Electromyogram (EMG)

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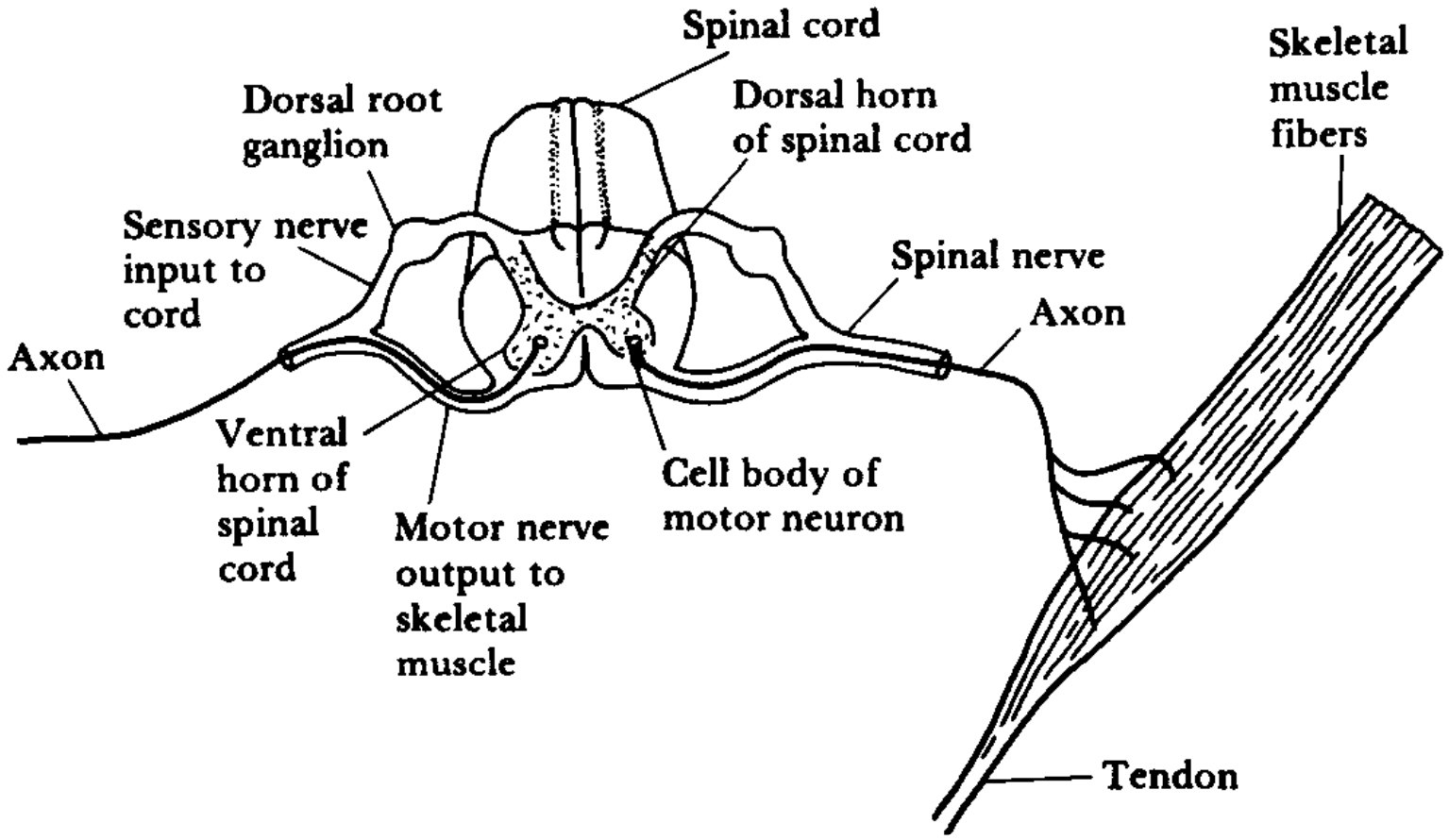
