Measuring Autonomic Sleep Stability

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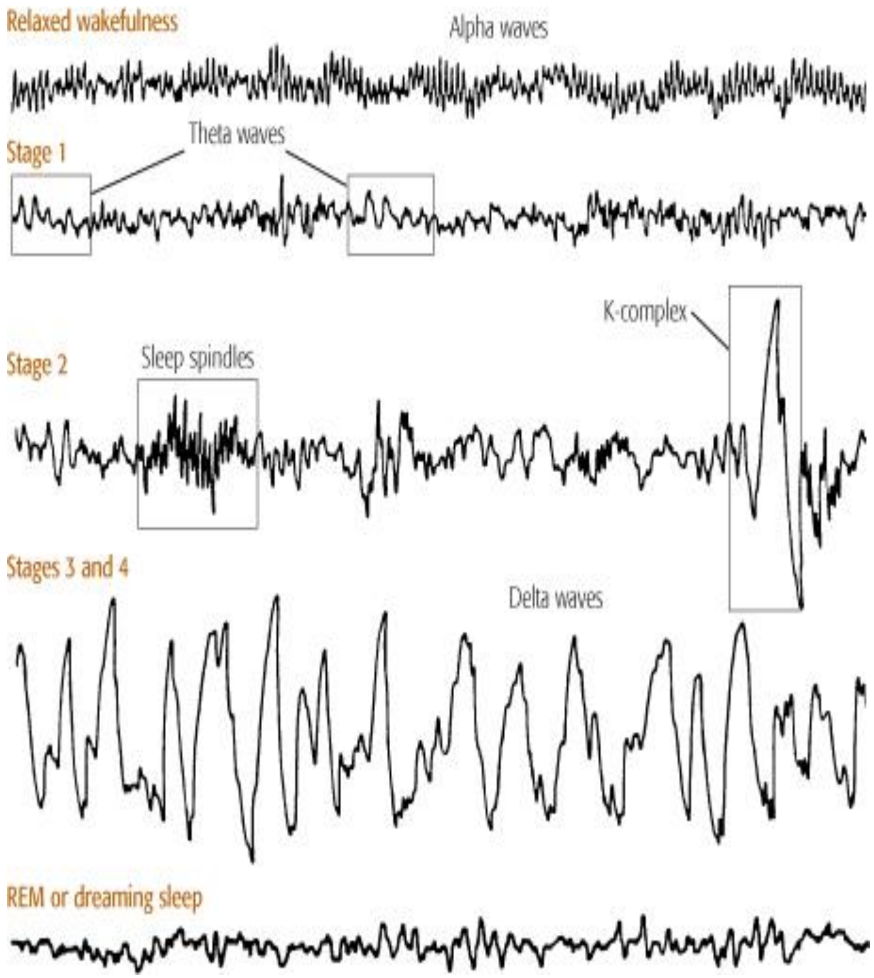
Slow Wave Sleep (Delta Wave)



- Slow wave sleep is correlated with **restorative** function of sleep
- Slow wave sleep is considered as **deep** sleep

Picture taken from www.aolhealth.com

Hobson JA (2005) Nature 437, 1254-1256

Limitations of Slow Wave Sleep

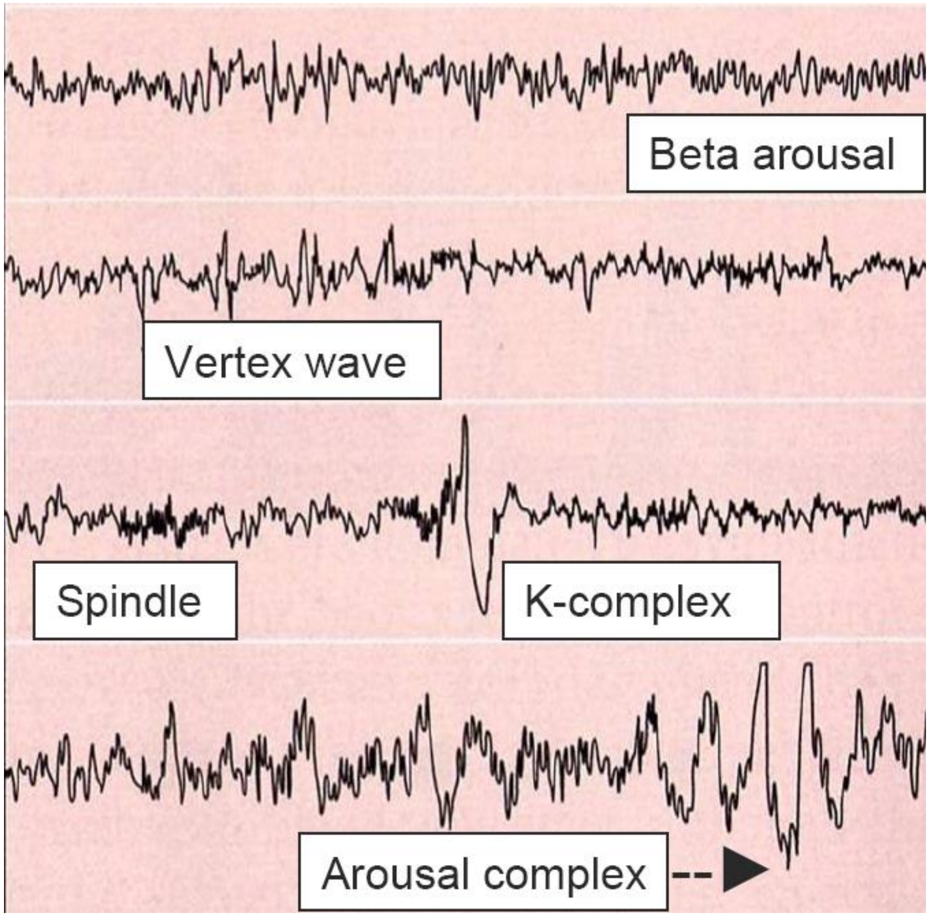
- Depth criteria are **arbitrary**.
- Classic benzodiazepines **reduce** "depth" despite improving subjective and objective measures of sleep quality.
- **Poor correlations** with perceived sleep quality.

Conventional sleep staging based on EEG morphology gives less insight into physiologic conditions and sleep stability

Thomas RJ Cellscience Rev 2007;3:49-62

Cyclic Alternating Patterns (CAP)

EEG Patterns of **Arousal**



The cyclic activity of these arousal complexes in NREM sleep is termed Cyclic Alternating Pattern.

CAP is a marker for **sleep instability**, whereas absence of CAP (non-CAP) reflects a condition of consolidated sleep.

Terzano MG, et al Sleep 1985;8:137-145

Cyclic Alternating Patterns (CAP)

A marker for **sleep instability**

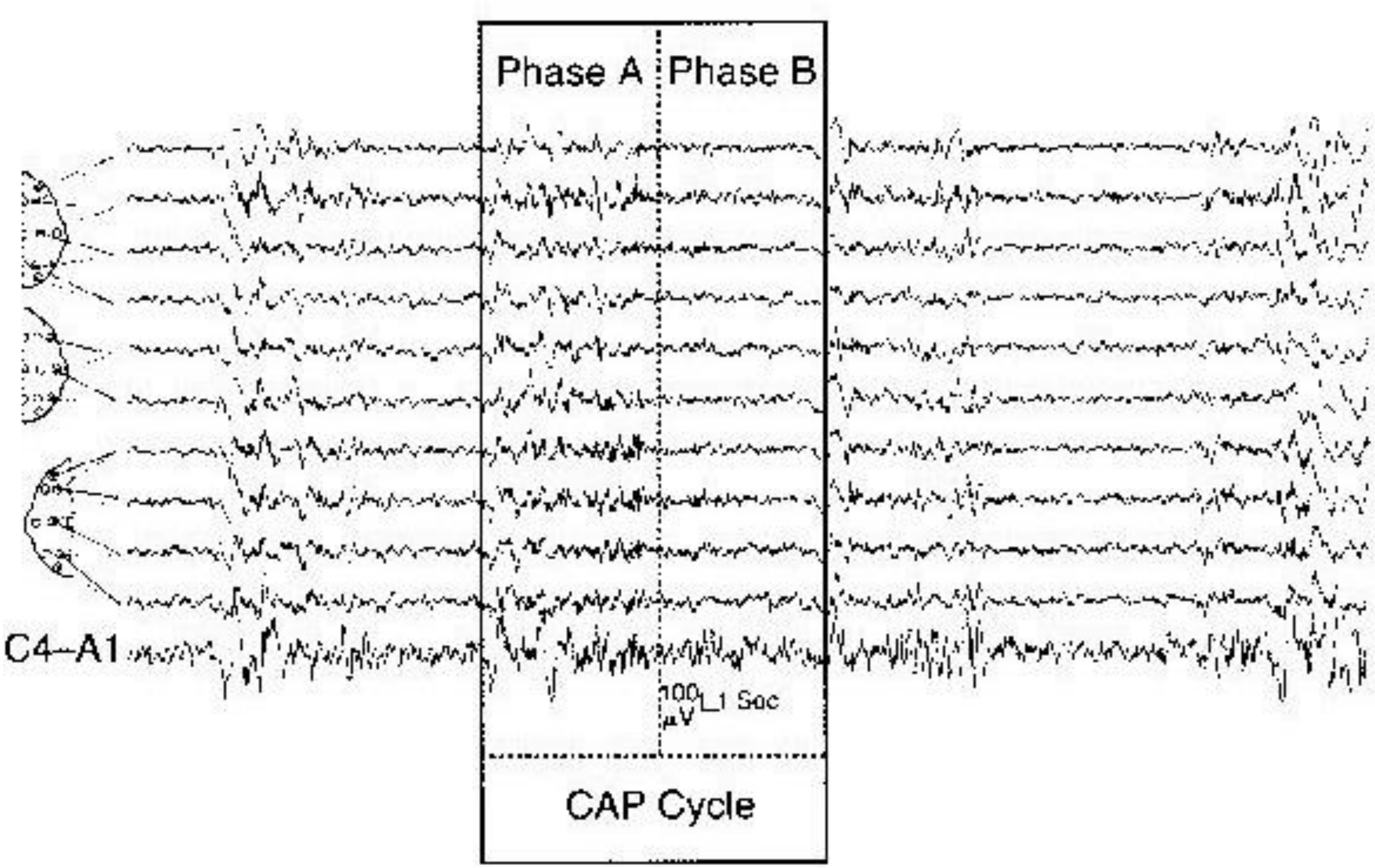
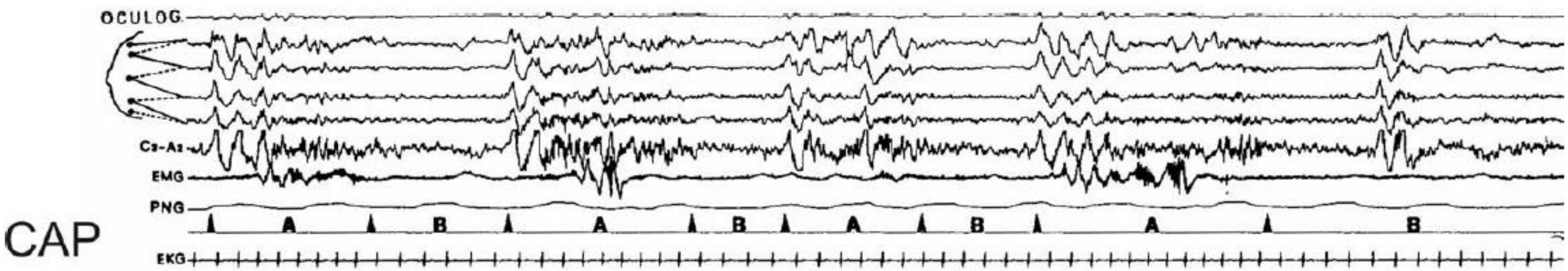


