On Spectral Analysis of Heart Rate Variability during Very Slow Yogic Breathing

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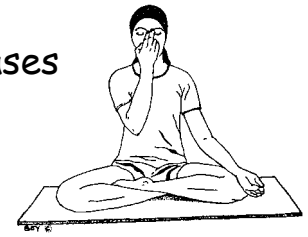
Introduction

- Slow breathing provides valuable insights into mechanisms of cardio respiratory synchronization
  - Normal breathing (> 9 b/min) →HF (0.15-0.4Hz)
  - Slower breathing →LF (0.04-0.15Hz)
  - Very slow breathing (>25 sec/breath) → VLF (0.003-0.04Hz)
- Reported resonant characteristic
  - Vaschillo, Song & Lehrer
  - Available physiological margin?
- Very slow yogic breathing ~ 1 breath/min

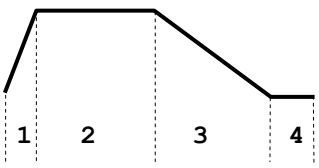
Methods

- Eight measurements of Nadi Shodhana Pranayama on a single practitioner
  - Healthy practitioner with 10 year experience
- Measurements
  - Respiration, HRV, and SpO2
  - Before, during, and after exercise HRV – WHRM system (1 ms precision)
  - Respiration (NIMS Respitrace 200 system)
    - Ribcage, Abdominal, and total Volume, Flow
  - Blood oxygen saturation (Ares / Advanced Brain Monitoring)
  - External synchronization very hard

Nadi Shodhana Pranayama

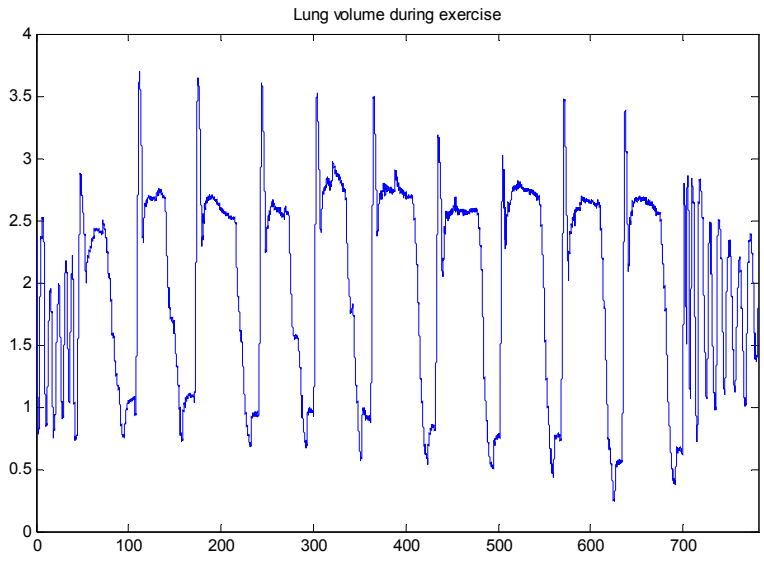


- Yogic breathing - three phases
  - abdominal, chest, clavicular)
- Breathing phases
  - 1. Inhalation
  - 2. Internal retention
  - 3. Exhalation
  - 4. External retention