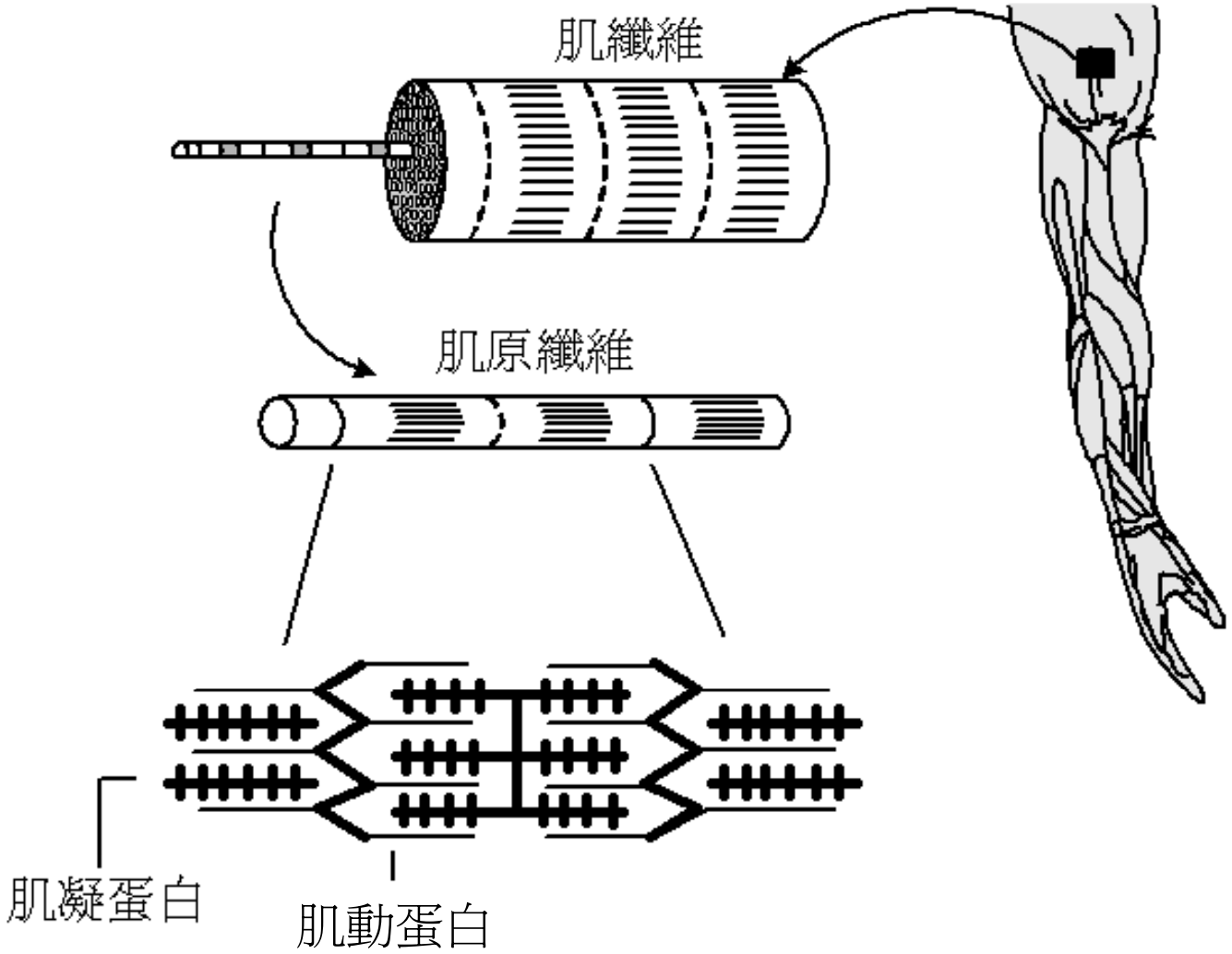
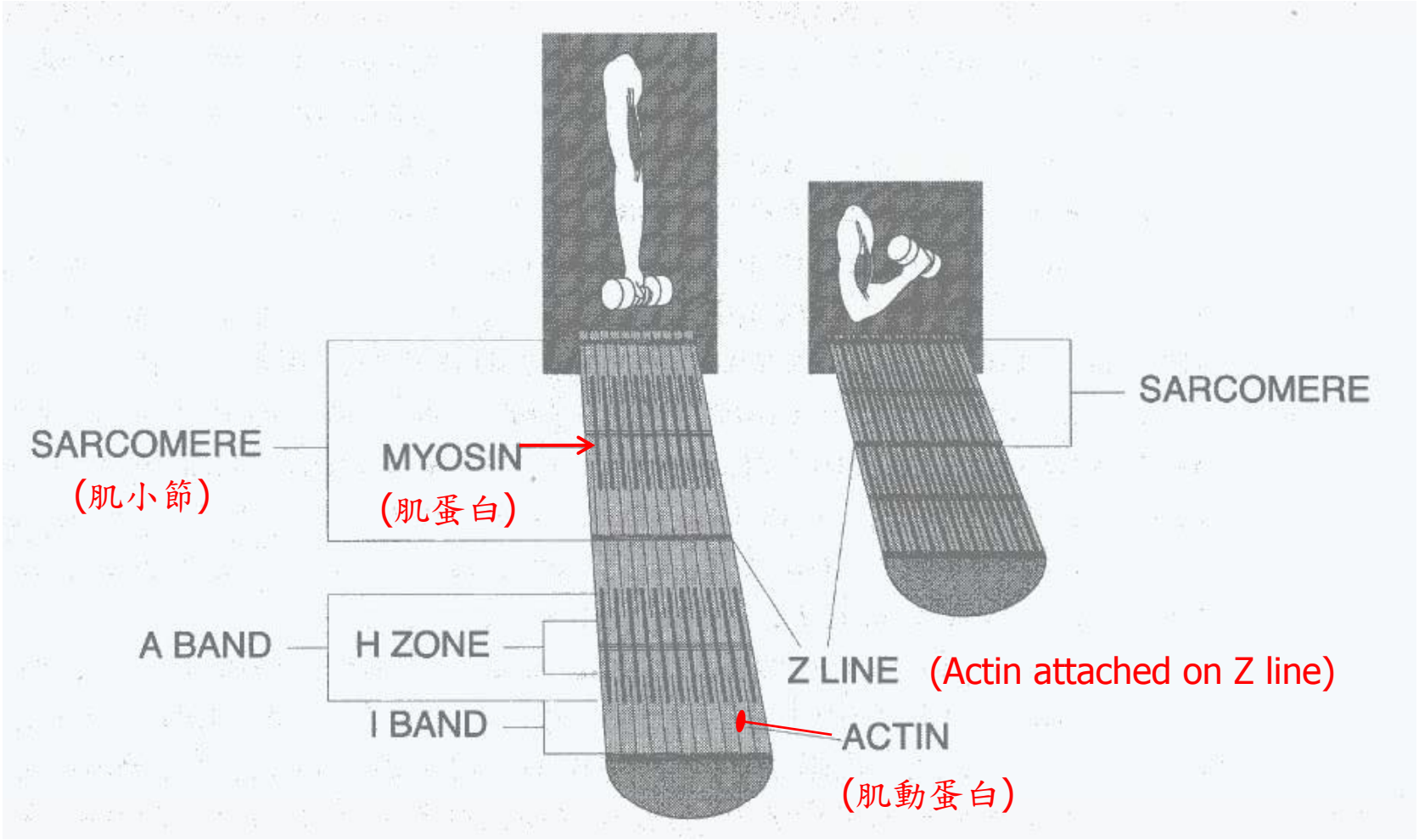
Single motor unit