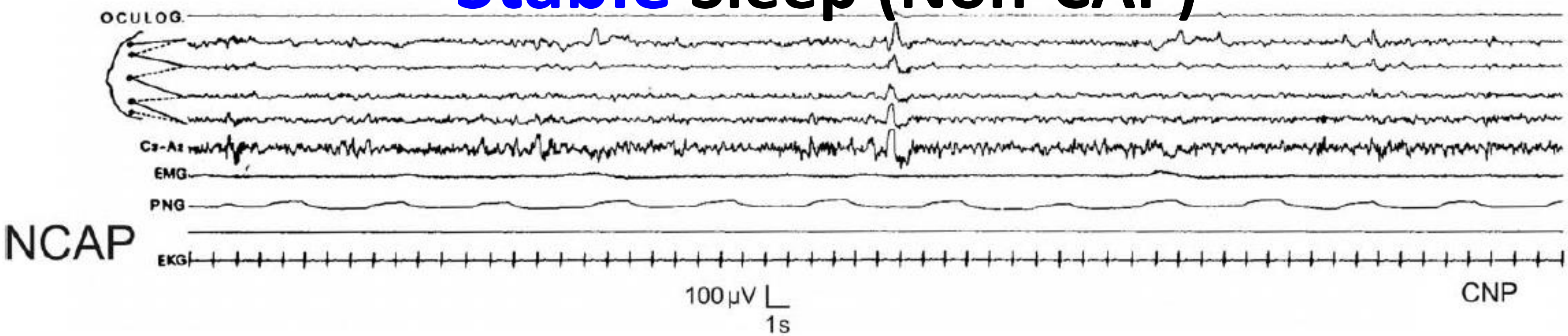
Figure from Chokroverty S, Thomas R, Bhatt M. Atlas of Sleep Medicine 2005

Cyclic Alternating Patterns (CAP)

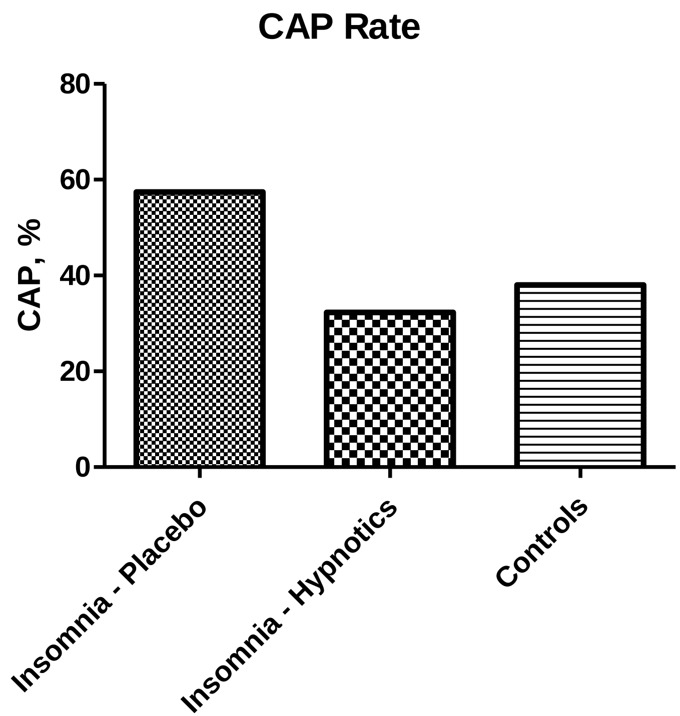
Unstable Sleep (CAP)

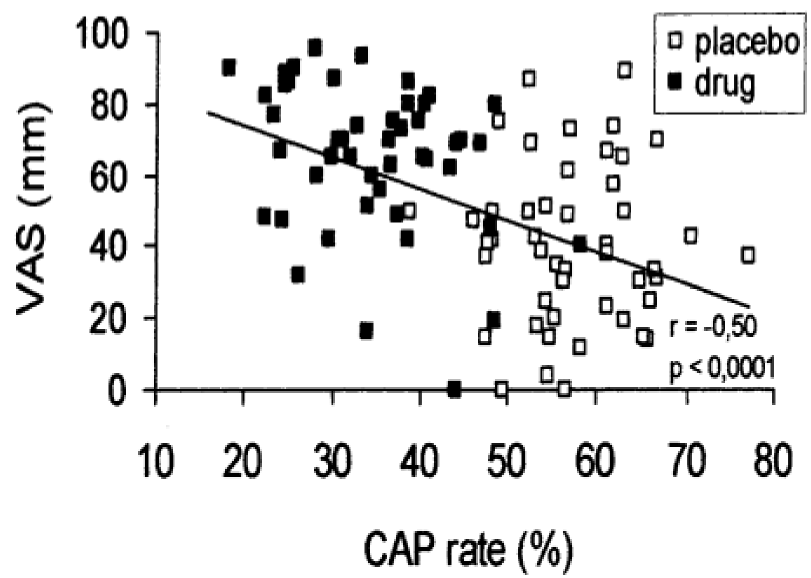


Stable Sleep (Non-CAP)



CAP and Insomnia





- 47 insomnia patients and 25 controls
- CAP rate showed significant correlation with subjective sleep quality by visual analogue scale

Terzano MG, et al. Clin Neurophysiol 2003;114:1715-1723

Cyclic Alternating Patterns (CAP)