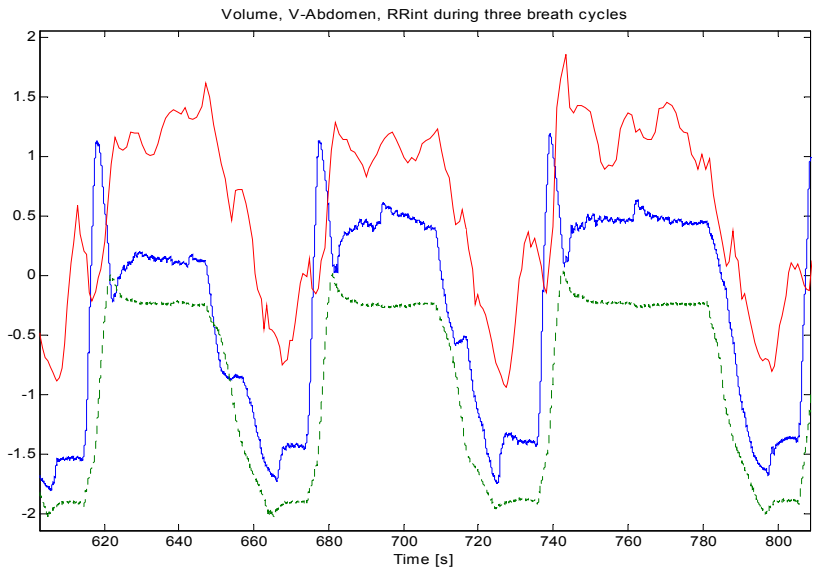


- Alternating nostrils
- Duration ratio 1:2:2:1 (10:20:20:10 sec)

