Can We Predict Obstructive Sleep Apnea (OSA) during Wakefulness?

Zahra Moussavi, Ph.D., P.Eng., CAE Fellow

Biomedical Engineering Program, University of Manitoba

http://bme.eng.umanitoba.ca/bmelab

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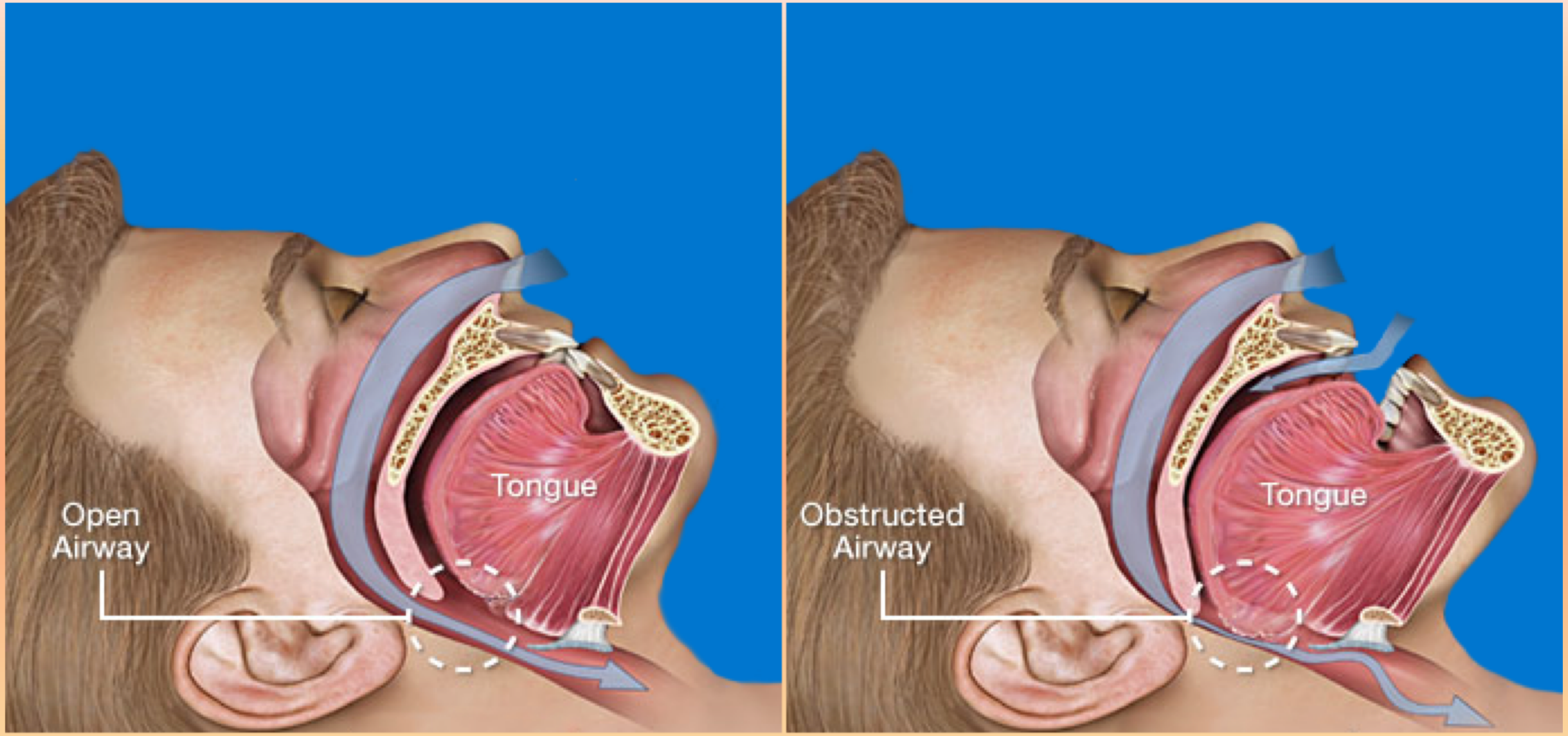
Hoboken train crash, Sept. 29, 2016

The driver of a commuter train that slammed into a station going double the speed limit, killing a woman and injured 17, suffered from severe sleep apnea that had gone undiagnosed.

Sleep Apnea can kill by causing catastrophic accidents

Associated with: snoring, high blood pressure, daytime symptoms, cardiovascular disease, obesity, etc.

What is Sleep Apnea?

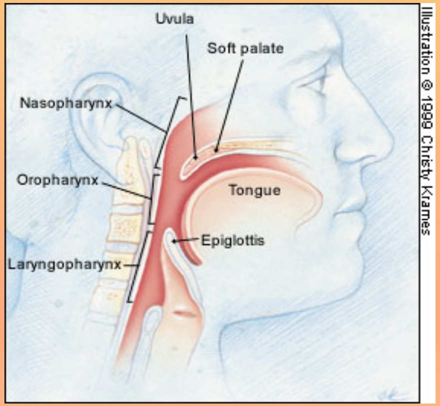


Non-Obstructed Airway

Obstructed Airway

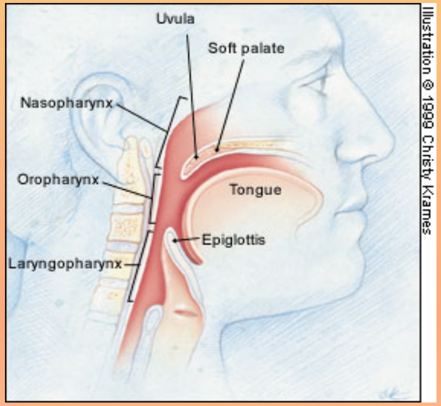
Definition of Sleep Apnea

- Apnea (hypopnea) : cessation (reduction > 50%) of air flow for at least 10 sec that is usually associated with a drop>4% in blood Oxygen Saturation level (SaO2).
  - Central Sleep Apnea – rare ~5%
  - **Obstructive sleep Apnea (OSA) – common 85%**
  - Mixed apnea ~10%



Causes or Contributing Factors to Sleep Apnea

- Anatomical, e.g. big tongue (falling backward, closing the airway), big tonsils, jaw deformities
- Neurological, e.g., stroke, MS, etc.
- Physiological, e.g., Loss of muscle tone due to aging or obesity, etc.



Sleep or Die!

SLEEP: PAST, PRESENT AND FUTURE

Sleep Deprivation in the Rat: An Update of the 1989 Paper

Allan Rechtschaffen PhD, and Bernard M. Bergmann, PhD

Departments of Psychiatry and Psychology, University of Chicago, Chicago, Illinois, U.S.A.

CONFIRMATION OF EARLIER RESULTS

THE REPRINTED REPORT[1] LISTED SEVERAL MAJOR SLEEP DEPRIVATION EFFECTS (SDES) WHICH WERE APPARENT IN ALL RATS subjected to prolonged total sleep

responses of physiological or behavioral change. These are correlated responses. We cannot confidently interpret the physiological and behavioral changes as effects of the sleep loss until we can discount the plausibility of other putative mediators of the

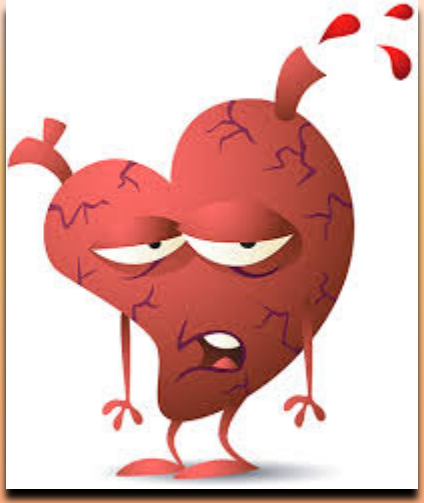
Can Sleep Apnea cause death?