Unstable Sleep

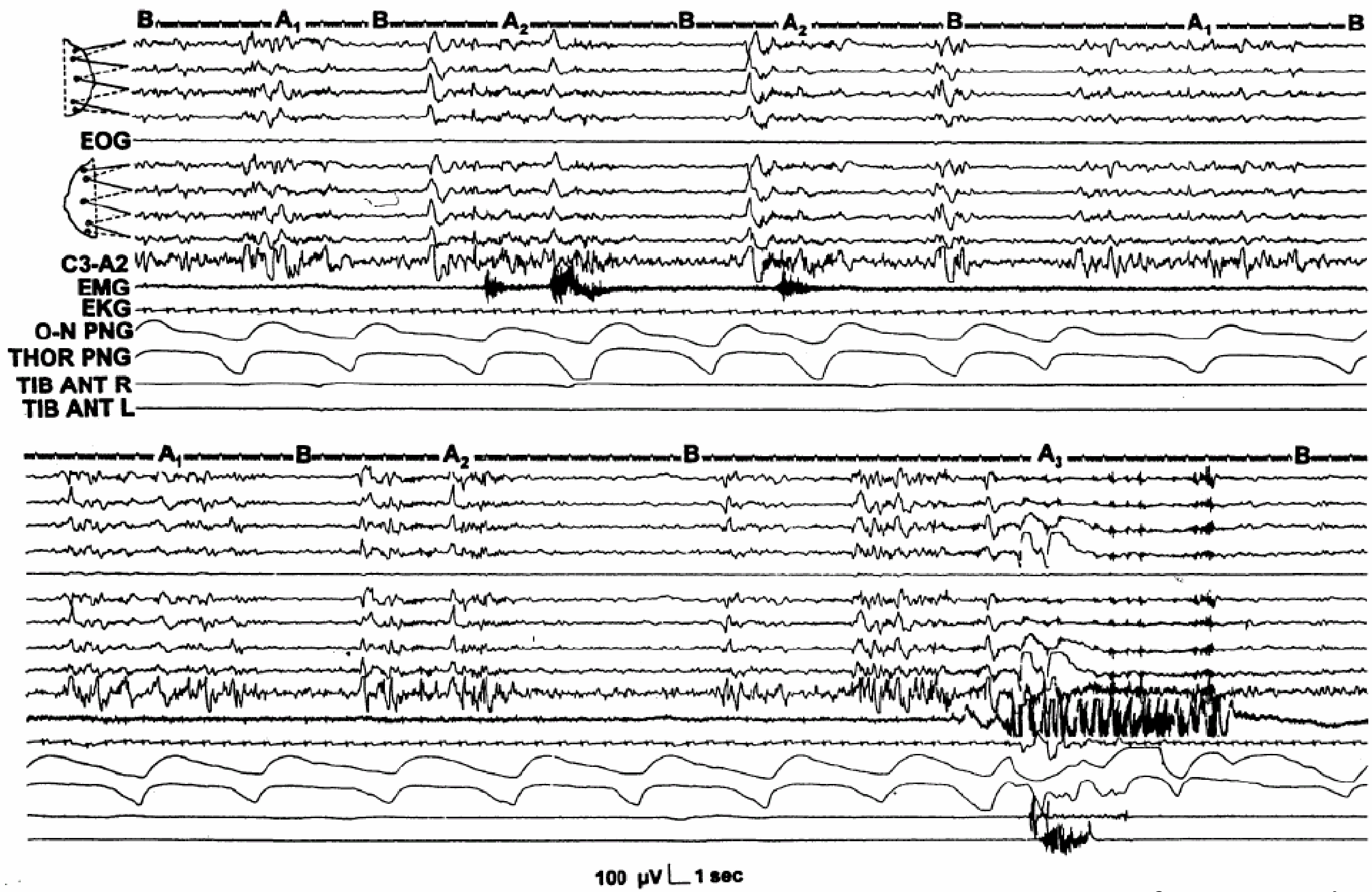


Figure from Dr. Robert Thomas

Non-Cyclic Alternating Patterns (Non-CAP)

Stable Sleep

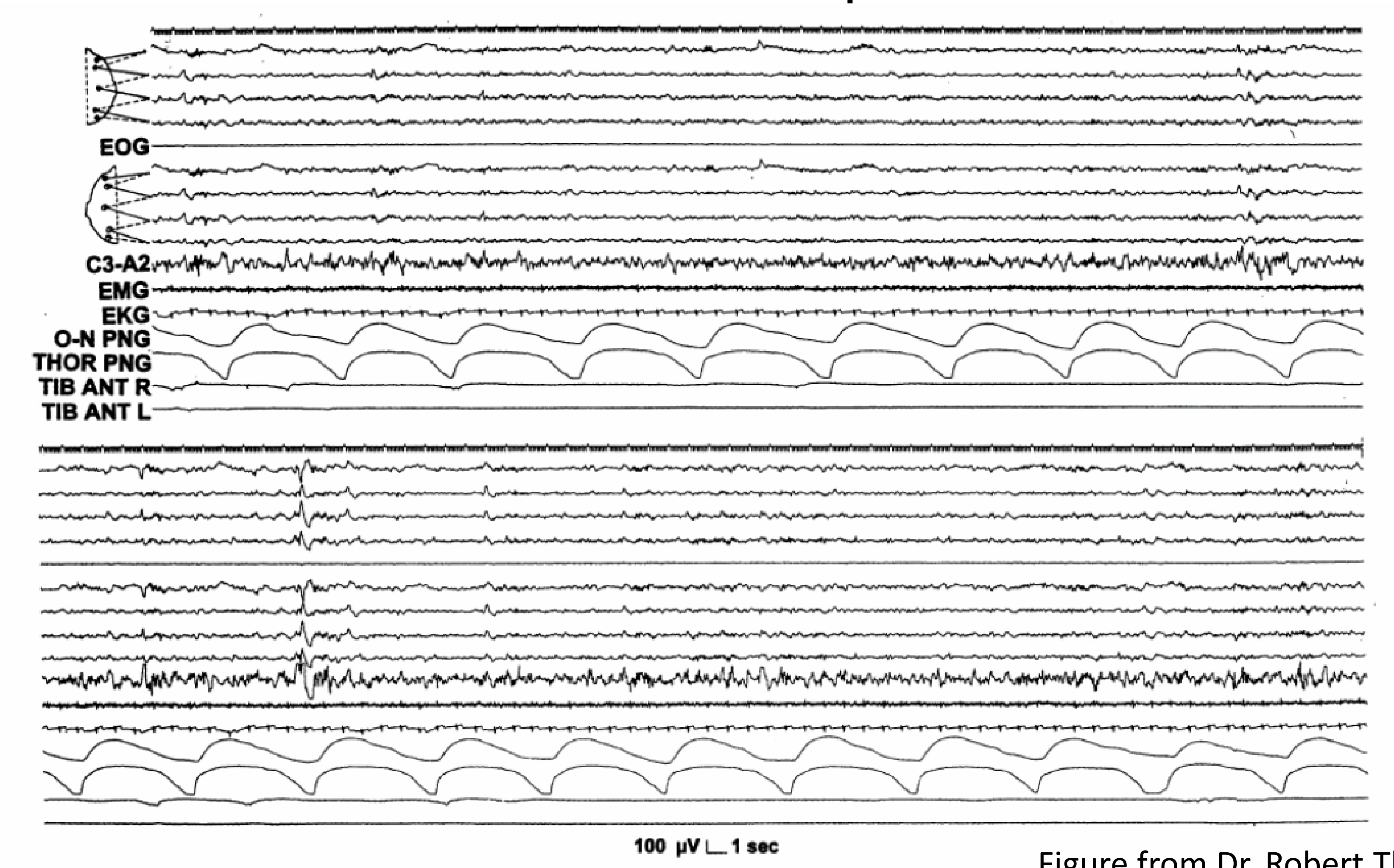


Figure from Dr. Robert Thomas

CAP is Associated with Autonomic Arousal

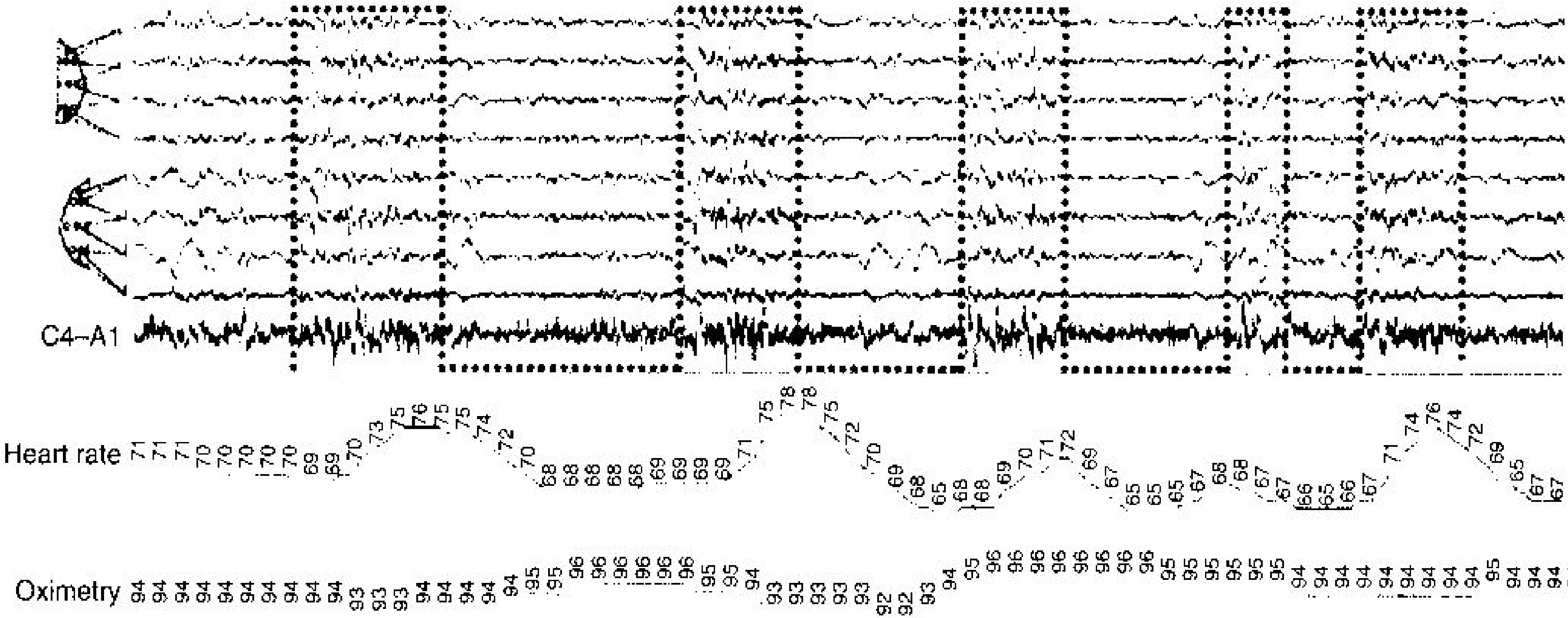


Figure from Chokroverty S, Thomas R, Bhatt M. Atlas of Sleep Medicine 2005

Cardiopulmonary Coupling Analysis

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SLEEP MEDICINE

Heart Tracings Reveal Sleep Patterns for Health and Disease

Stable and Unstable Sleep Found Distinct from Traditional Non-REM Stages

During the most restful sleep, the resting heart speeds up and slows down slightly with each breath in and out. But when the heart rhythm drops out of sync with breath-to-breath respiration, slumber becomes more fitful and tiring.