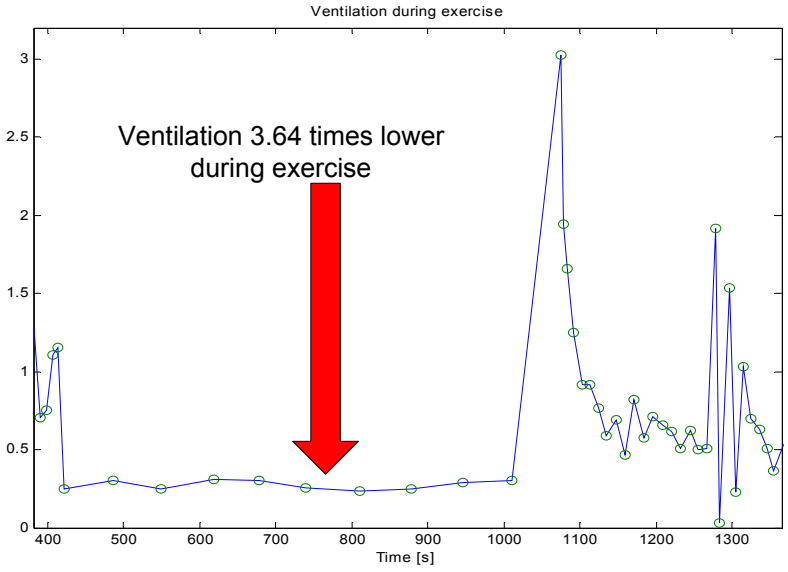
Lung volume during exercise



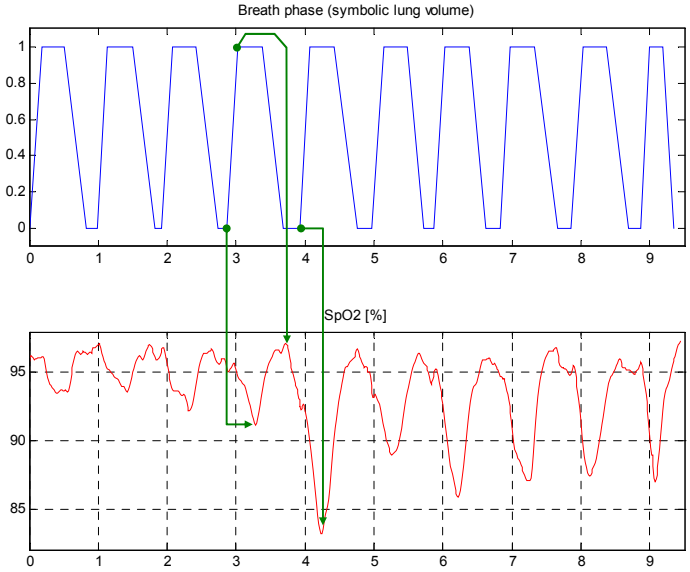
Lung volumes detail



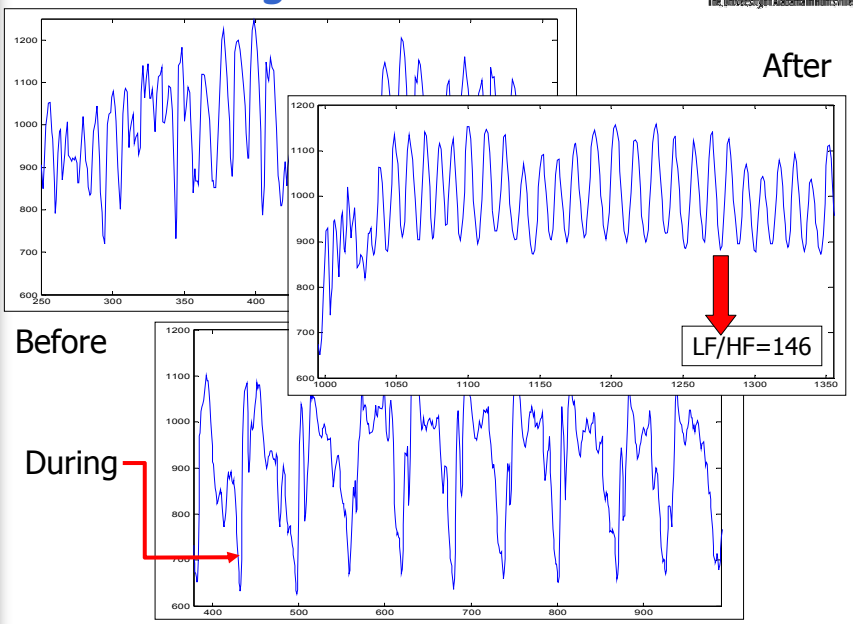
Ventilation during exercise



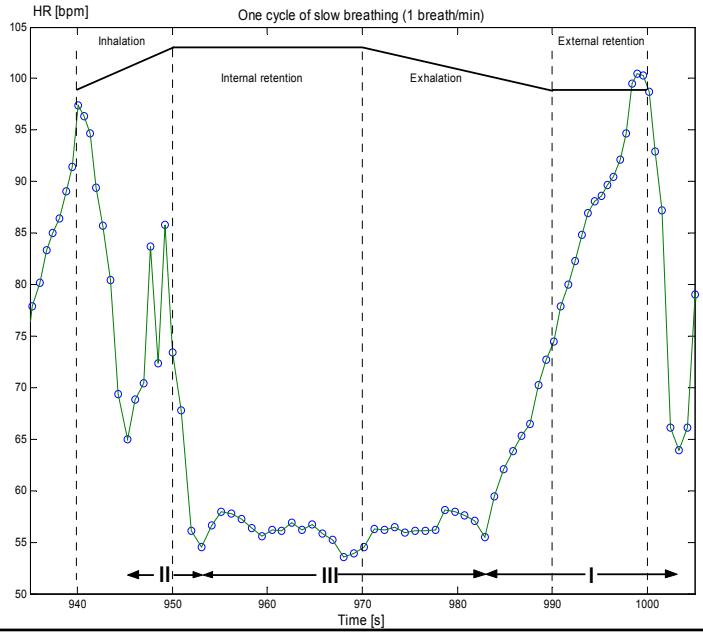
Blood oxygen saturation



RRint during exercise

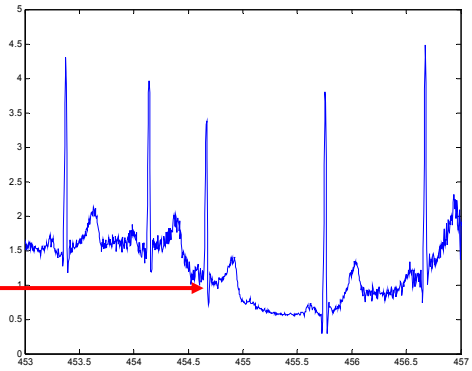


Typical changes during one cycle

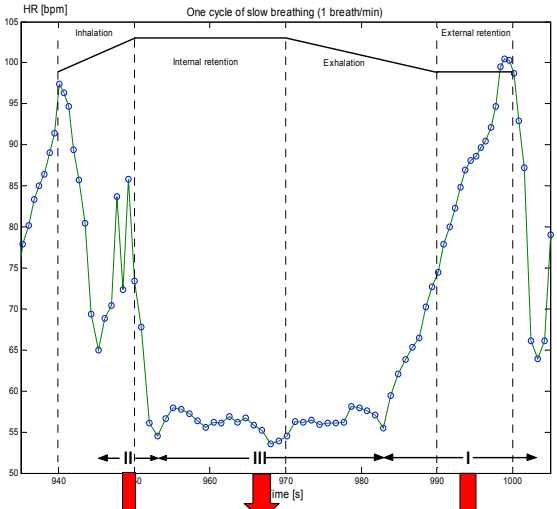


Ectopic beats

- Probably due to overstimulation of vagus during rapid abdominal inhalation
  - Atrial extra-systoles
- Number of ectopic events in the given set of experiments
  - E01 (3), E03(1), and E05(4)
  - Average relative position of 6 events 74 s (63s)
    - Two events at 190 and 490 seconds
- Typical example



Spectral Components

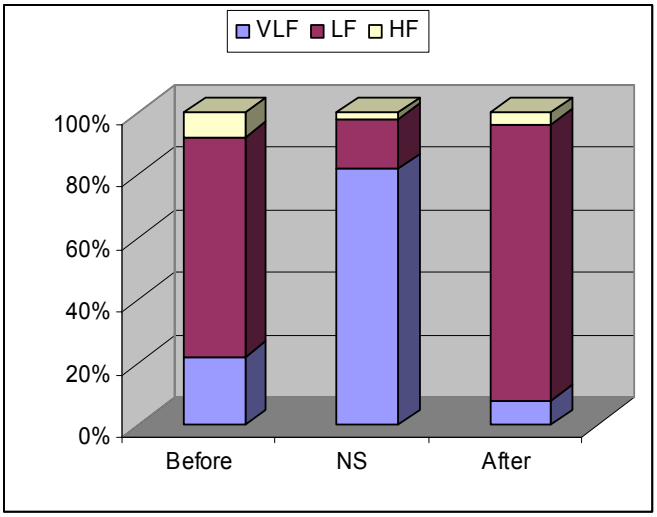


$T_3 \approx 31$ sec (0.032Hz)

$T_1 \approx 22$ sec (0.045Hz)

$T_2 \approx 6$ sec (0.16Hz)

HRV spectrum



Typical spectral components

Parameter	Before exercise	During exercise	After exercise
Mean RRint (SE)	959.29 (10.26)	904.13* (11.81)	998.98‡ (14.45)
Total HRV power [ms²] (SE)	11,625.62 (1,386.70)	9,036.96 (836.64)	10,931.74 (1,075.58)
VLF power [ms²] (%)	2,329.14 (21.71)	7,472.99* (81.96*)	734.28* (7.70‡)
LF power [ms²] (%)	8,494.94 (70.54)	1,352.76* (15.80*)	9,823.10 (88.65‡)
HF power [ms²] (%)	801.54 (7.75)	211.21* (2.24‡)	374.36* (3.64‡)