High blood pressure — 37% also with sleep apnea

Drug-resistant high blood pressure — 83% also with sleep apnea

Atrial fibrillation — 49% also with sleep apnea

Males with congestive heart failure — 76% also with sleep apnea




Over-Weight
Males
African-Americans
Medical Conditions
Sleep Apnea Risk Factors
Post-Menopausal Women
Increasing Age
Family History
Large Neck Size
Alcohol Use
Smoking

How is Sleep Apnea measured?

The severity of sleep apnea is measured by Apnea/hypopnea Index (AHI) per hour of sleep.

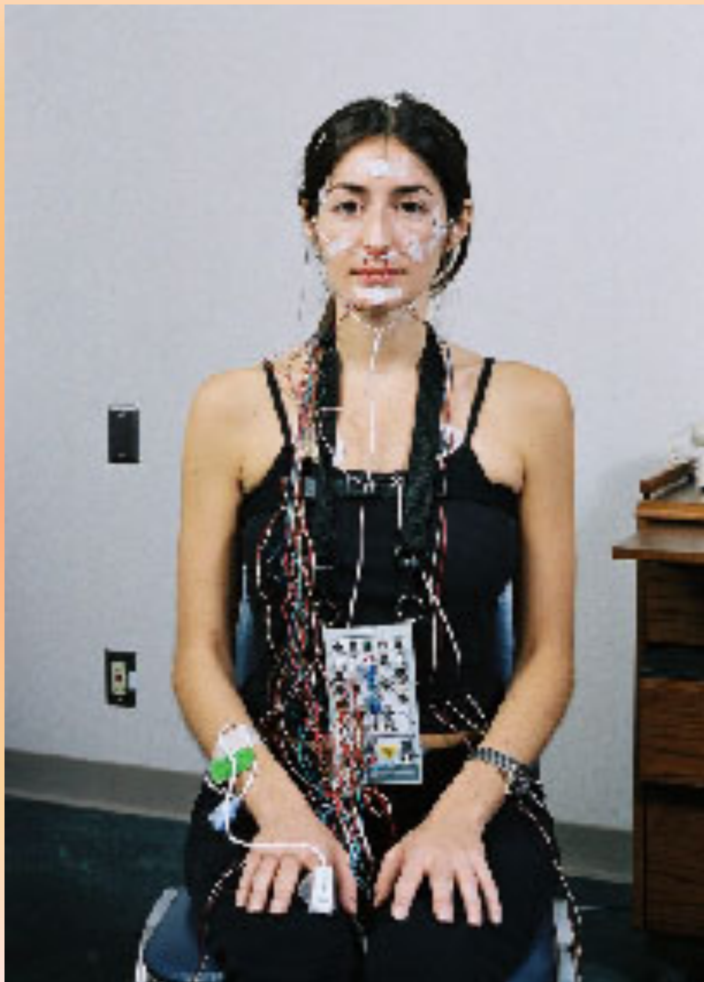
- Total AHI per night
- Supine AHI

In adults:

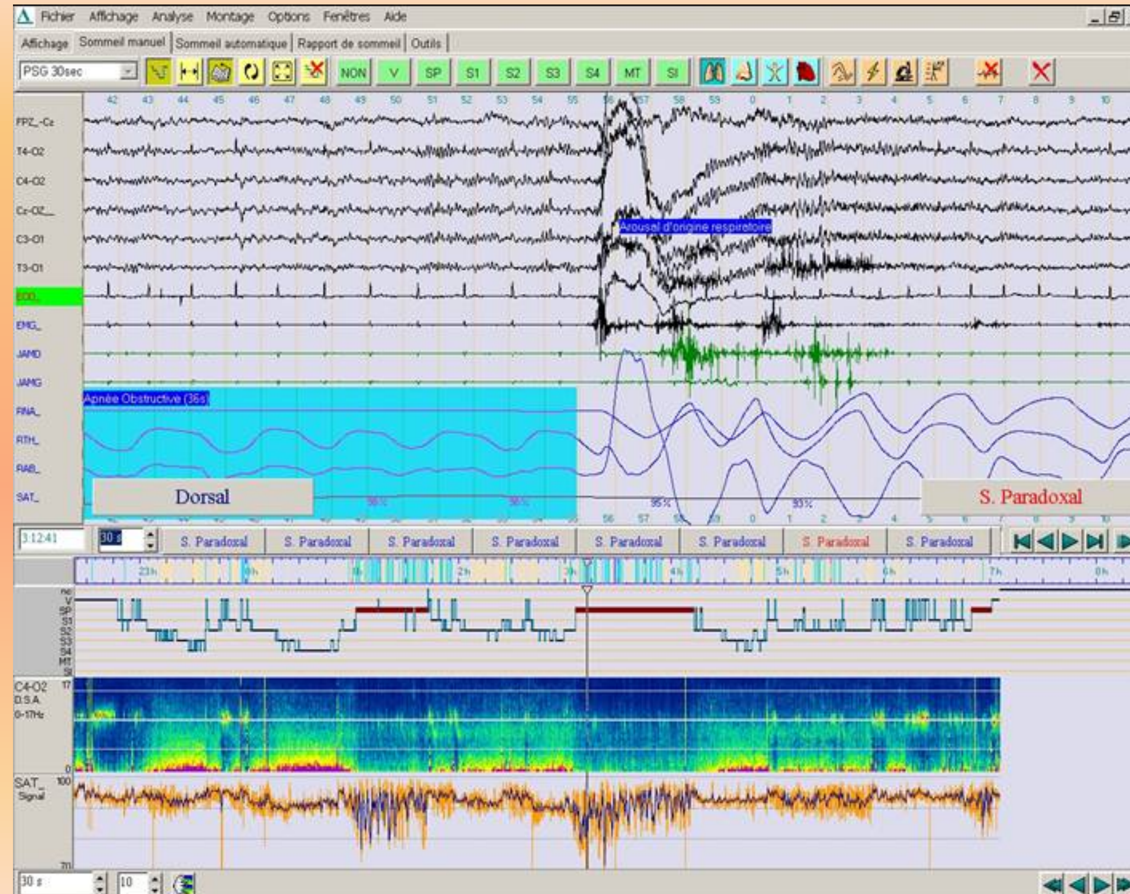
- AHI<5 : non-OSA
- 5< AHI <15: Mild OSA
- 15< AHI < 30: Moderate and in need of treatment
- AHI > 30 : Severe

Is AHI the most accurate measure for sleep apnea?!

Polysomnography (PSG) System for Sleep Apnea Diagnosis



PSG electrodes

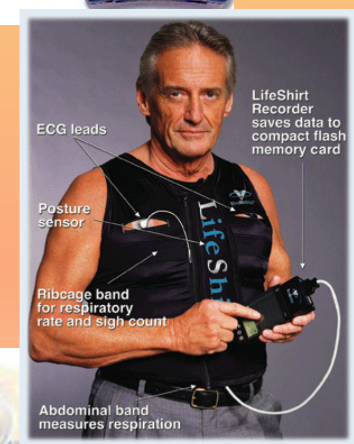


Waiting Time ~ 1-4 years!