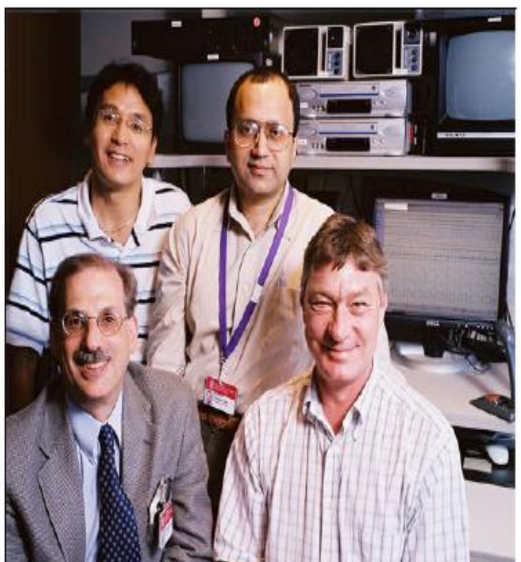


Photo by Graham Ramsay

An electrocardiogram could provide more information on sleep stability and quality than a dozen monitoring devices, say (clockwise from top left) Chung-Kang Peng, Robert Thomas, Joseph Mietus, and Ary Goldberger.

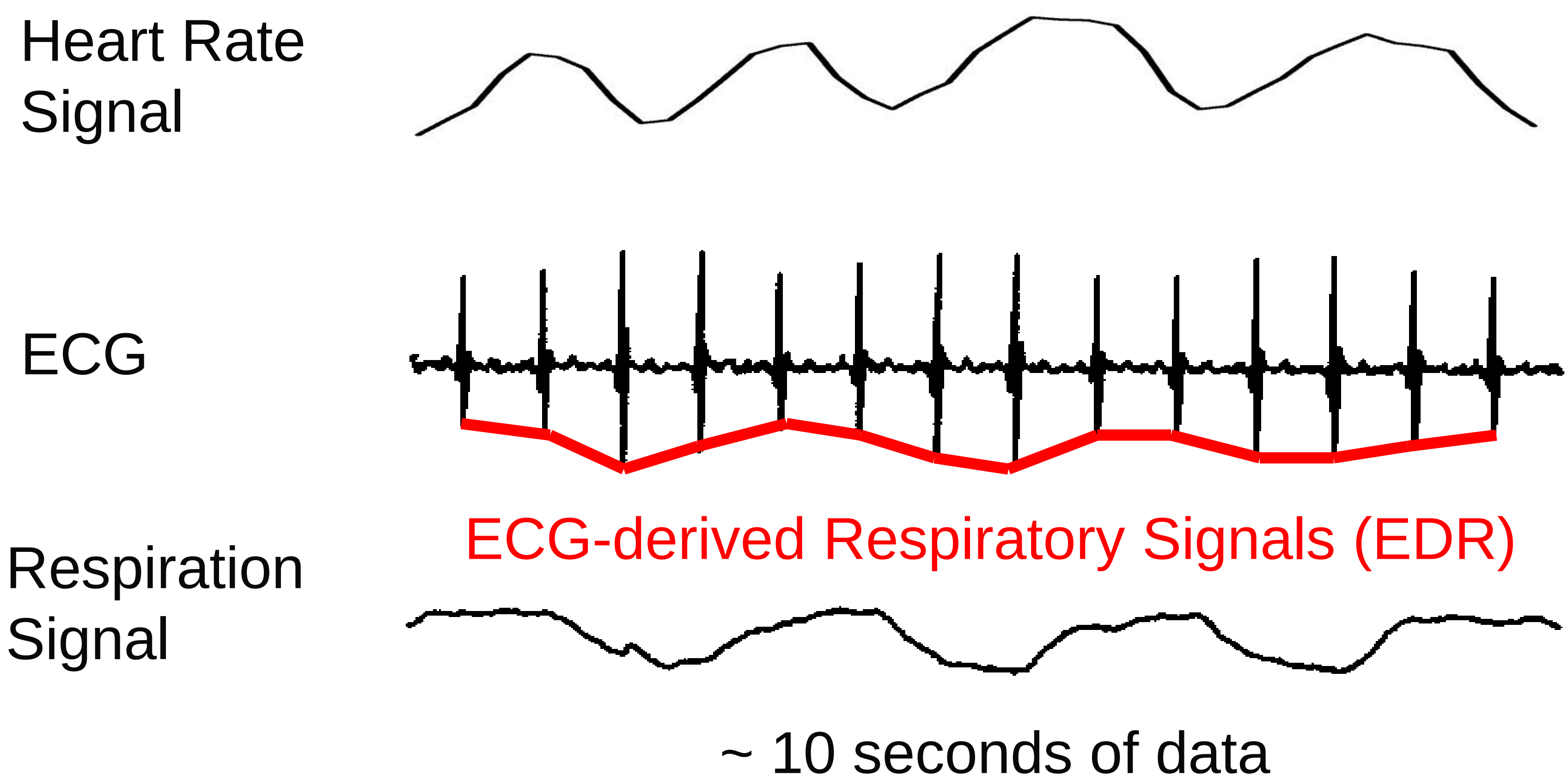
Thomas RJ, Mietus JE, Peng CK, Goldberger AL. An electrocardiogram-based technique to assess cardiopulmonary coupling during sleep. Sleep. 2005;28(9):1151-61.

Gilmartin G, Mietus J, Peng C-K, Goldberger A, Thomas RJ. Sleep spectrograms and central sleep-disordered breathing in the sleep heart health study. Sleep 2006;29:A159.

Thomas RJ et al., Differentiating obstructive from central and complex sleep apnea using an automated electrocardiogram-based method. Sleep 2007;30:1756-1769.

Yeh GY et al., Enhancement of sleep stability with Tai Chi exercise in chronic heart failure: Preliminary findings using an ECG-based spectrogram method. Sleep Medicine 2008;9:527-536.

Cardiopulmonary Coupling Analysis



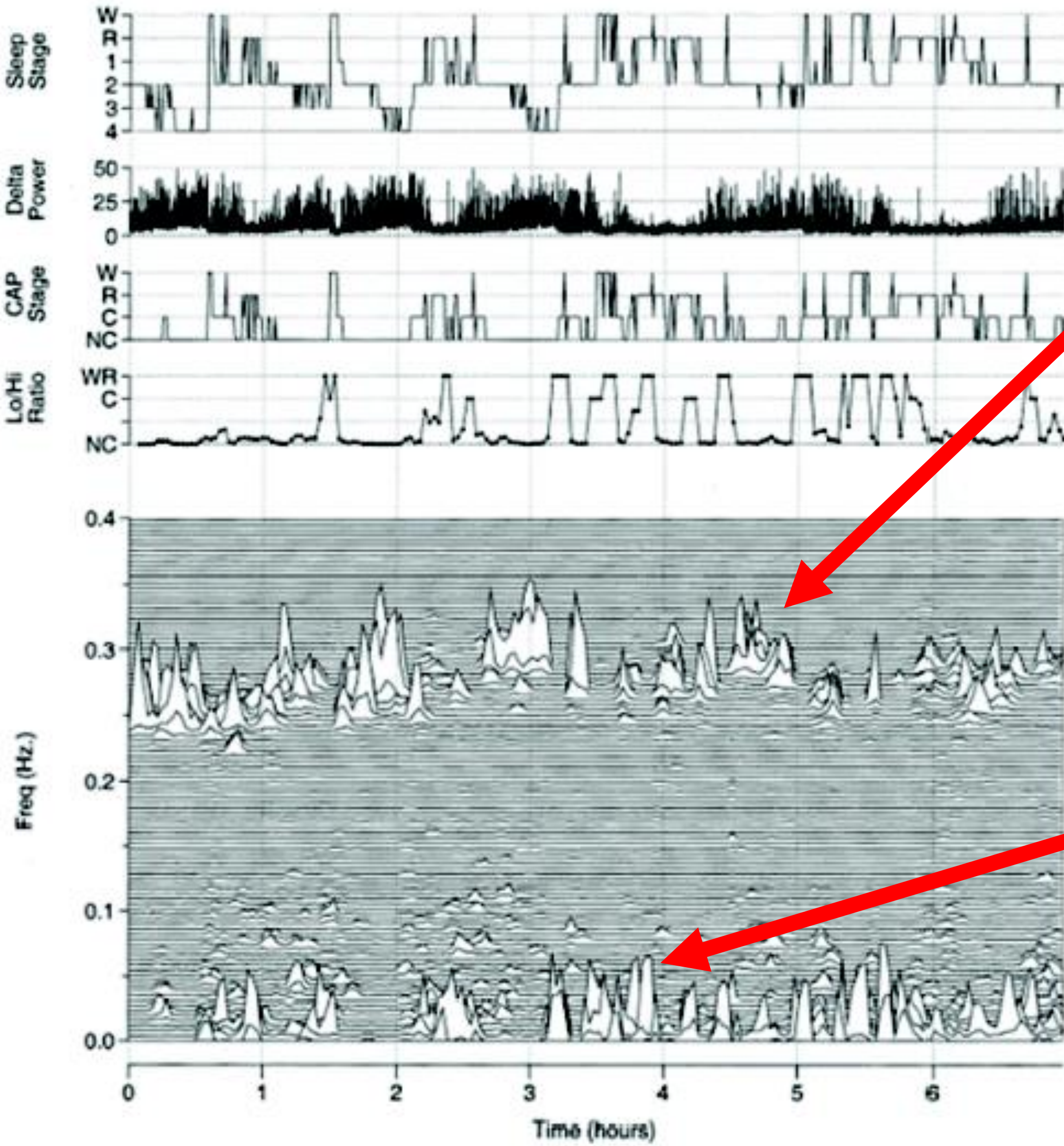
Association of EEG-CAP with Physiologic Parameters

Mathematically, when combining heart rate dynamics and respiration signals to determine the degree of "coupling" …

- **EEG-CAP (unstable sleep)** is associated with **low-frequency coupling** (0.01-0.1Hz)
- **EEG-Non-CAP (stable sleep)** is associated with **high-frequency coupling** (0.1-0.4Hz)
- **REM/Wake** is associated with **very-low-frequency coupling** (<0.01Hz)