Skeletal muscle (骨骼肌)

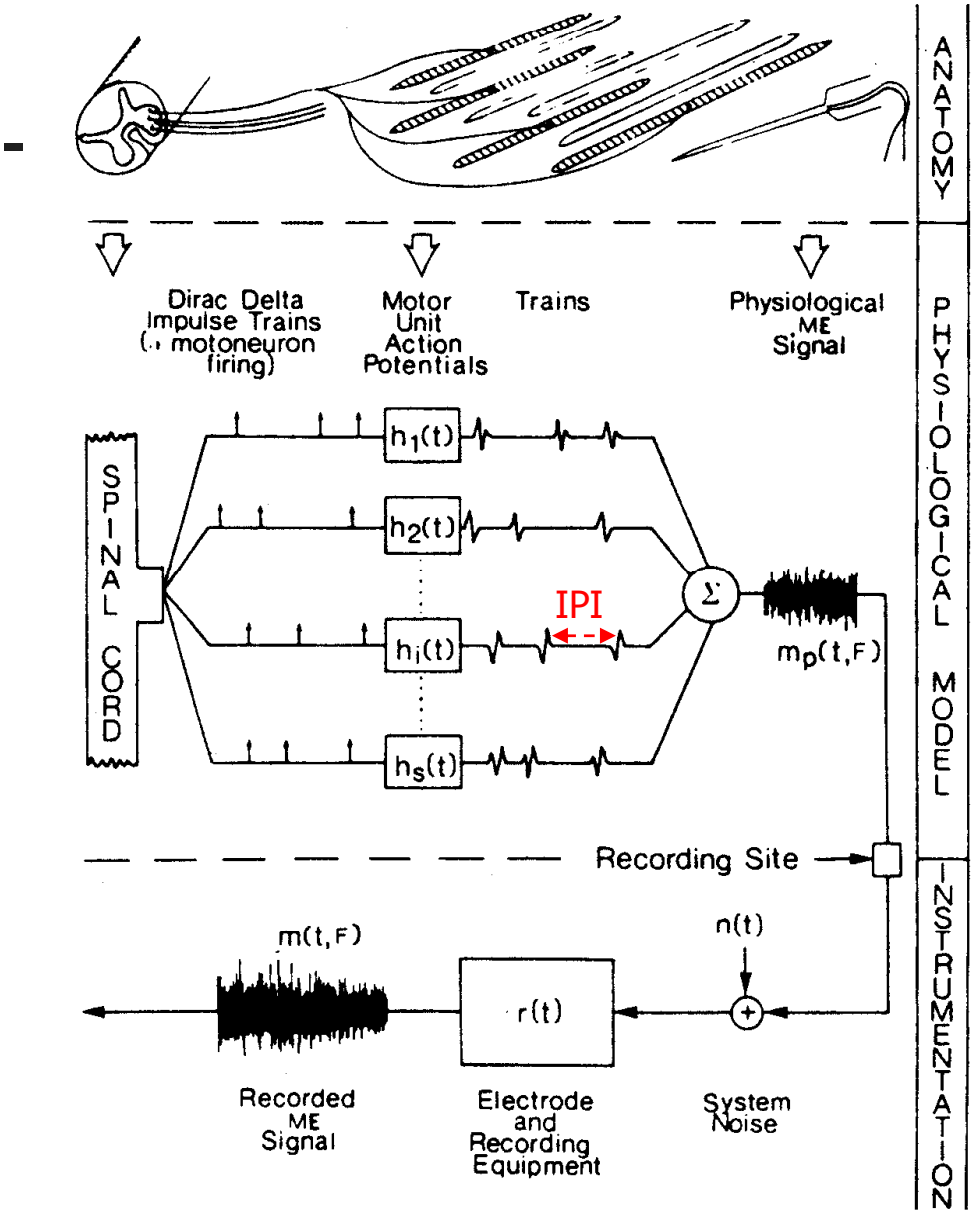


Sarcomere (basic unit of skeletal muscles)



J. Enderle, Introduction to Biomedical Engineering, Academic Press, 2000.

Motor-unit firing pattern



SMUAP wave

$$y(t) = \int_0^t h(t-\tau)x(\tau)d\tau$$

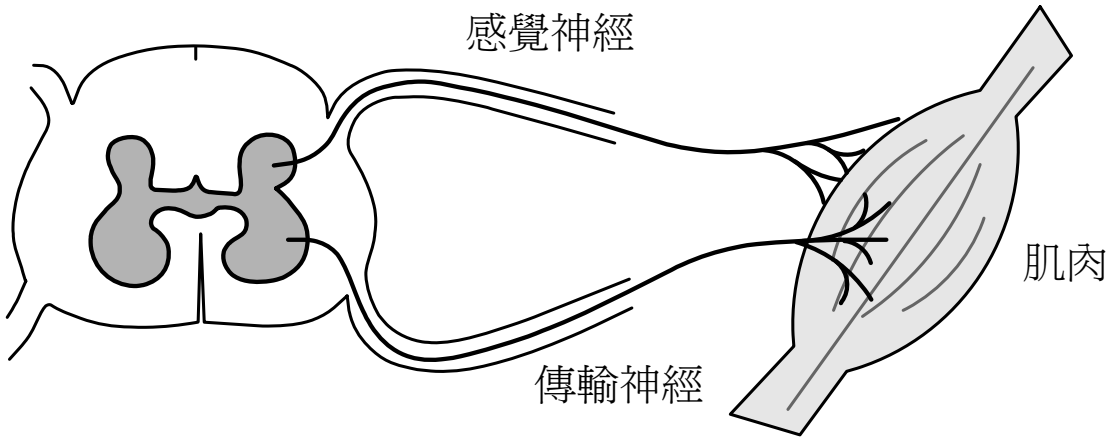
Point process:

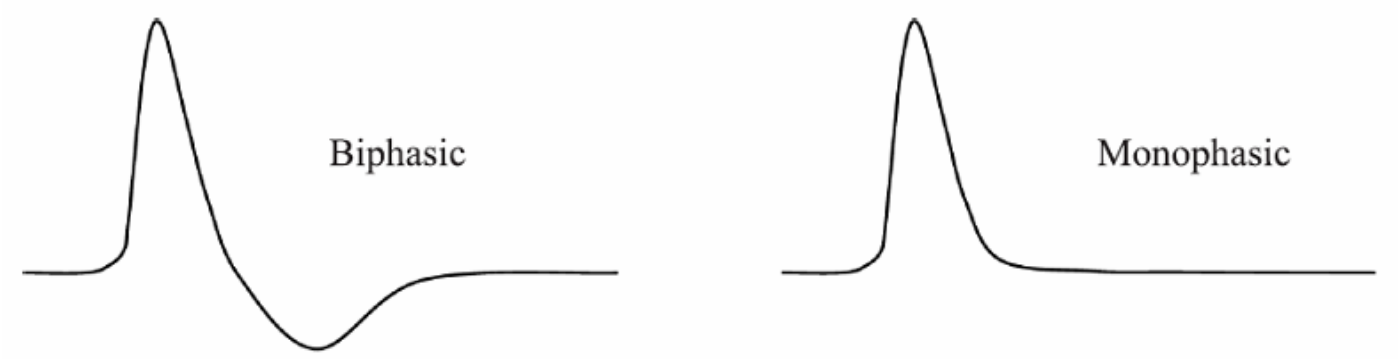
A series of impulse or Dirac delta function

Inter-pulse interval (IPI) > SMUAP duration

R. Rangayyan, Biomedical Signal Analysis, John Wiely & Sons, 2002.

Single-motor-unit action potential (SMUAP)

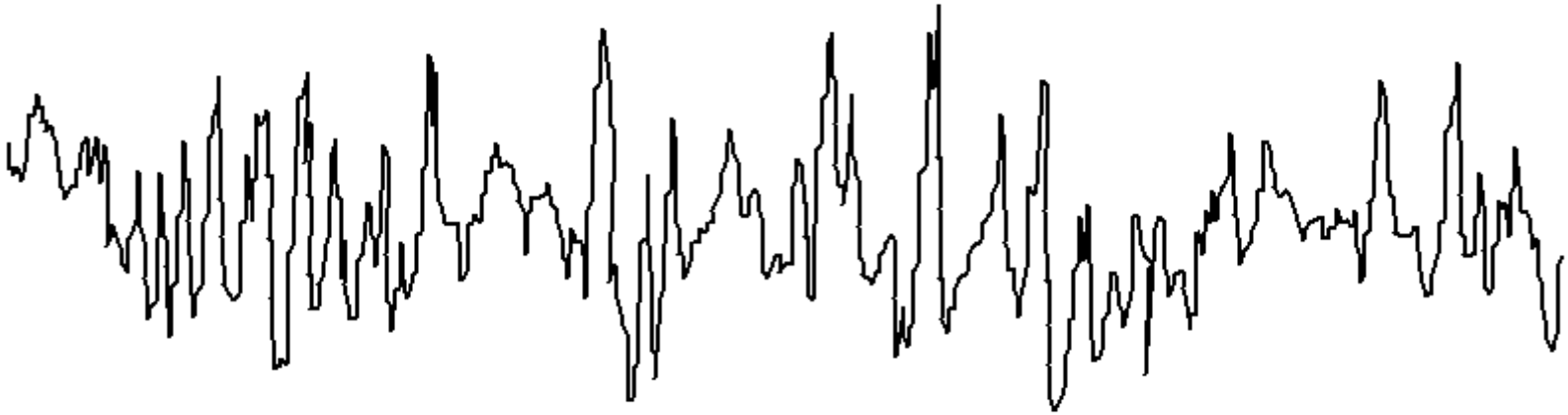




Electromyography (EMG, 肌電圖)

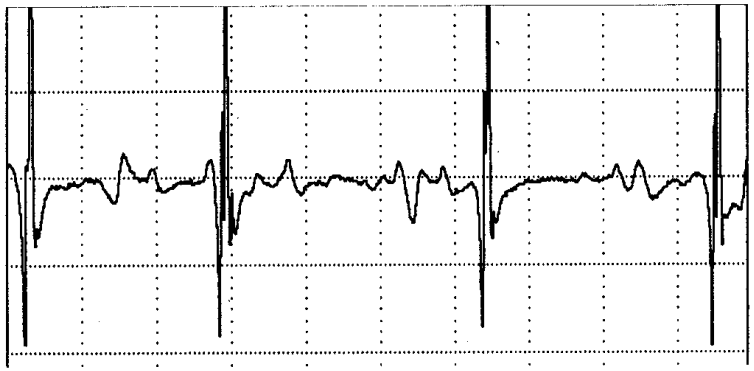
Resting state

Muscle contraction

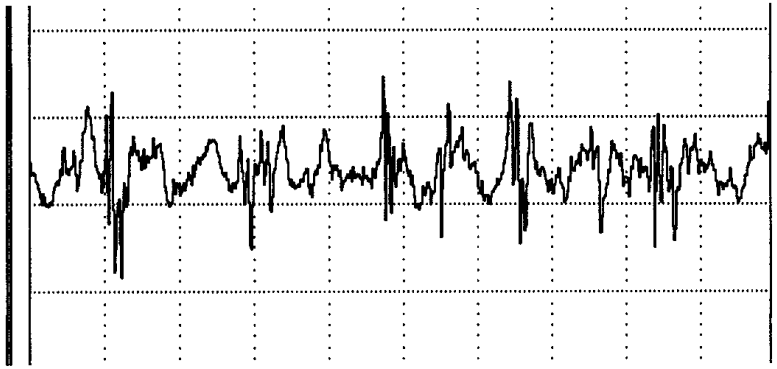


SMUAP (Cont.)