Current PM Products for Sleep Study

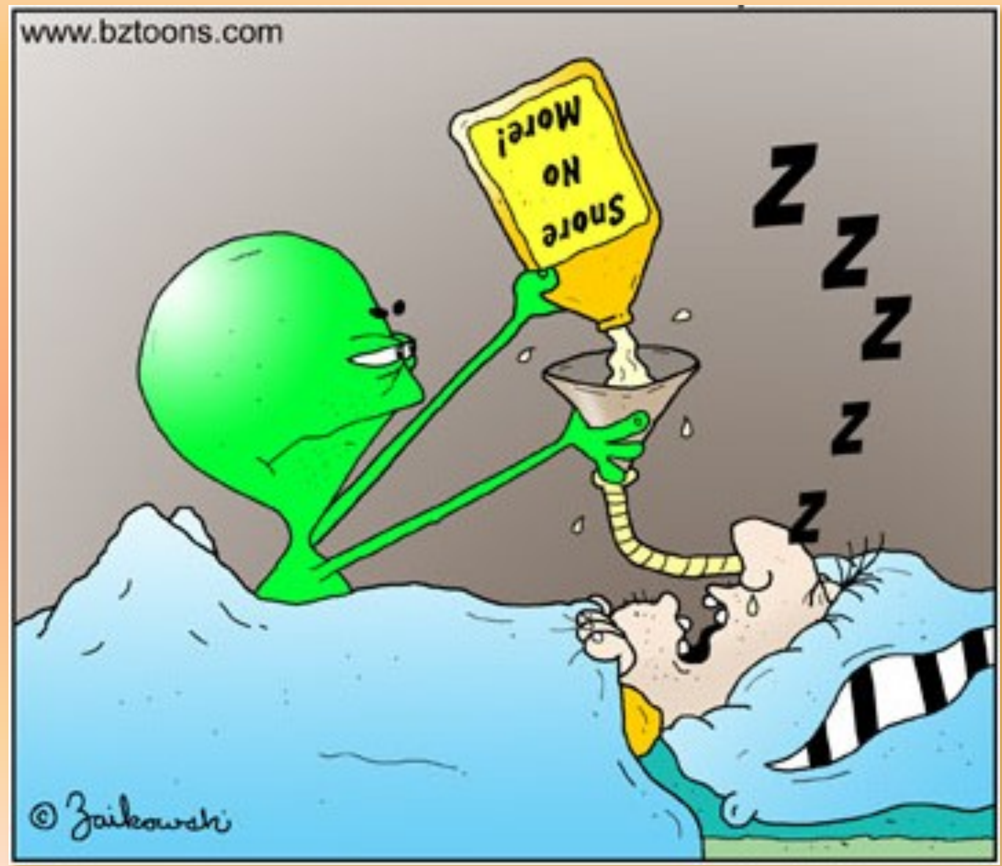
- SleepStrip
- Respironics stardust
- Watch-Pat 100
- LifeShirt
- ApneaLink
- Sandman Pocket
- SnapLabs
- ARES



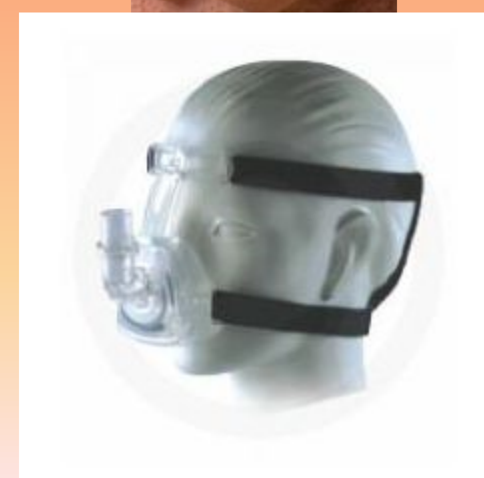




Our Acoustic OSA System (ASAD)

Existing Treatments



Existing Treatments



- **Medical devices:**
  - **Dental appliances: help bring the tongue and lower jaw forward during sleep.**
  - **Nasal strips: keep nasal airway open.**
  - **CPAP (Continuous Positive Airway Pressure) generates required air pressure to keep the airway open**
- **Surgery**

Our Goal

- To screen Obstructive Sleep Apnea (OSA) and its severity by breathing sounds analysis during **wakefulness**

- Diagnosis people with OSA during **sleep**: easy! *Many methods including our acoustic OSA detection detect OSA with high accuracies (>95%)*

- Identifying people with OSA during **wakefulness**: Very challenging!
  - Sleep apnea is a multifactorial disorder
  - Very heterogeneous population

Obstructive Sleep Apnea Syndrome: From Phenotype to Genetic Basis

M Casale,[1,*] M Pappacena,[1] V Rinaldi,[1] F Bressi,[2] P Baptista,[3] and F Salvinelli[1]

Current Genomics
BENTHAM SCIENCE PUBLISHERS LTD.

Identifying OSA during **wakefulness**:

- Using voice analysis (studies in Spain and Israel)

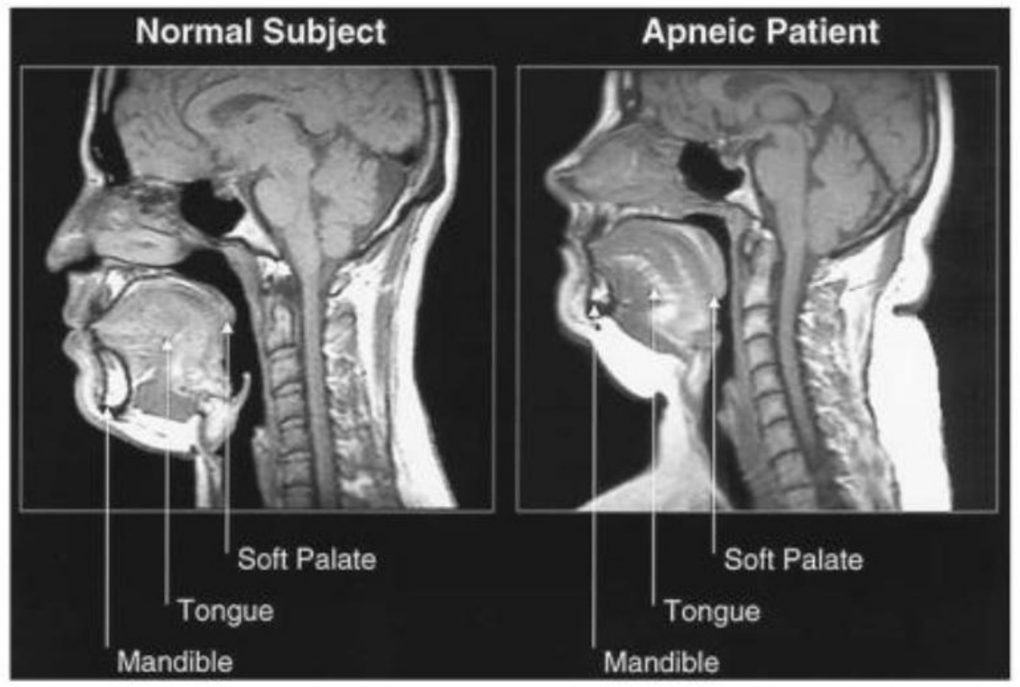
- Using breathing sounds analysis (our group and two more groups in Israel and Spain)

Rationale

On average, compared to those with normal airway, people with OSA have:

- **narrower and more collapsible pharynx**

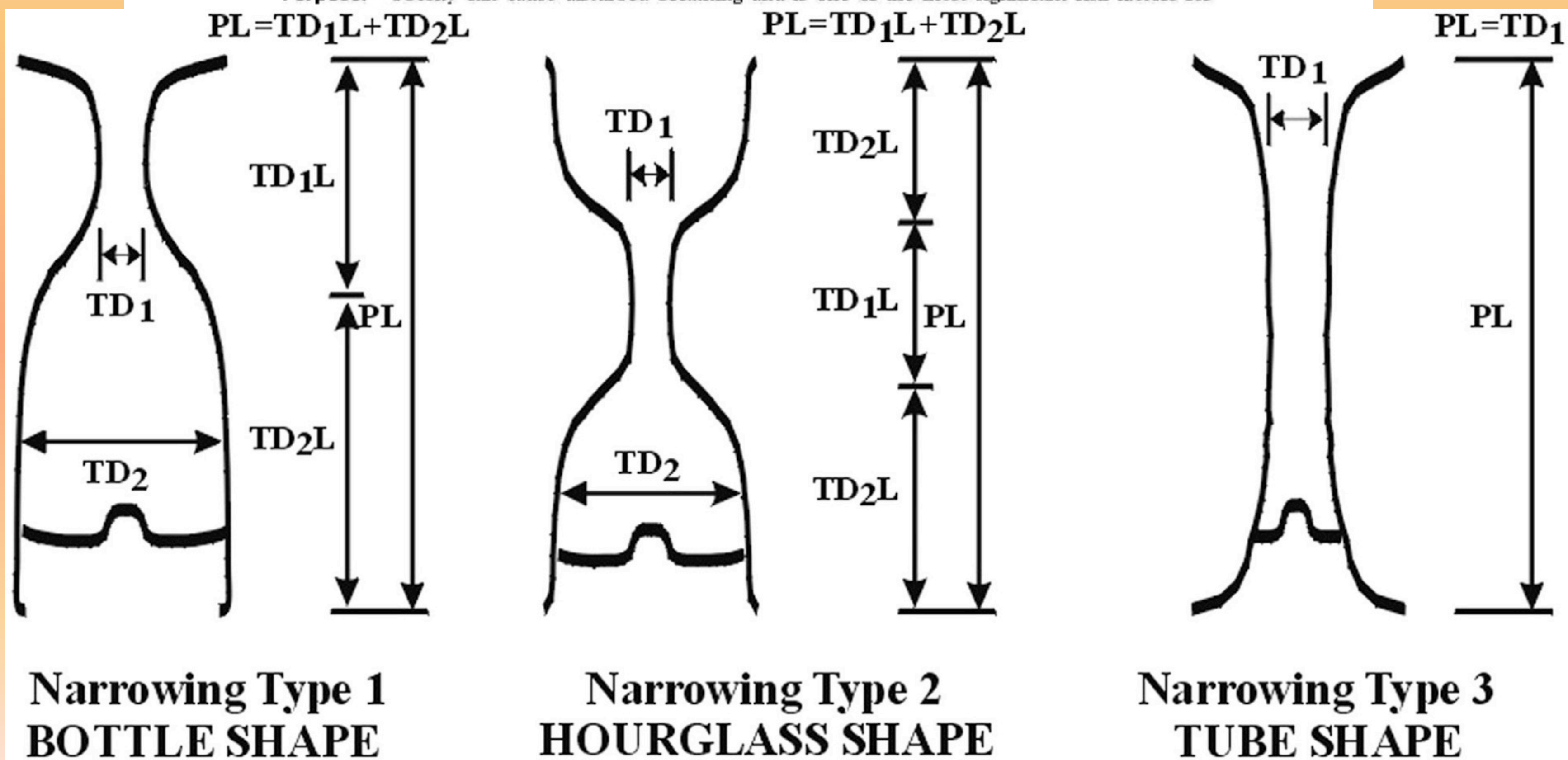
This is compensated by the increased dilator muscle activity during wakefulness.



Velopharyngeal Anatomy in Patients With Obstructive Sleep Apnea Versus Normal Subjects

Yehuda Finkelstein, MD, MA, Lior Wolf, PhD,† Ariela Nachmani, PhD,‡ Uri Lipowezky, PhD,§ Mordechai Rub, BPT,‖ Sa'ar Shemer, BSc,¶ and Gilead Berger, MD***

Purpose: Obesity can cause disturbed breathing and is one of the most significant risk factors for



Center, Kfar Saba, Israel, and Communication Disorders Faculty, Hadassah Academic College, Jerusalem, Israel.
§Tel Aviv University School of Computer Science, Tel Aviv, Israel.
e-mail: liorwolf@gmail.com
Received October 1 2013
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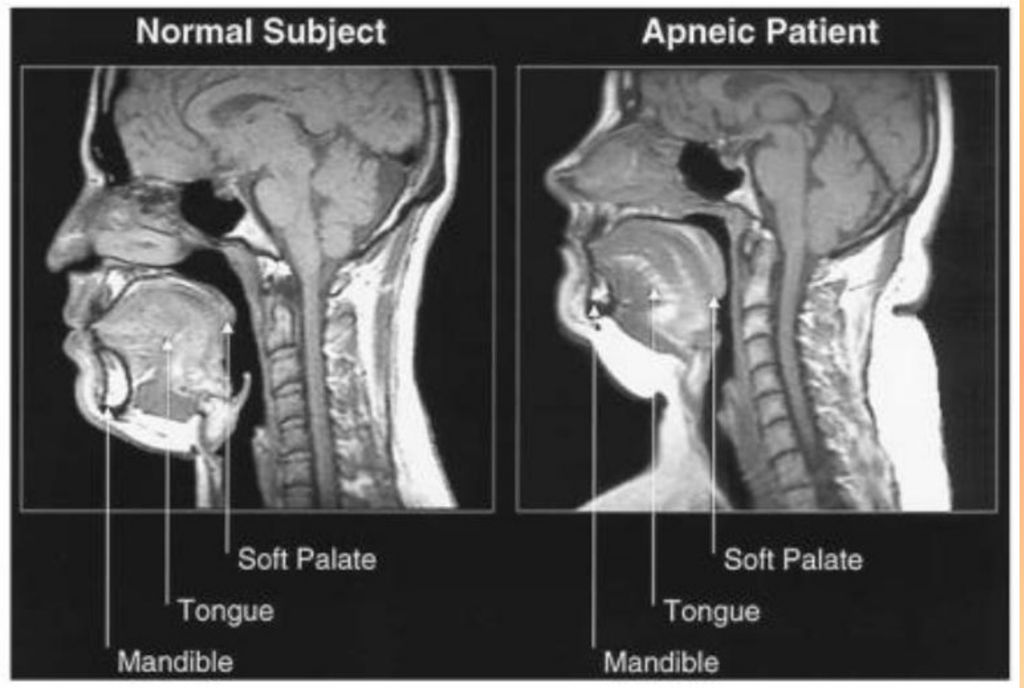
Our Hypotheses

- There must be significant differences in breathing sounds between OSA and non-OSA individuals.

- This difference should be detectable during wakefulness by spectral (2nd order) and higher order statistics (HOS) characteristics of tracheal breathing sounds.



Our Work!

Challenges

- Biological data are often stochastic and non-stationary; more importantly, **they have a heterogeneous nature.**
- The underlying pathopathology of OSA is **multifactorial**, and **varies considerably between individuals**.
- Problems when analyzing breathing sounds of people with sleep apnea:
  - **Imbalance groups,**
  - **Large group overlap caused by high inter-group variability**
  - **Many confounding variables**

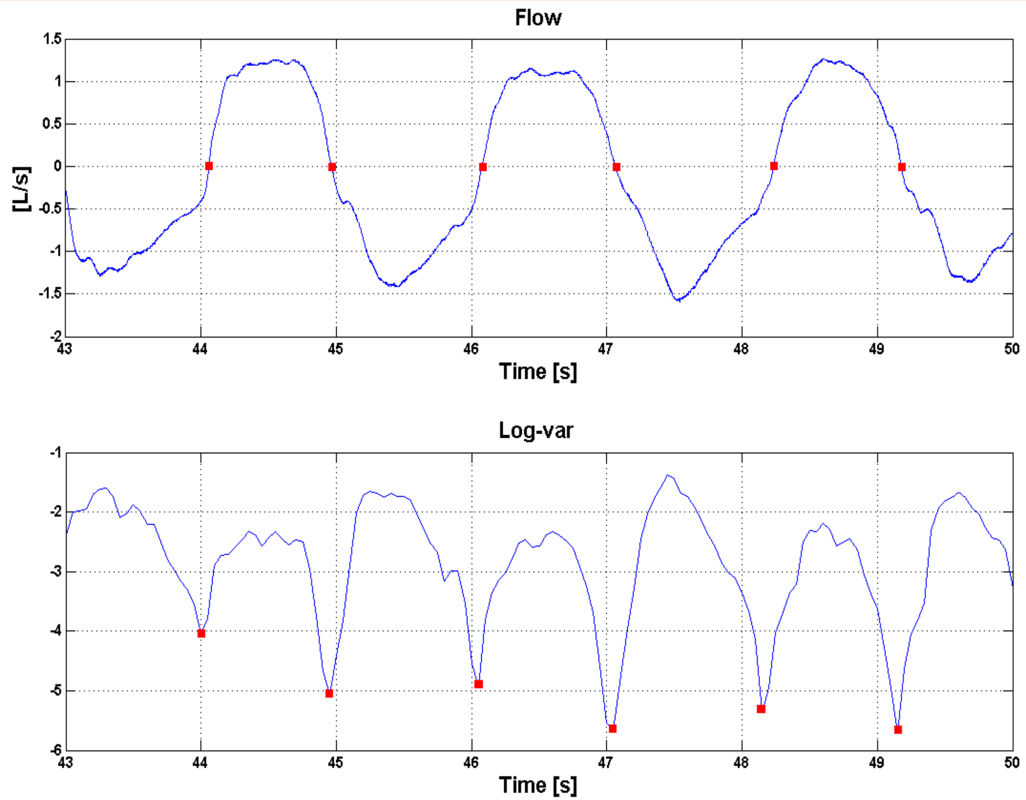
Methods: Recording Data

Experimental Procedure

- Record tracheal breath sounds during wakefulness in **Supine position** and **2 breathing manoeuvres.**
- Breathing Manoeuvres: **Nose & Mouth** breathing, each 5 **Deep** breaths at the same flow rate.