Thomas RJ, Mietus JE, Peng CK, Goldberger AL. Sleep. 2005;28(9):1151-61

CPC Sleep Spectrogram



Non-CAP

High-Frequency Coupling

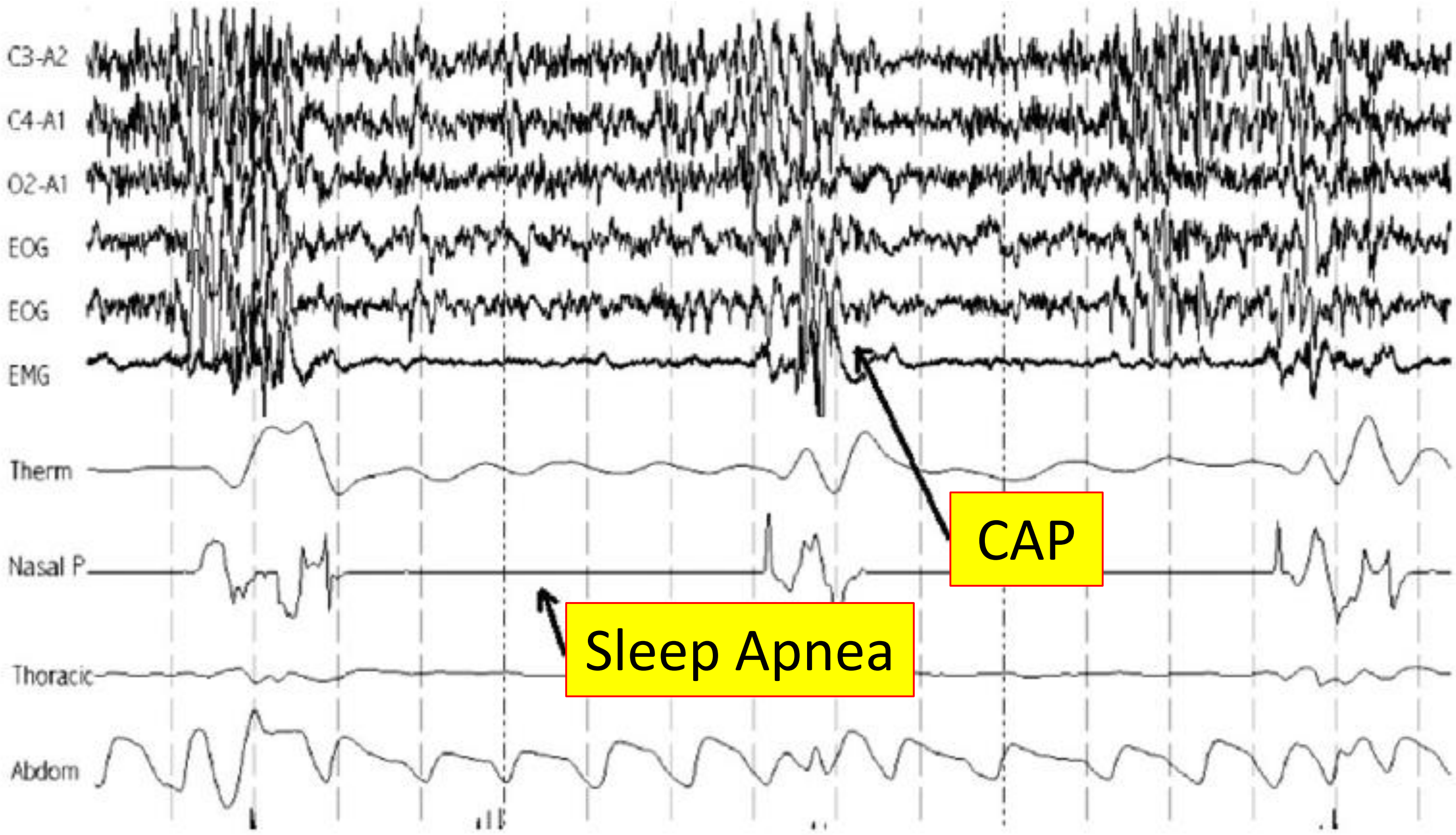
("Stable Sleep")

CAP

Low-Frequency Coupling

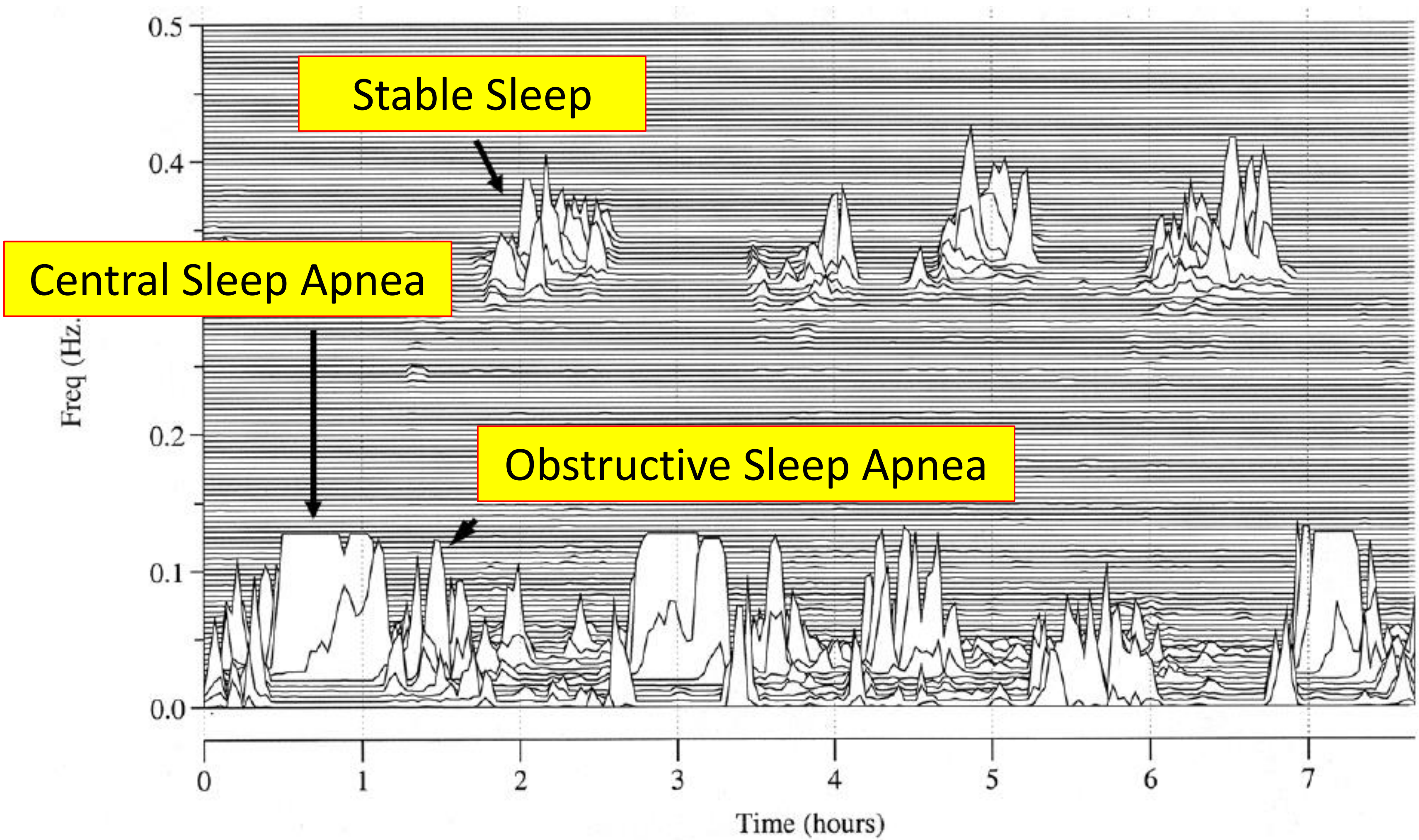
("Unstable Sleep")