(a)



(b)



(c)

Normal:

- Mostly biphasic, 3-5 ms duration

Neuropathy (brachial plexus in injury):

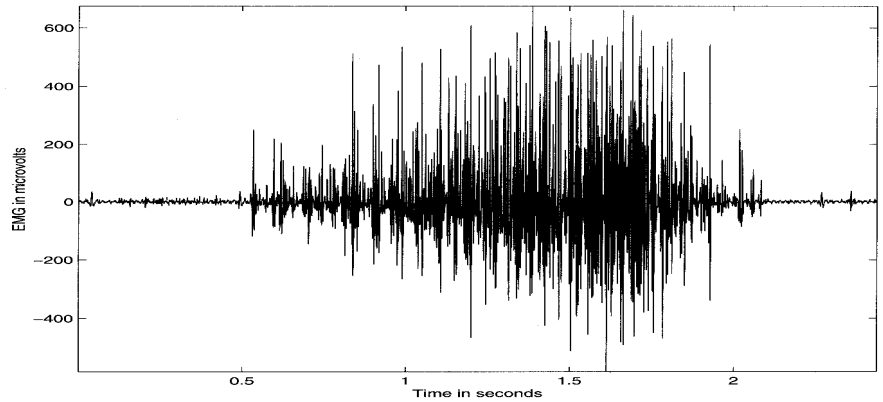
- Slow conduction
- Polyphasic, large amplitude (800 μV)

Myopathy:

- Loss of muscle fibers in motor unit
- Recruitment of more motor units at a low level of effort