LF/HF (SE)	14.33 (3.73)	9.50 (1.80)	50.93† (16.35)
LF max. frequency [Hz] (SE)	0.091875 (0.00494)	0.07525 (0.00956)	0.07125‡ (0.00370)
HF max. frequency [Hz] (SE)	0.174125 (0.00679)	0.16 (0.00402)	0.185625 (0.01438)

The results of raw HRV data processing; ectopic heart beats are not filtered out.
Significant differences when compared against the state before exercise: † $p < 0.05$, ‡ $p < 0.01$, * $p < 0.001$

Results

- Rapid abdominal inhalation stimulates vagus and increases heart rate
  - Arrhythmia – ectopic beats
- Relative power of VLF band is significantly smaller after exercise
  - M=21.71% → M=7.7%, $t(7)=-4.02$, $p<.005$.
- HF power significantly reduced during exercise, and remains small after exercise
- Decrease of breathing frequency after exercise
  - 5.5 → 4.3 b/min
- Increase of HF/LF
  - 14.33 → 50.93

Conclusions

- Model development
  - ANS characterization in the absence of RSA (extended "quiet" periods)
- Serious problems with instrumentation
- Similar state before and after
  - Conditioning after years of practice
- Resonant characteristics of the RSA
  - Resonant frequency not fixed, influenced by state
  - Available physiological margin increased by systematic practice
- Future experiments
  - more participants - experienced practitioners/beginners
  - Blood pressure measurement and correlation