Detecting Sleep Apnea



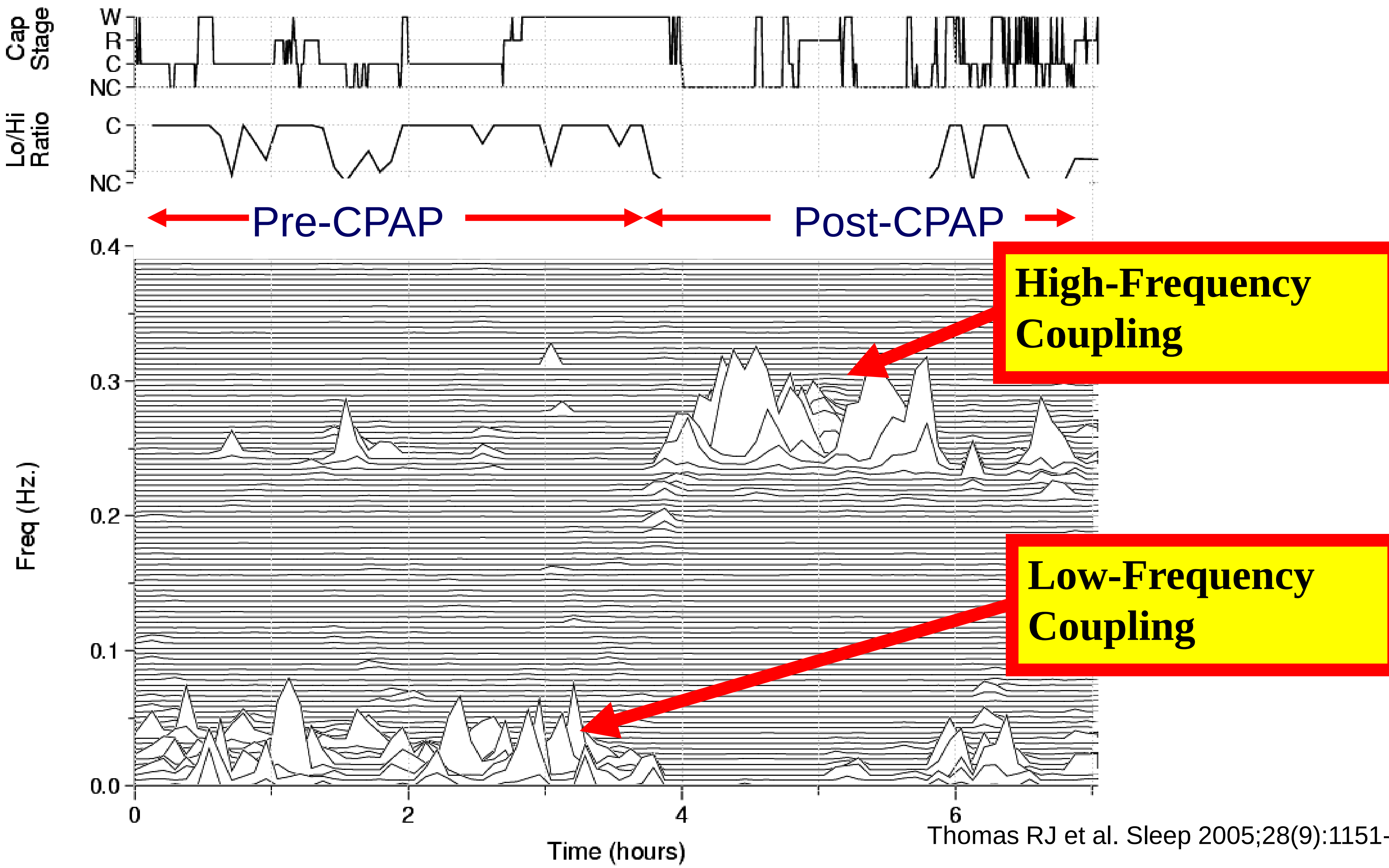
Thomas RJ et al. Sleep 2005;28:1151-61.

Phenotyping Sleep Apnea



Thomas RJ et al Sleep 2007;30:1756-1769.

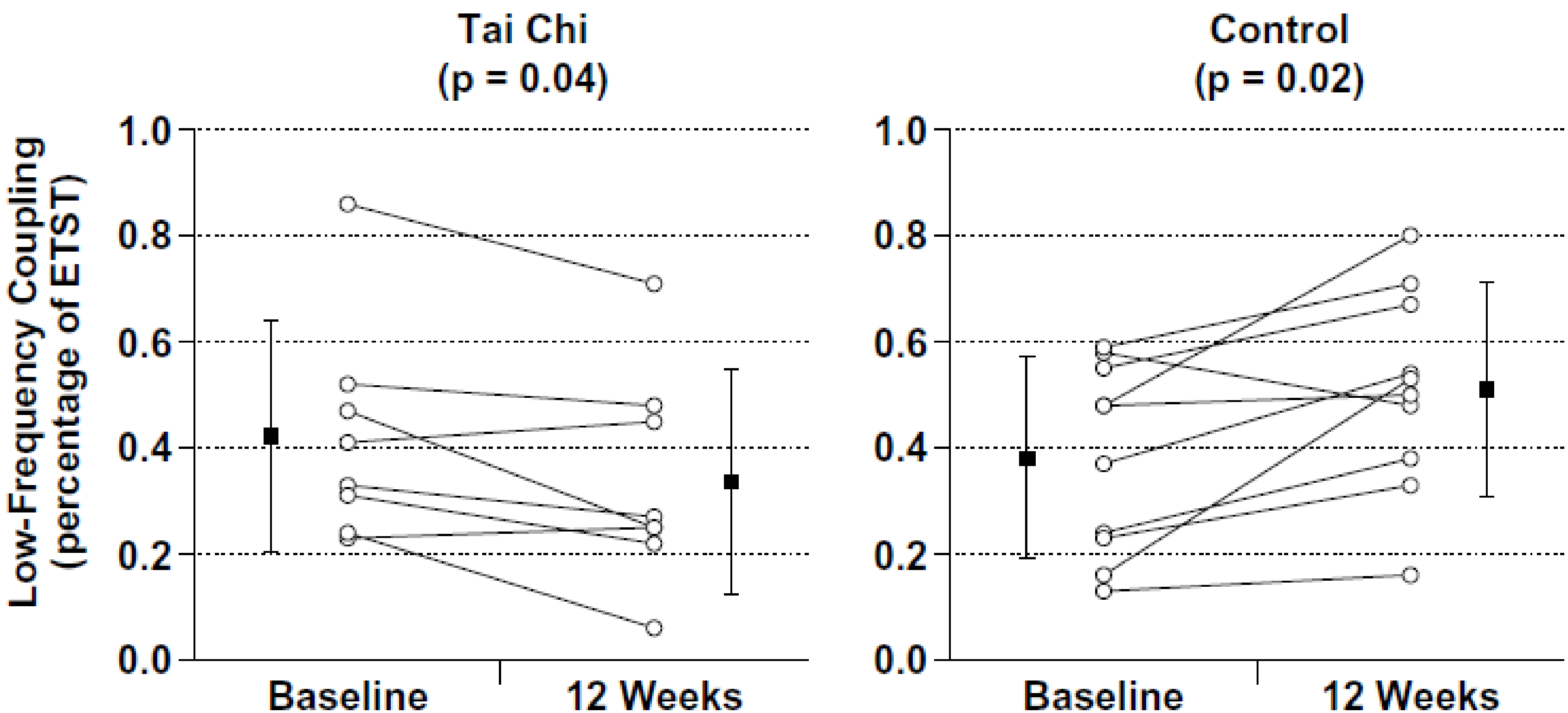
Tracking Treatment Efficacy in Sleep Apnea



Thomas RJ et al. Sleep 2005;28(9):1151-61.

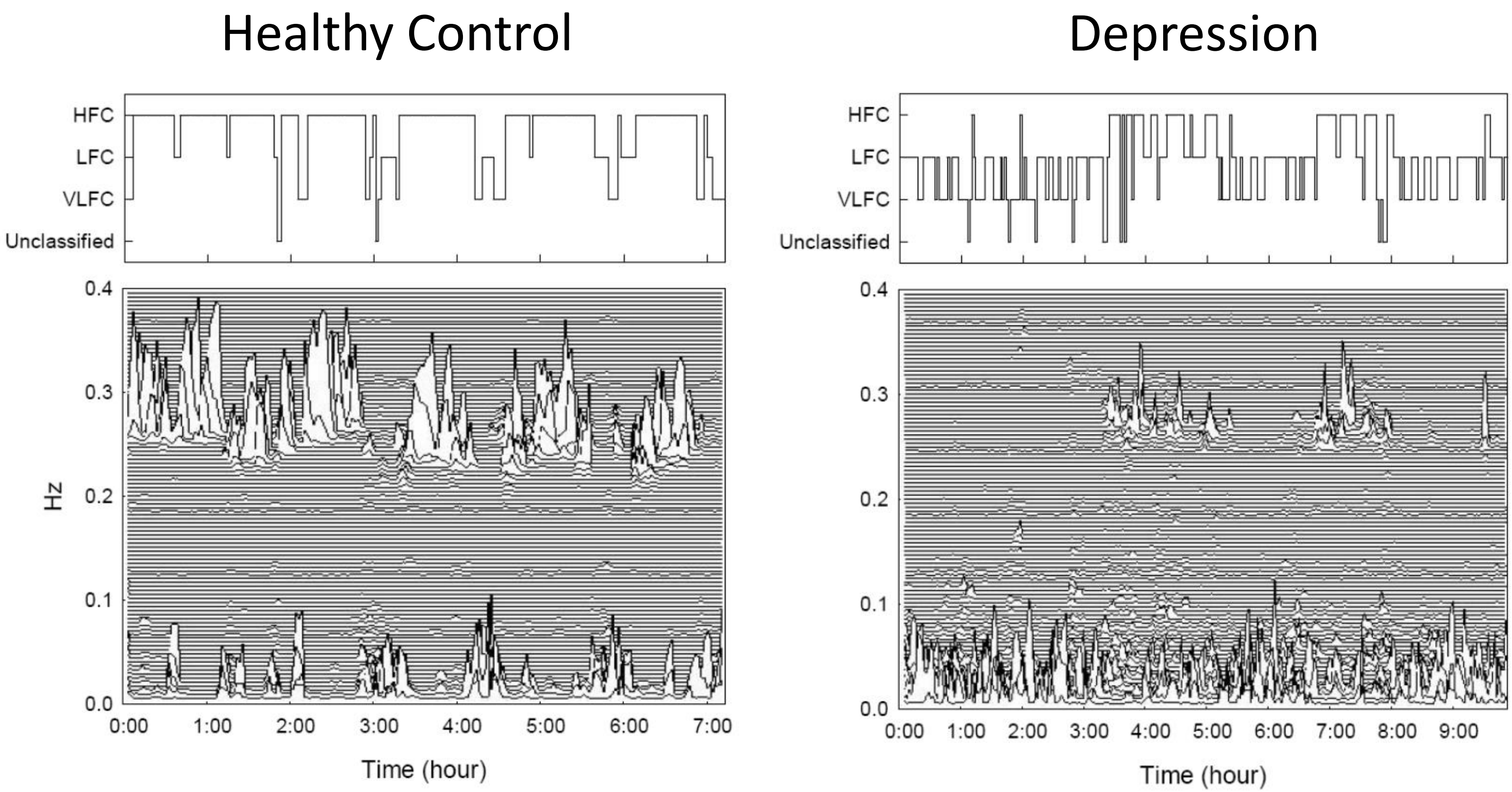
Harrington J et al. Sleep Breath 2013;17:1071–78