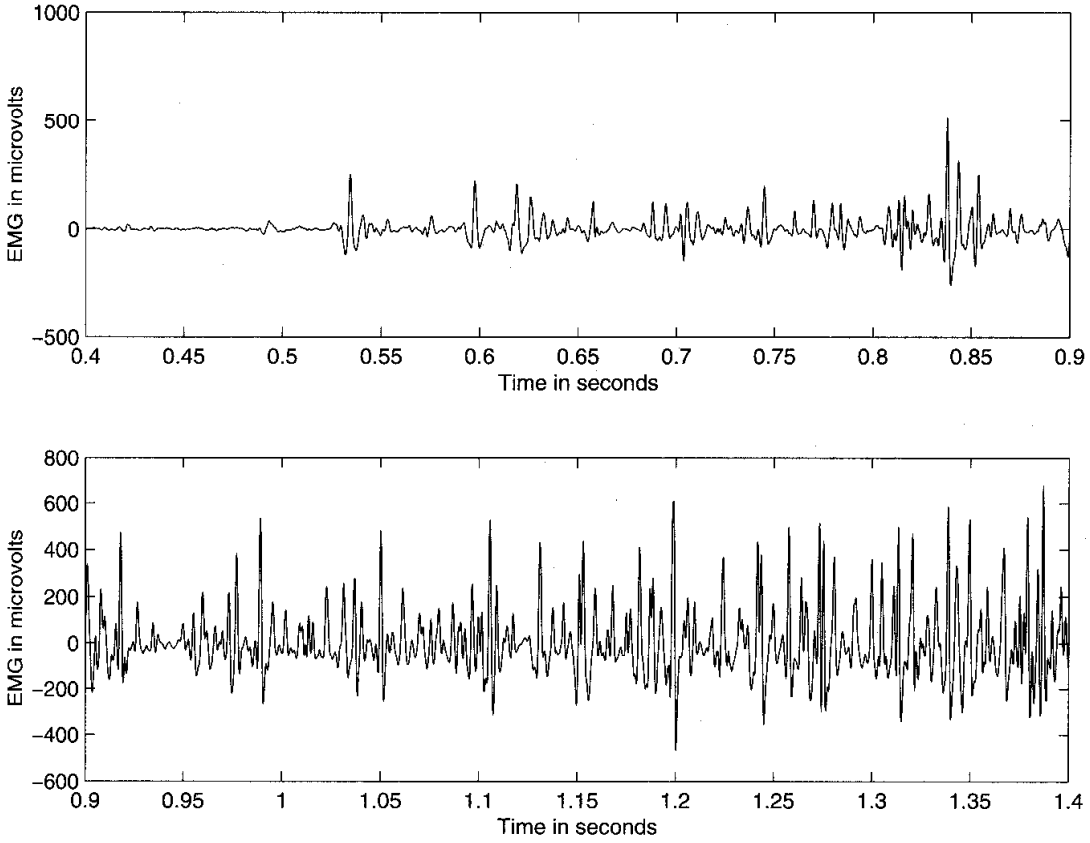
Gradation of muscular contraction

- Spatial recruitment
  - Activating new motor units with increasing effort
- Temporal recruitment
