml	265	7920	5	SpO2 desaturation	7929.4	31.6	SAO2	88	3
shhs1-200001-profusion.xml	265	7920	5	Arousal ()	7948.8	5	EMG	NA	NA

# Predictor datasets

- HARD: Raw signal file



Time	SaO2	HearRate	EEG(sec)	ECG	EMG	EOG(L)	EOG(R)	EEG	THOR	ABDO	POS	LIGHT	AIRFLOW	OXSTAT
0	95.3124	77.3442	-4.90196	0.02941	12.5	28.4314	11.7647	-2.94118	0.21177	0.31373	2	1	5.88235	0
0.008			4.90196	0.02941	3.67647			0.98039						
0.016			1.96078	0.02941	-3.67647			-9.80392						
0.02						16.6667	0.98039							
0.024			0	0.02941	-2.69608			-6.86275						
0.032			-0.98039	0.03922	8.33333			-0.98039						
0.04			-10.7843	0.03922	1.47059	24.5098	9.80392	-10.7843						
0.048			2.94118	0.03922	9.31373			-12.7451						
0.056			11.7647	0.03922	-8.82353			-12.7451						
0.06						18.6275	4.90196							
0.064			-1.96078	0.03922	-2.69608			-7.84314						
0.072			-2.94118	0.02941	12.9902			0.98039						
0.08			-8.82353	0.02941	-12.9902	-5.88235	16.6667	5.88235						
0.088			8.82353	0.02941	3.43137			8.82353						
0.096			23.5294	0.02941	-0.98039			-22.549						
0.1						-9.80392	17.6471		0.21177	0.25098			5.88235	

# Data access example

- <https://sleepdata.org/datasets/shhs>

The screenshot shows the SHHS dataset page on the sleepdata.org website. The top navigation bar includes links for NSRR, About, Datasets (which is underlined), Tools, Forum, and Blog. A search bar and a user icon are also present. The main title is "Sleep Heart Health Study". Below the title are three tabs: Documentation (selected), Files, and Variables. Under the Documentation tab, there are four cards: "What" (Multi-cohort study focused on sleep-disordered breathing and cardiovascular outcomes), "Who" (5,804 adults aged 40 and older), "When" (Two exam cycles, 1995-1998 and 2001-2003. Cardiovascular disease outcomes were tracked until 2010.), and "Funding" (National Heart, Lung, and Blood Institute). At the bottom of the page, there are links for "shhs > pages", "Data Access Approved" (with a checkmark icon), and "Hide Menu". On the right side, there is a sidebar titled "SHHS" with a "mop" icon, followed by a list of eight documents: 03-data-analysis-tip-sheet..., 04-dataset-introduction.md, 05-polysomnography-intro..., 06-reliability-shhs1.md, 07-reliability-shhs2.md, and 08-equipment-shhs1.md.

Sleep Heart Health Study

Documentation Files Variables

What Who When Funding

Multi-cohort study focused on sleep-disordered breathing and cardiovascular outcomes.

5,804 adults aged 40 and older.

Two exam cycles, 1995-1998 and 2001-2003. Cardiovascular disease outcomes were tracked until 2010.

National Heart, Lung, and Blood Institute

shhs > pages Data Access Approved Hide Menu

About

The Sleep Heart Health Study (SHHS) is a multi-center cohort study implemented by the National Heart Lung & Blood Institute to determine the cardiovascular and other consequences of sleep-disordered breathing. It tests whether sleep-related breathing is associated with an increased risk of coronary heart disease, stroke, all cause mortality, and hypertension. In all, 6,441 men and women aged 40 years and older were enrolled between November 1, 1995 and January 31, 1998 to take part in SHHS Visit 1. During exam cycle 3 (January 2001- June 2003), a second polysomnogram (SHHS Visit 2) was obtained in 3,295 of the participants. CVD Outcomes data were monitored and adjudicated by parent cohorts between baseline and 2011. More than 130 manuscripts have been published investigating predictors and outcomes of sleep disorders. [Click here for a full description of SHHS.](#)

Read more about SHHS at [ClinicalTrials.gov \(NCT00005275\)](#).

SHHS

mop

- 03-data-analysis-tip-sheet....
- 04-dataset-introduction.md
- 05-polysomnography-intro...
- 06-reliability-shhs1.md
- 07-reliability-shhs2.md
- 08-equipment-shhs1.md

# Variable description (available without data access)

The image shows two screenshots of a software interface for viewing variable descriptions. The left screenshot shows a list of variables under the 'Variables' section of the SHHS dataset. The right screenshot shows a list of measurements under the 'Measurements' section of the 'Polysomnography' dataset.