Improving Sleep Stability with Tai-Chi Training



Yeh GY et al. Sleep Medicine 2008;9:527–536

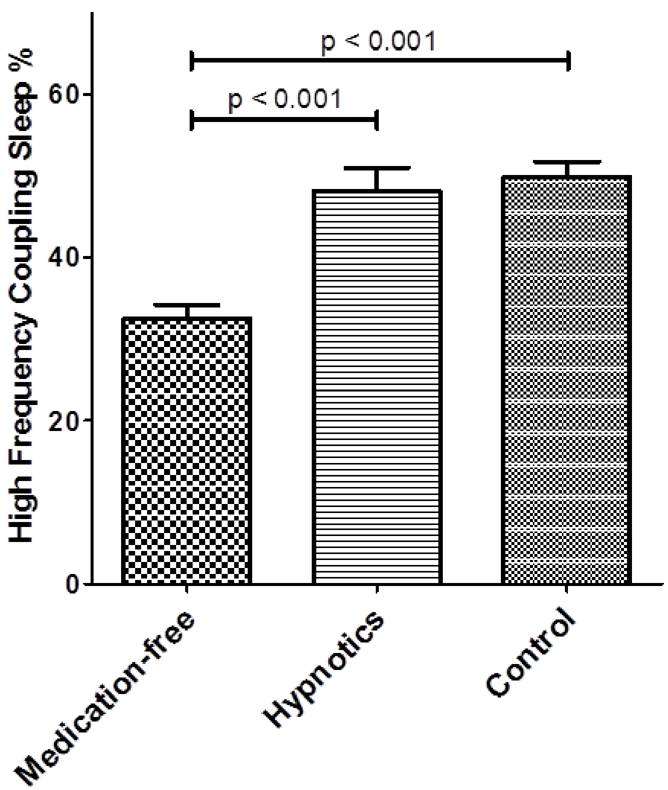
Quantifying Insomnia



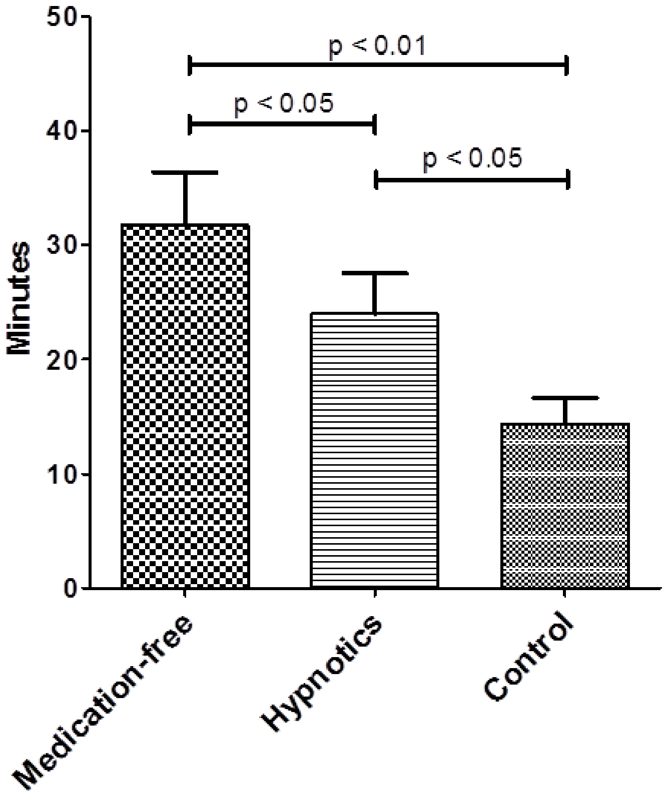
Yang AC et al. **Psychophysiology** 2011;48:285-291

Quantifying Insomnia

Stable Sleep



Stable Sleep Latency



Yang AC et al. **Psychophysiology** 2011;48:285-291

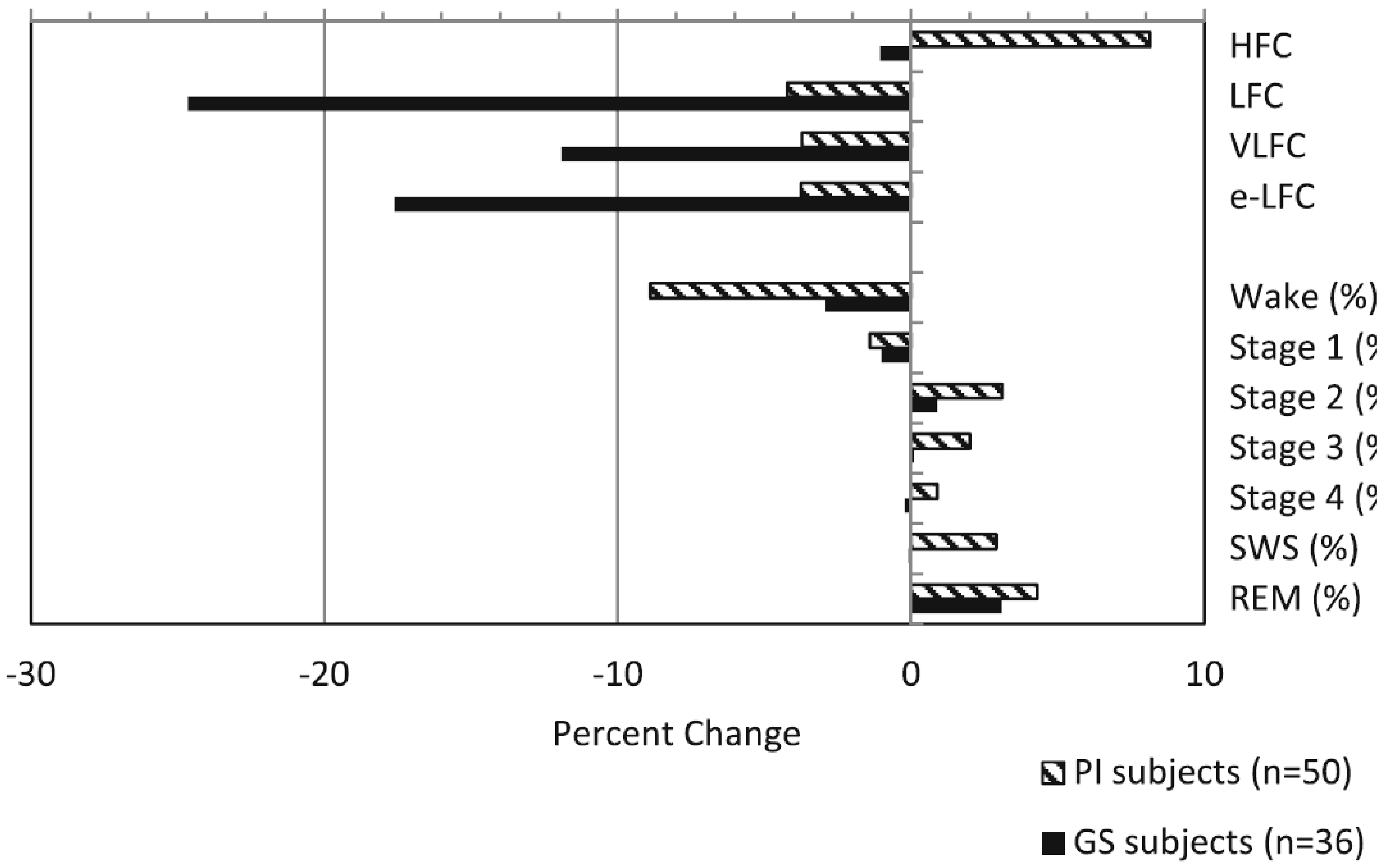
Quantifying Insomnia

- Stable sleep was significantly correlated with the HAM-D insomnia (r=-0.35), and the BDI insomnia score (r=-0.33).

- REM/wakeful state was significantly correlated with the HAM-D score (r=0.42), the PSQI (r=0.31), the BDI (r=0.31), and the BDI insomnia score (r=0.41)