  - Increasing frequency of firing rate of each motor unit with increasing effort



EMG at diaphram muscle

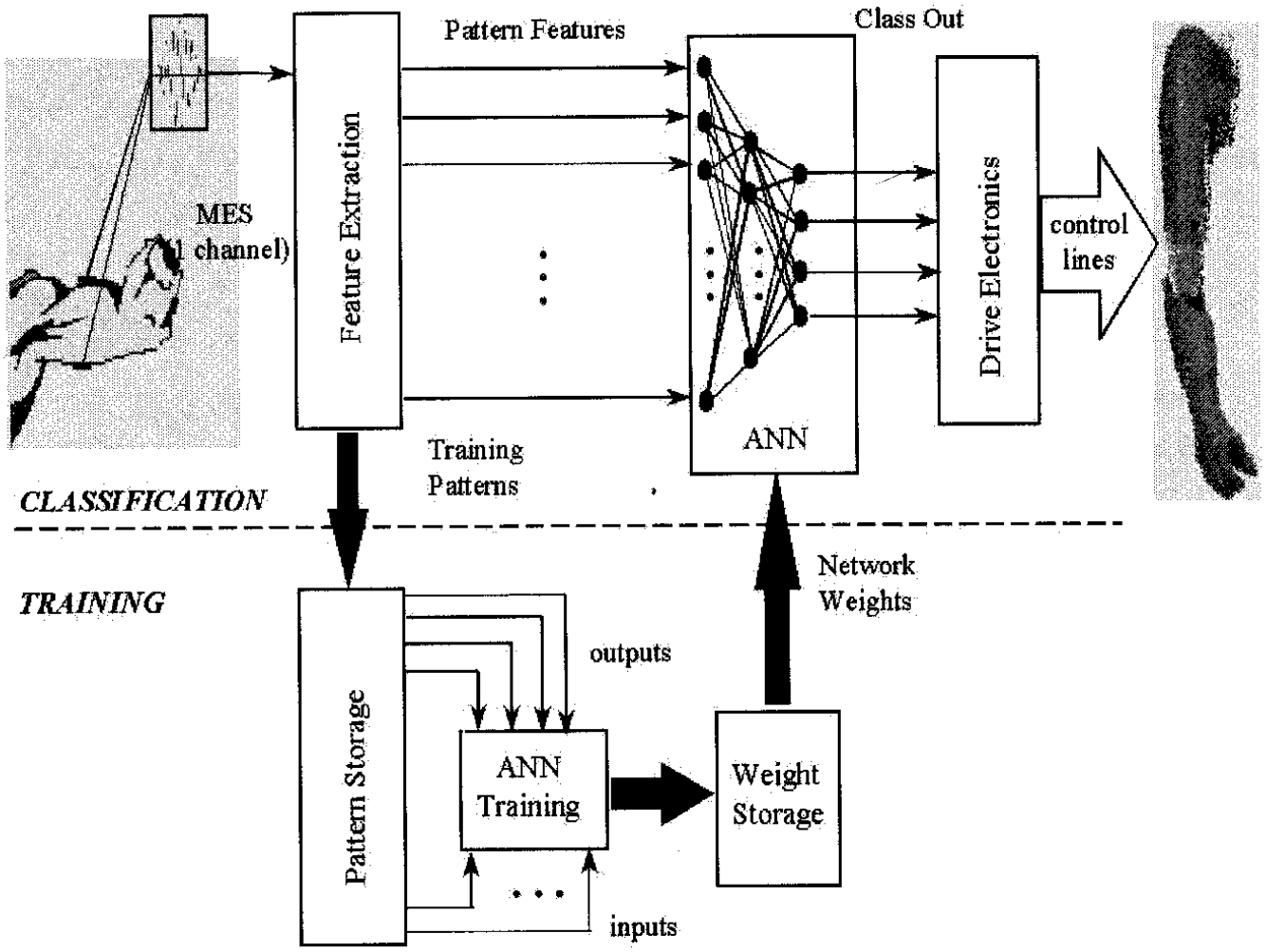
Gradation of muscular contraction (cont.)