**Left Screenshot (Variables):**

Name
visitnumber
afibincider
afibprevalence

**Right Screenshot (Measurements):**

Name	Label
ai_all	Arousal Index Total number of arousals per hour of sleep
avgsat	Average oxygen saturation (SaO <sub>2</sub> )
minsat	Minimum oxygen saturation (SaO <sub>2</sub> )

A large black arrow points from the left screenshot to the right screenshot, indicating a relationship or comparison between the two datasets.

# Variable description (available without data access)

Name	Label	Folder
★ <a href="#">ai_all</a>	Arousal Index Total number of arousals per hour of sleep. Ratio of count of arousals to total sleep time in hours.	Measurements/Polysomnography/Arousal
★ <a href="#">avgsat</a>	Average oxygen saturation (SaO2) in sleep	Measurements/Polysomnography/Oxygen Saturation
★ <a href="#">minsat</a>	Minimum oxygen saturation (SaO2) in sleep Lowest oxygen saturation (SaO2)% during sleep	Measurements/Polysomnography/Oxygen Saturation
★ <a href="#">ahi_a0h3</a>	Apnea-Hypopnea Index (AHI) >= 3% - number of [all apneas] and [hypopneas with >= 3% oxygen desaturation] per hour of sleep	Measurements/Polysomnography/Respiratory Events/Indexes
★ <a href="#">ahi_a0h3a</a>	Apnea-Hypopnea Index (AHI) >= 3% - number of [all apneas] and [hypopneas with >= 3% oxygen desaturation or arousal] per hour of sleep	Measurements/Polysomnography/Respiratory Events/Indexes
★ <a href="#">ahi_a0h4</a>	Apnea-Hypopnea Index (AHI) >= 4% - number of [all apneas] and [hypopneas with >= 4% oxygen desaturation] per hour of sleep	Measurements/Polysomnography/Respiratory Events/Indexes
★ <a href="#">ahi_a0h4a</a>	Apnea-Hypopnea Index (AHI) >= 4% - number of [all apneas] and [hypopneas with >= 4% oxygen desaturation or arousal] per hour of sleep	Measurements/Polysomnography/Respiratory Events/Indexes
★ <a href="#">ahi_c0h3</a>	Central Apnea-Hypopnea Index (AHI) >= 3% - number of [central apneas] and [hypopneas with >= 3% oxygen desaturation] per hour of sleep	Measurements/Polysomnography/Respiratory Events/Indexes
★ <a href="#">ahi_c0h3a</a>	Central Apnea-Hypopnea Index (AHI) >= 3% - number of [central apneas] and [hypopneas with >= 3% oxygen desaturation or arousal] per hour of sleep	Measurements/Polysomnography/Respiratory Events/Indexes

# File storage and download (only with access)

shhs > files

✓ Data Access Approved

« 1 to 4 of 4 »

- datasets
- documentation
- forms
- polysomnography

[nsrr download shhs](#)

Don't have the NSRR gem?

Install using our [NSRR Gem Installation Instructions](#).

# File storage and download (only with access)

## datasets

PREDICTOR DATA (easy)

CHANGELOG.md	2017-12-20 09:50:55	9.94 KB
KNOWNISSUES.md	2017-12-20 09:50:56	11 KB
shhs1-dataset-0.13.0.csv	2017-12-20 09:50:33	23.2 MB
shhs2-dataset-0.13.0.csv	2017-12-20 09:50:50	11.3 MB
shhs-cvd-events-dataset-0.13.0.csv	2017-12-20 09:50:21	123 KB
shhs-cvd-summary-dataset-0.13.0.csv	2017-12-20 09:50:21	464 KB
shhs-data-dictionary-0.13.1-domains.csv	2017-12-20 09:50:54	10.2 KB
shhs-data-dictionary-0.13.1-forms.csv	2017-12-20 09:50:54	2.62 KB
shhs-data-dictionary-0.13.1-variables.csv	2017-12-20 09:50:55	479 KB
shhs-interim-followup-dataset-0.13.0.csv	2017-12-20 09:50:22	1.2 MB

OUTCOME DATA

## polysomnography

PREDICTOR DATA  
(moderate)  
PREDICTOR DATA (hard)

### annotations-events-nsrr

### annotations-events-profusion

### edfs