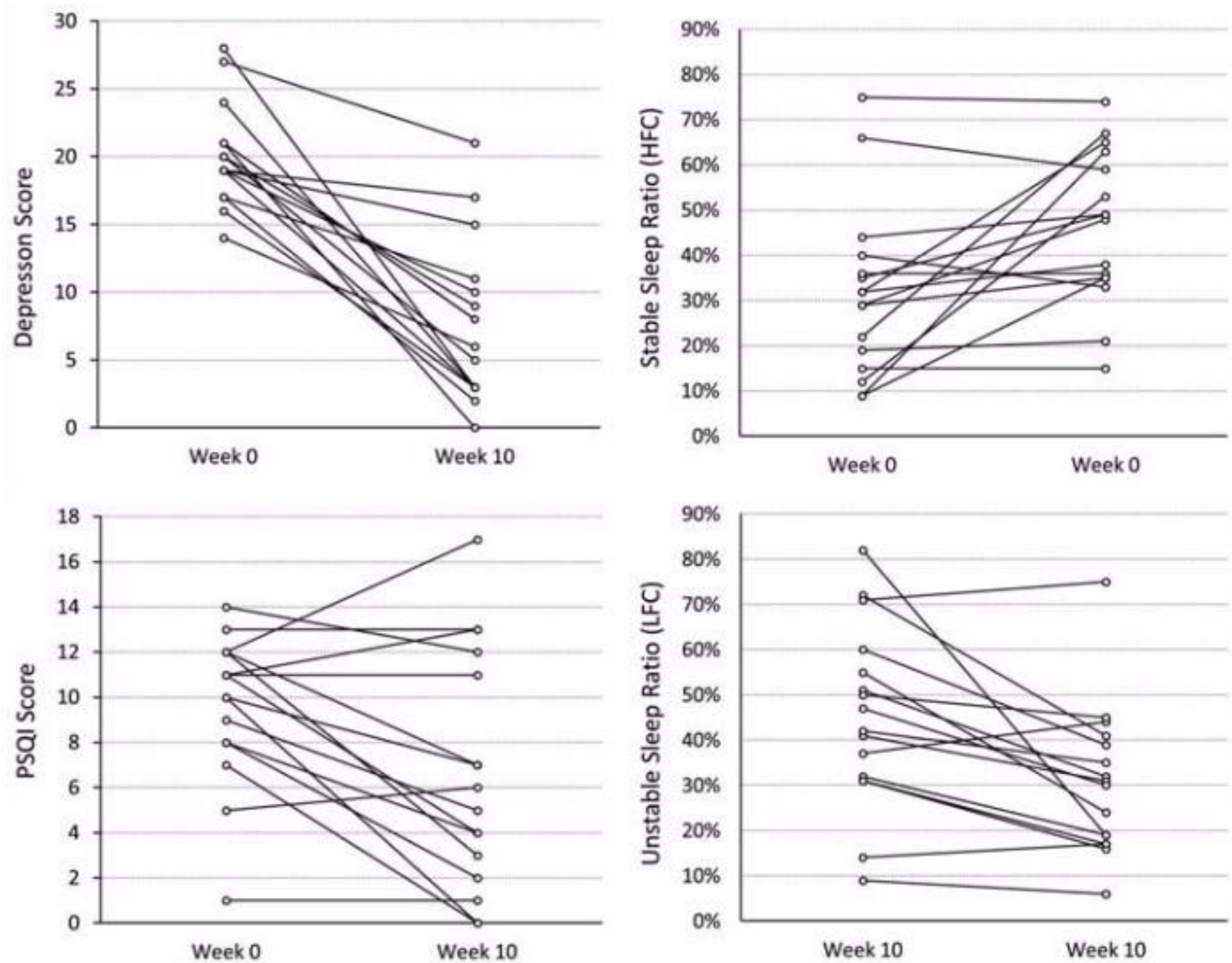
Yang AC et al. **Psychophysiology** 2011;48:285-291

Quantifying Insomnia



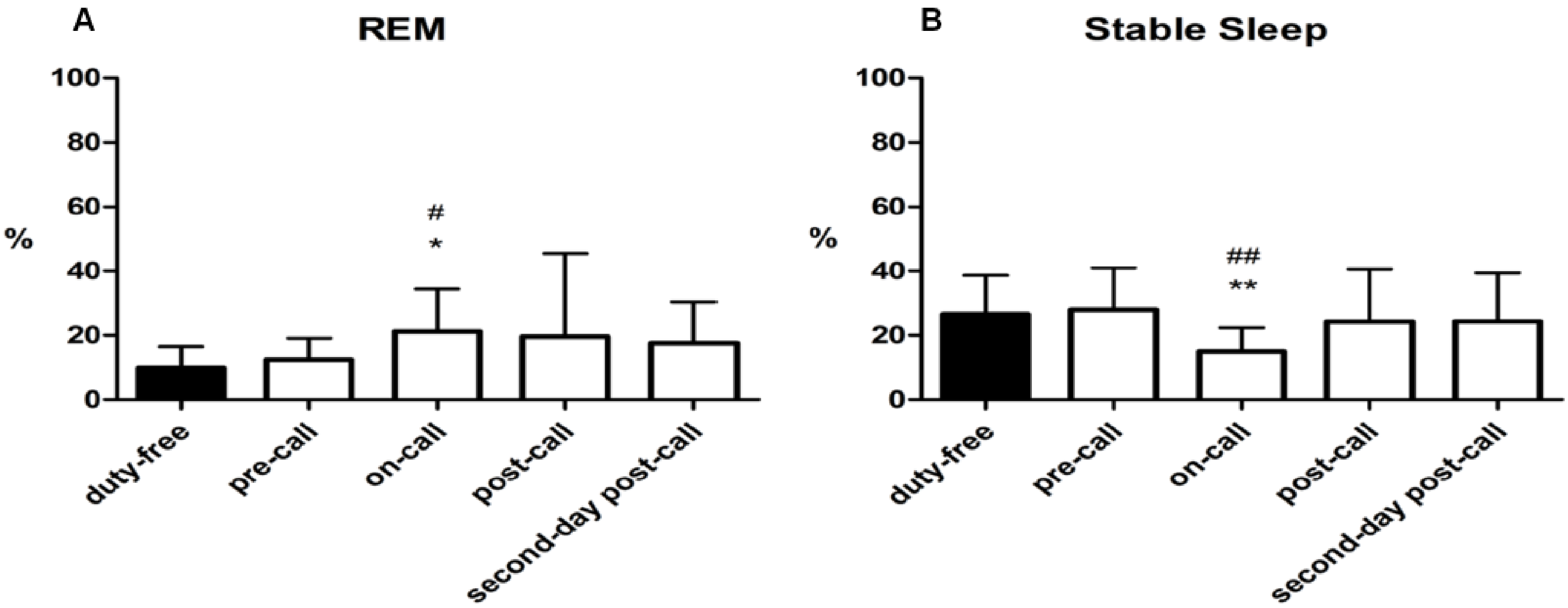
Schramm PJ et al. Sleep Breath 2013;17:713–721

Improved Sleep Stability in Depression with Tai-Chi Exercise



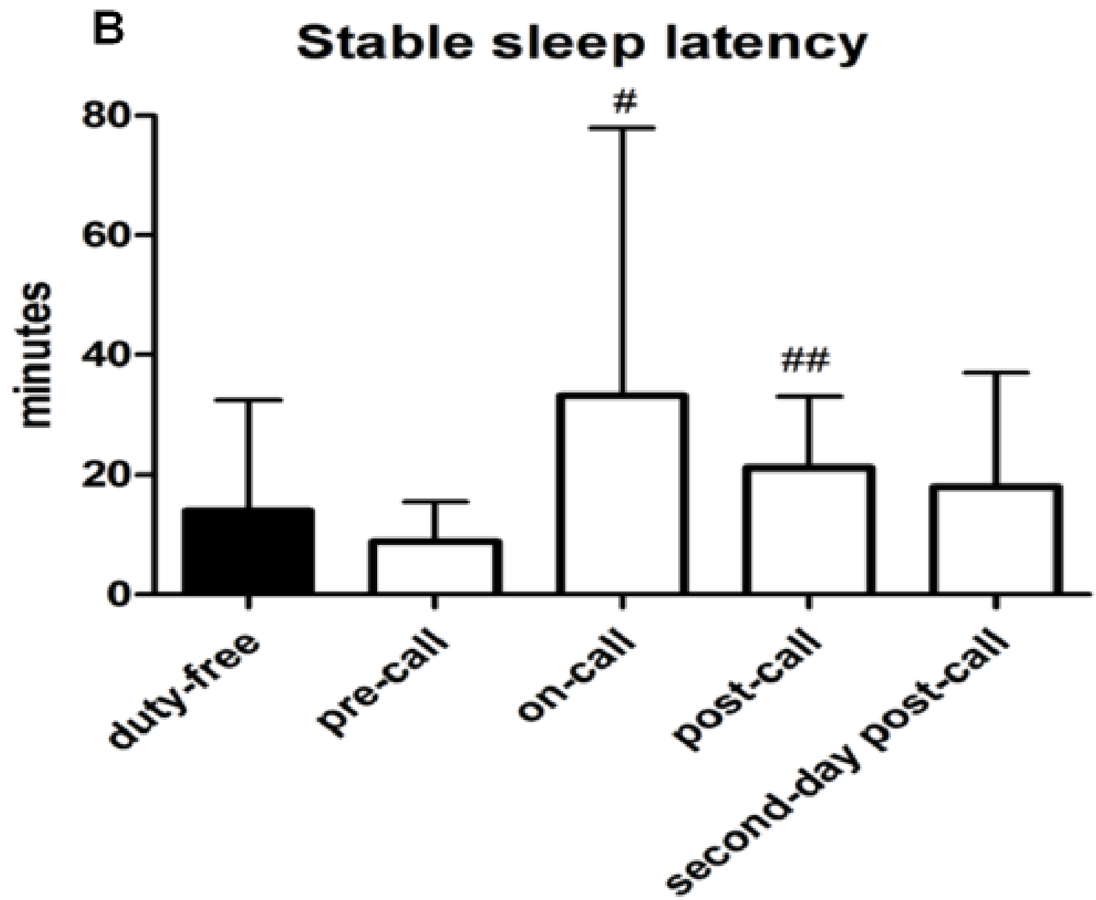
Ma Y. et al. Behavioral Sleep Medicine 2016

Quantifying Stress



Lin Y-H…**Yang AC** et al. PLoS ONE 2013;8:e65072.

Quantifying Stress



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Normal CPC Sleep Parameters

Variable	PSQI $\leq$ 5 (N=82)
PSQI	3.3 ± 1.3
Age, years	38.8 ± 13.0
Gender, female (%)	61 (74)
Epworth Sleepiness Scale	9.5 ± 3.9
Beck Depression Inventory	3.7 ± 3.9
Stable sleep index, %	41.2 ± 16.8
Unstable sleep index, %	33.9 ± 14.7
REM/Wake index, %	23.3 ± 7.7
Sleep duration, hours	6.8 ± 1.5

Yang AC et al **Taiwanese Journal of Psychiatry** 2010;24:201-09