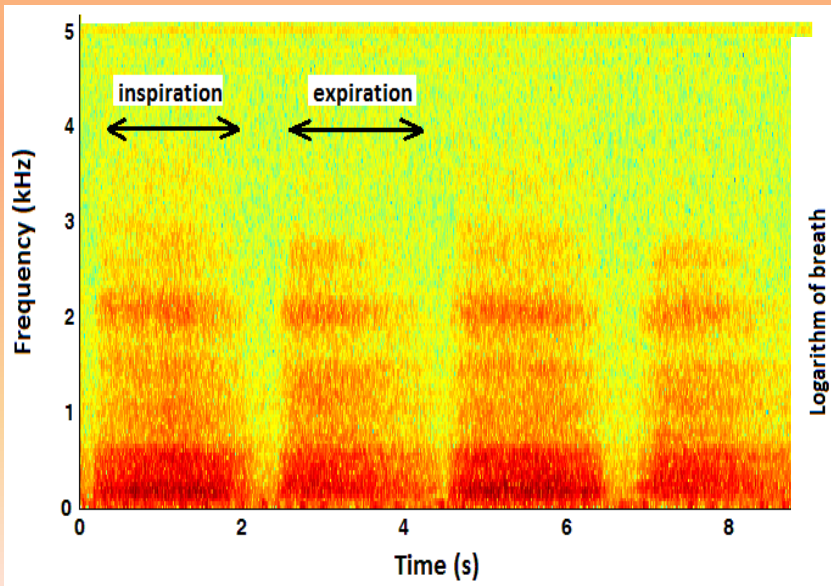
❖ **Analyze inspiratory & expiratory phases separately** → 8 different signals/subject

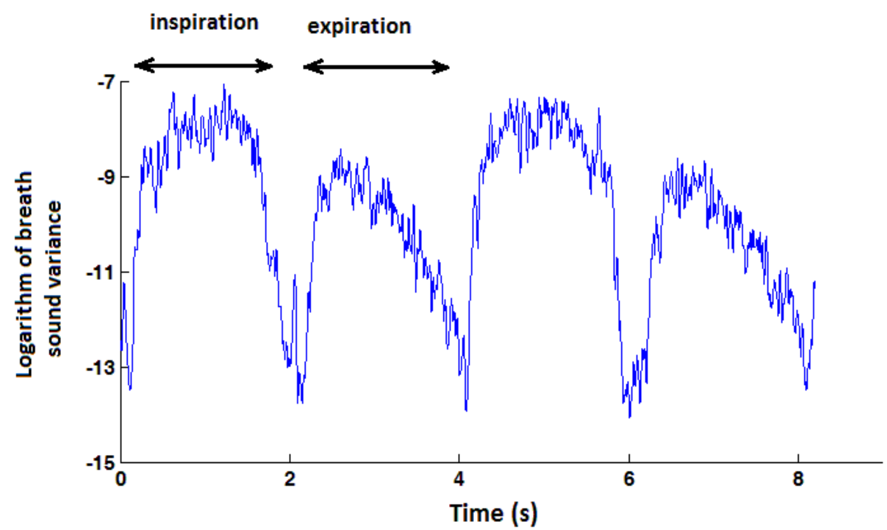
Flow-Sound Relationship to Separate respiratory phases



Method: Analysis

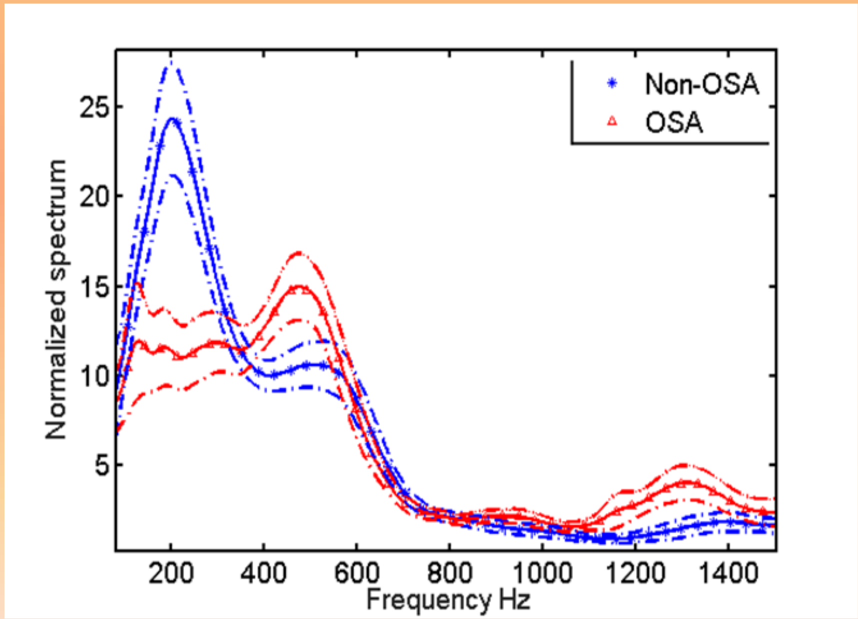
- Separating inspiratory/expiratory phases
- Filtering [75-3000 Hz]
- Normalization (by signal's energy and also its variance envelope)
- Selecting the stationary part of the signal (middle part corresponding to upper 40% of flow)

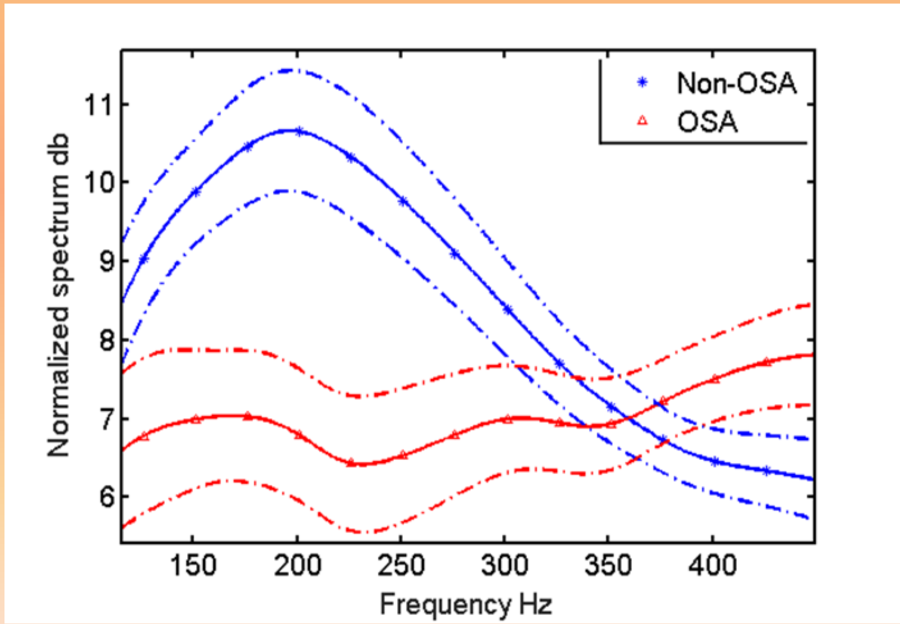




Method: Signal Analysis

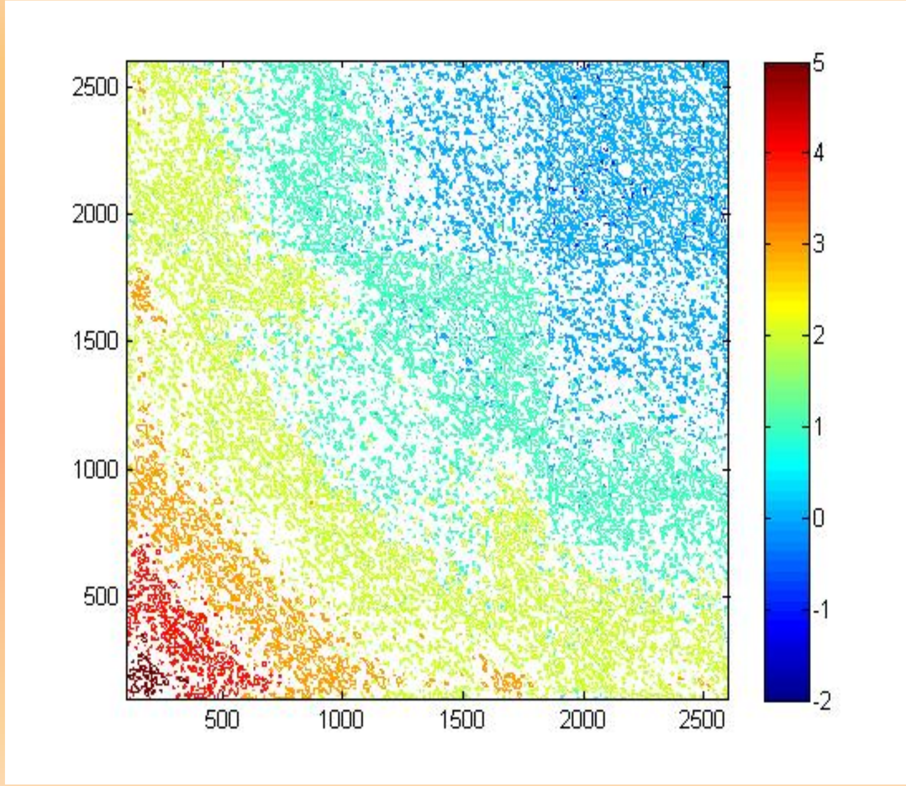
- Estimate power spectral density (PSD) and bispectrum of the signals, using 25ms running window (Hanning, 50% overlap).
- Look at the non-overlapping area between OSA and non-OSA groups in the training set and extracted spectral features.



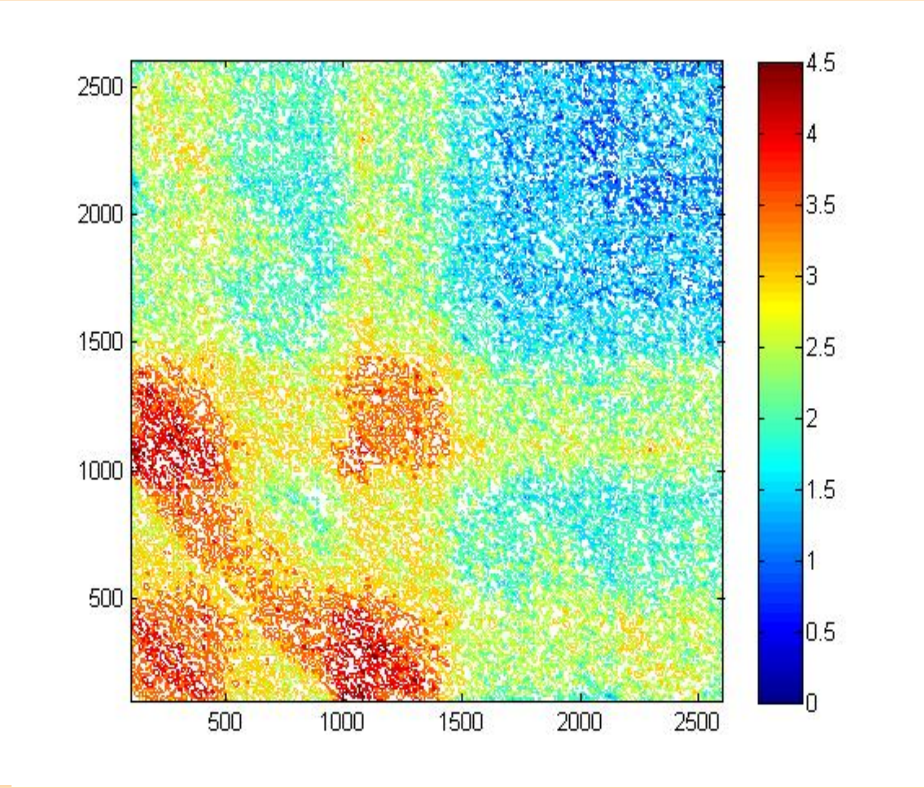


Methods – Bispectrum Estimation

Used the conventional direct method of bispectrum estimation



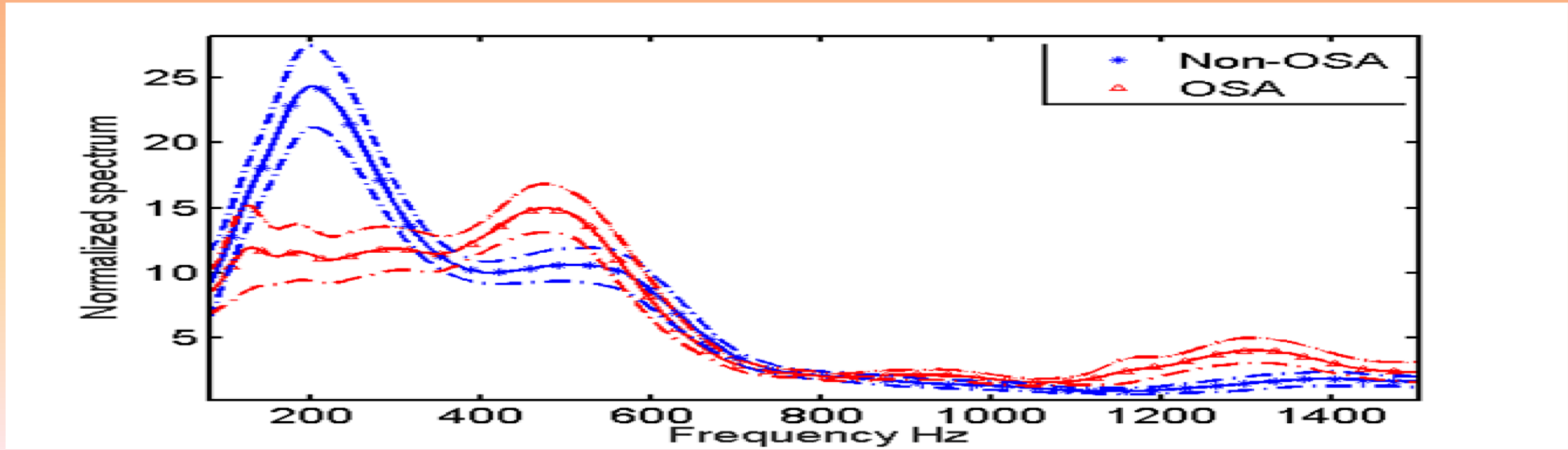
AHI=0



AHI=30

The reduced pharyngeal width (reduced area) increases the compliance (more collapsibility), and that will be reflected in lowering the resonant frequencies according to Helmholtz resonance equation for a bottle : $f_c = \frac{\vartheta}{2\pi}\sqrt{\frac{A}{VL}}$, where ϑ, A, V and L are speed of sound in air, cross section area, volume of cavity and length of the bottle neck →

- the formant frequencies in OSA group shifts toward lower frequencies,
- a difference of low frequency sound energy components because more compliant materials absorb sound more low than high frequencies



Our Previous Work Method & Result

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Obstructive Sleep Apnea Screening and Airway Structure Characterization During Wakefulness Using Tracheal Breathing Sounds

AHMED ELWALI and ZAHRA MOUSSAVI

Biomedical Engineering Program, University of Manitoba, Winnipeg, MB, Canada

(Received 19 April 2016; accepted 23 August 2016; published online 6 September 2016)

Associate Editor Merryn Tawhai oversaw the review of this article.

Abstract—Screening for obstructive sleep apnea (OSA) disorder during wakefulness is challenging. In this paper, we present a set of tracheal breathing sounds characteristics with classification power for separating individuals with apnea/hypopnea index (AHI) ≥ 10 (OSA group) from those with AHI ≤ 5 (non-OSA group) during wakefulness. Tracheal breathing sound signals were recorded during wakefulness in supine position; subjects were instructed to have a few deep breaths through their nose, then through their mouth. Study participants were 147 individuals (80 males) referred to overnight polysomnography (PSG) assessment; their AHI scores were collected after their overnight-PSG study was completed. The signals were normalized; then, their power spectra were estimated. After conducting a multi-stage process for feature extraction and selection on a subset of training data, two spectral features showing significant differences between the two groups were selected for classification. These features showed a correlation of 0.42 with AHI. A 2-class support vector machine classifier with a linear kernel was used. Following this an exhaustive leave-two-out cross-validation was performed. The overall accuracies were 83.83 and 83.92% for training and testing datasets, respectively, while the overall sensitivity and specificity of the test datasets were 82.61 and 85.22%, respectively. We also applied the same method for anthropometric information (i.e., age, weight, *etc.*) as features, and they resulted in an overall accuracy of 77.6 and 76.2% for training and testing datasets, respectively. The results of this study show a superior classification power of respiratory sound features compared to anthropometric features for a quick screening of OSA during wakefulness. The relationship of the sound features and known morphological upper airway structure of OSA subjects are also discussed.

Keywords—Obstructive sleep apnea, Respiratory sounds, Upper airway structure, Support vector machine classifica-

INTRODUCTION

Sleep apnea is a highly prevalent sleep disorder that affects about 10% of the population in Canada and US, while it is also believed there are many undiagnosed cases.[28] Lack of diagnosis and treatment of sleep apnea impose a major cost to the healthcare system; in US the added cost on untreated sleep apnea (direct and indirect costs) is estimated to be between $65 and $165 billion annually.[17]

Obstructive sleep apnea (OSA), which is the most common (>75%) type of sleep apnea, is characterized by repetitive episodes of complete (apnea) or partial (hypopnea) cessation of breath due to pharyngeal collapse usually occurring after throat and tongue muscle relaxation. If such an event lasts at least 10 s, it is called an apnea/hypopnea event which is usually associated with >3% drop in blood oxygen saturation, and sometimes a subsequent arousal from sleep to restore airway patency and an increase in heart rate.[2] Signs and symptoms of OSA include lack of energy, morning headaches, depression, daytime sleepiness, nighttime gasping and choking, and sometimes snoring.

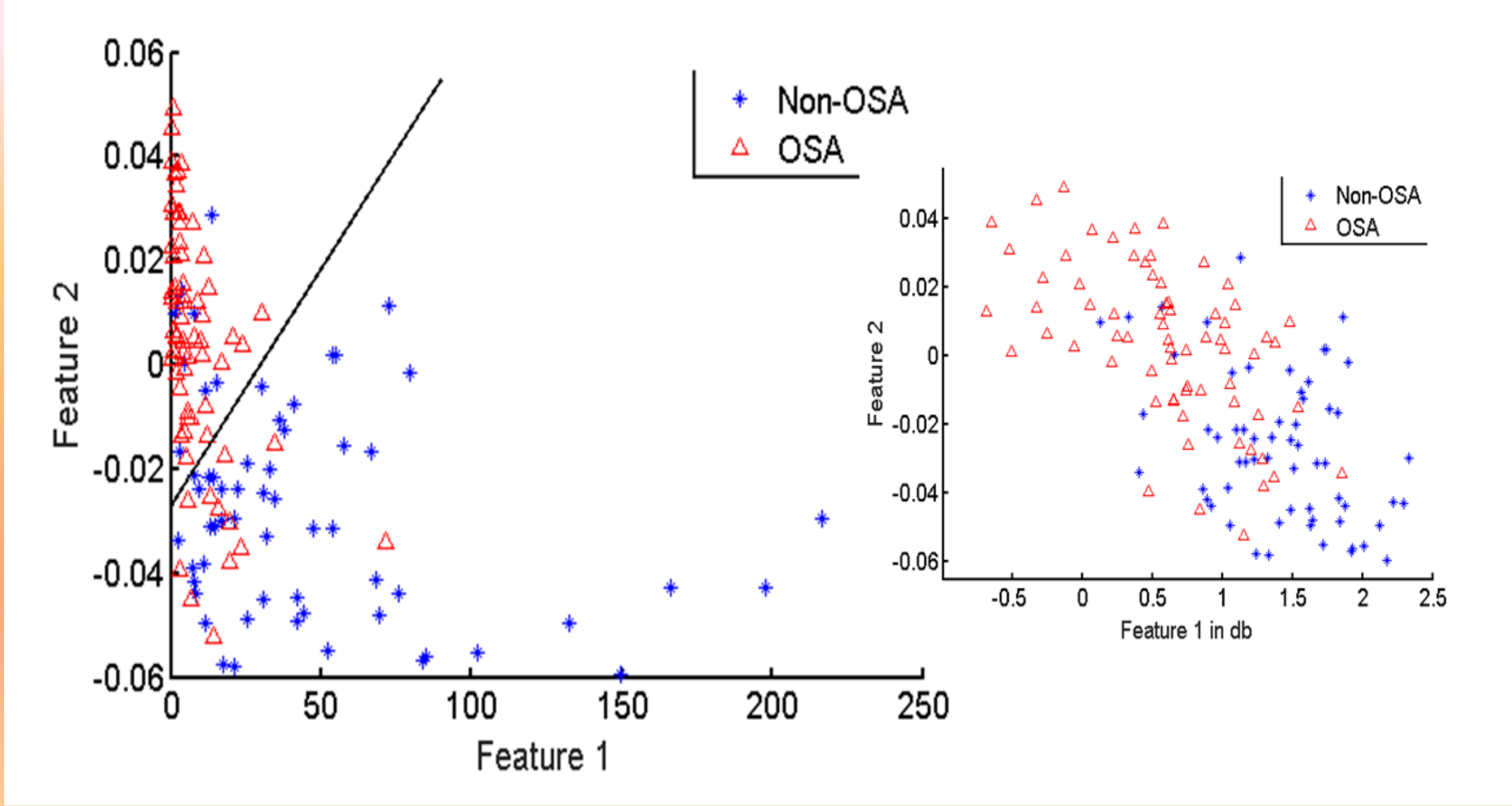
The severity of OSA is commonly determined by the apnea/hypopnea index (AHI) which is defined as the number of apnea/hypopnea episodes per hour of sleep. Commonly an AHI in the ranges of [0 5], [5 15], [15 30] and [>30] are referred as non-, mild-, moderate- and severe-OSA, respectively. The gold standard in determining the AHI and sleep apnea assessment is an

Our Previous Work Method & Result

- Used tracheal breathing sounds from 142 individuals to screen OSA (AHI>10) from non-OSA (AHI < 5), and ran exhaustive feature selection search and **machine learning** to maximize accuracy in the training set.

- We achieved **~85% accuracy in training set and ~84% unbiased test accuracy** (similar sensitivity and specificity).

Results



Scattered plot of the selected best features

How about using anthropometric info?

- It is used a means for quick screening before the surgery (Stop-Bang Questionnaire)

- Its sensitivity could be quite high (90%) but at the cost of a very low specificity (~20%)!

- How about adding those parameters to the sounds features?

Using Anthropometric Features

- Used the same method of feature selection/reduction for BMI, Mallampati score, gender, age, weight and height.

- Ran support vector machine (SVM) learning for 2-group classification on anthropometric best two features with and without sound features.

- Anthropometric features **alone** with SVM achieved about 70% accuracy (similar sensitivity and specificity)

- **Anthropometric + Sound features** increased the sensitivity by 6% but decreased specificity by 4%; thus, overall, it added the accuracy by 1% to when we used sound features only!

The Objectives of our recent Studies

- Investigate to what extend the sounds features are affected by anthropometric info.
- Investigate whether subdivision of the subjects based on their anthropometric info helps with the accuracy.
- For this study, we used AHI=15 as a sharp cut off threshold of grouping.
- Also used only supine AHI as opposed to total AHI.
- Feature selection and SVM routine were similar to those of our previous work.

Results

- BMI, Age, Gender, Mallampati scores were found to affect the sounds the most.

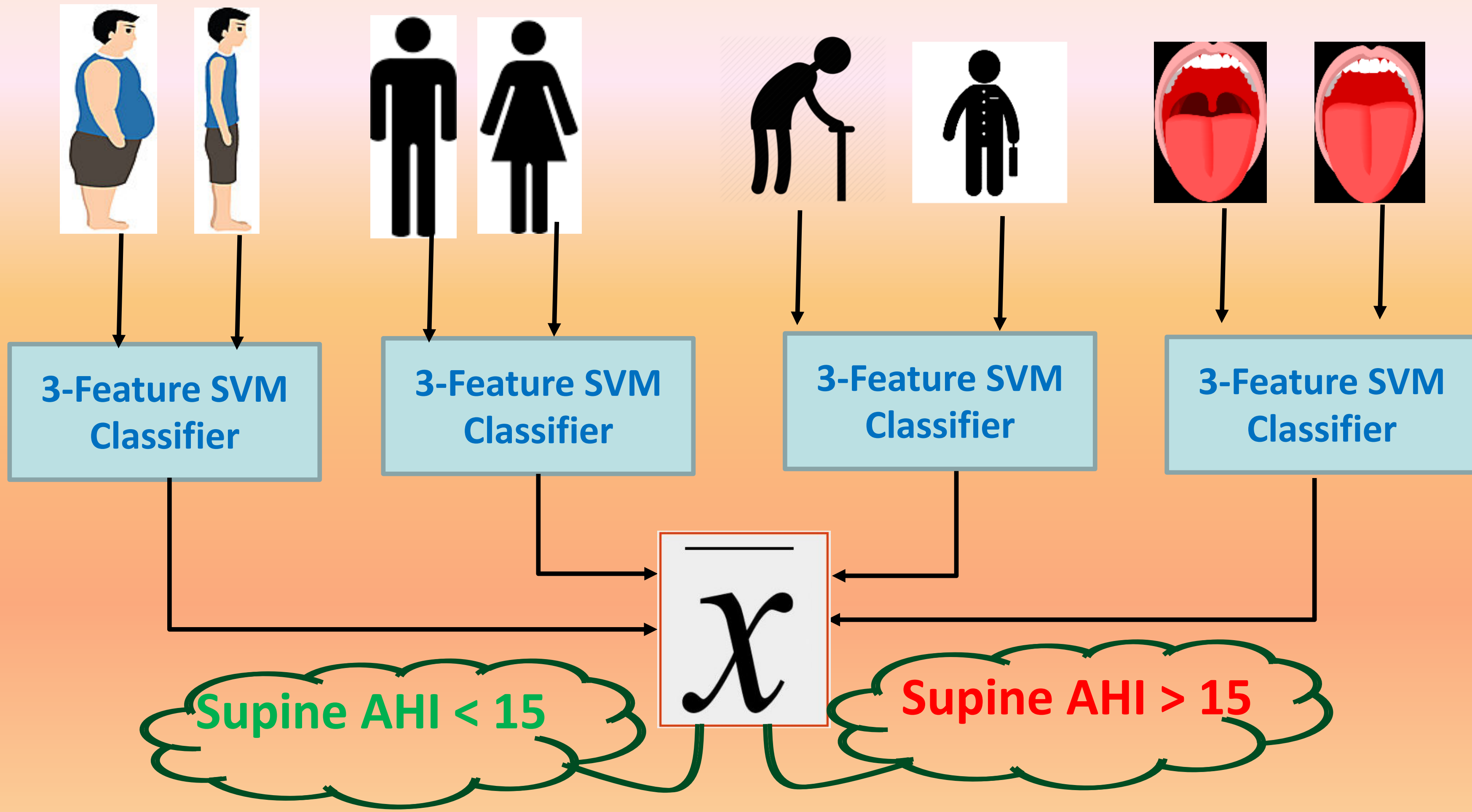
- Sound features with the least dependency on anthropometric info: Fundamental Spectral Frequency and bispectral entropy → resultant test accuracy was ~75%.

Results

- Also found sounds features for **each sub-division** based on BMI, age, gender, Mallampati score, etc.

- Used individual classifiers for each subgroup.

Our New Acoustic Diagnostic Classifier



Test Sensitivity, Specificity and Accuracy: 81%, 82% and 81.4%

(*Training accuracy: 83%*)

Our New Acoustic Diagnostic Classifier

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A Novel Decision Making Procedure during Wakefulness for Screening Obstructive Sleep Apnea using Anthropometric Information and Tracheal Breathing Sounds

Ahmed Elwali & Zahra Moussavi

Scientific Reports **9**, Article number: 11467 (2019) | Cite this article

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Abstract

Obstructive sleep apnea (OSA) is an underdiagnosed common disorder. Undiagnosed OSA,

Summary & Conclusion

- **There is a need for quick and cost effective screening for OSA.**
- **Sleep Apnea screening during wakefulness has great applications:**
  - Reducing health care cost by reducing the need for PSG study
  - Capability to be combined with iPhone Stethoscope and being used in people's homes for self screening and monitoring the improvements
  - Great use for quick screening before any anaesthesia (surgery); it can save lives!


Have a good sleep!

Acknowledgement

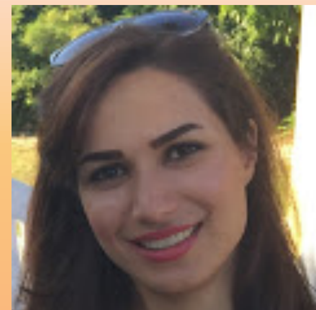
- The study was supported by NSERC, TRTech (Winnipeg) and Phillips (Respronics).

- Our studies on OSA have resulted 4 patents.

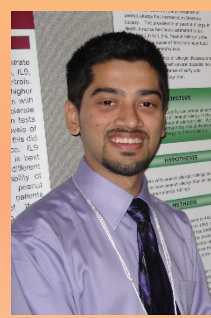
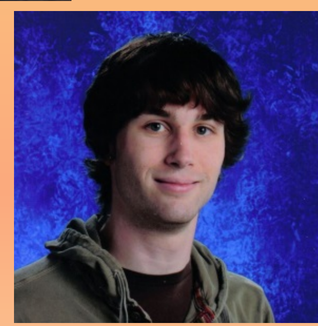
- Dr. Eleni Giannouli, and Dr. Sonia Mezra, M.D. FRCPC, collaborators from Faculty of Medicine.

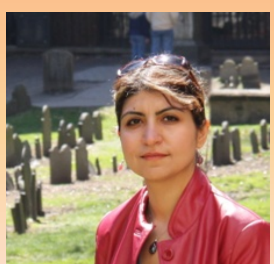
- Data were recorded all in Misericordia Hospital, Winnipeg.

Current and Former Acoustic Team Members



Any and all questions are welcome especially if this is a noisy crowd with oscillations between pros and cons!