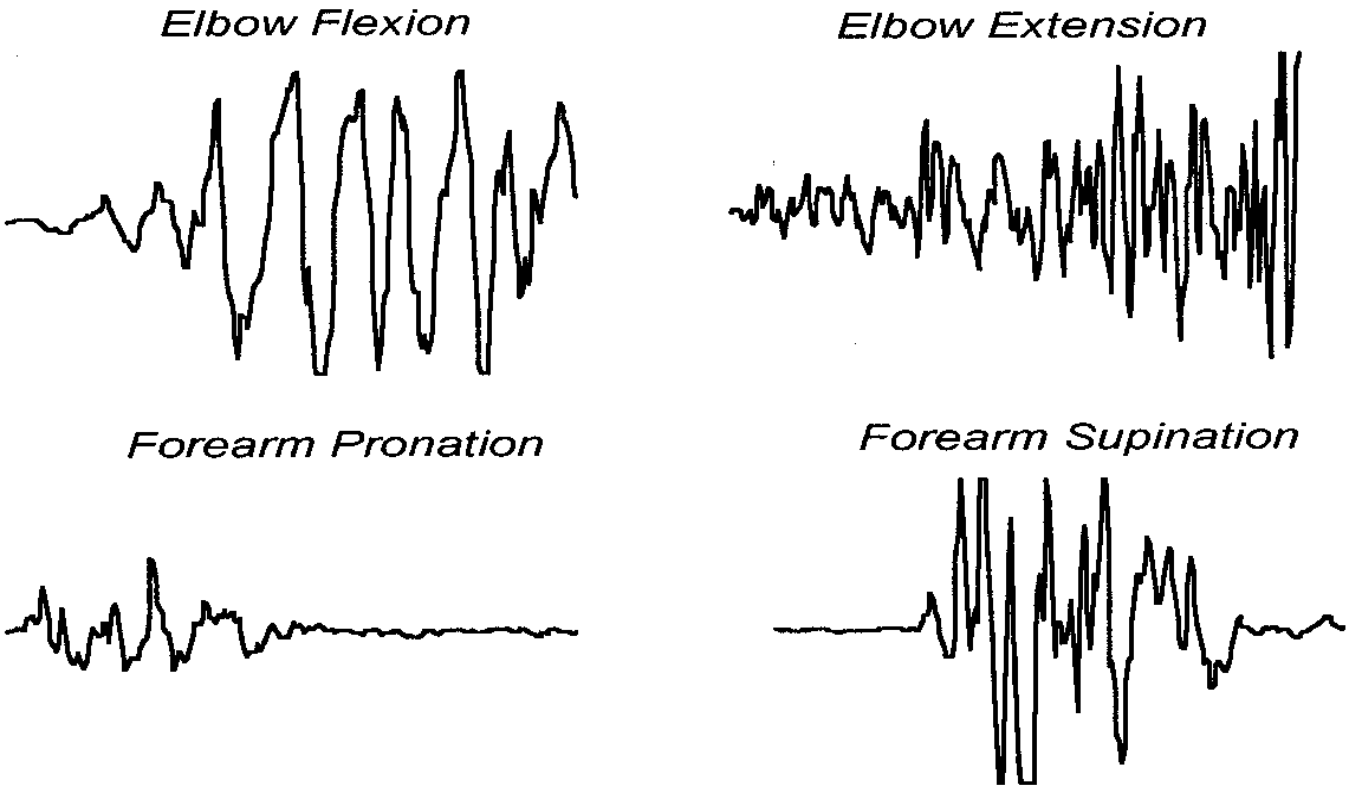
SMUAPs at initial stages of contraction, following by increasing of several MUAP

Electromyography (EMG) processing in prothesis control

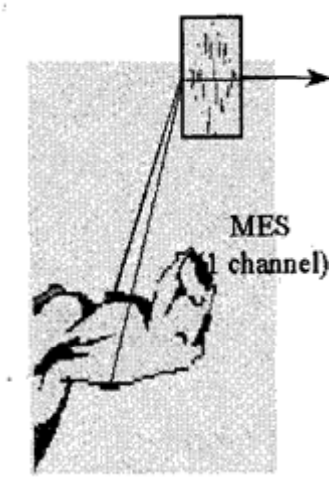
(Myoelectric Control System at University of New Brunswick, Canada)



EMG during different movements



Integrated EMG (IEMG)

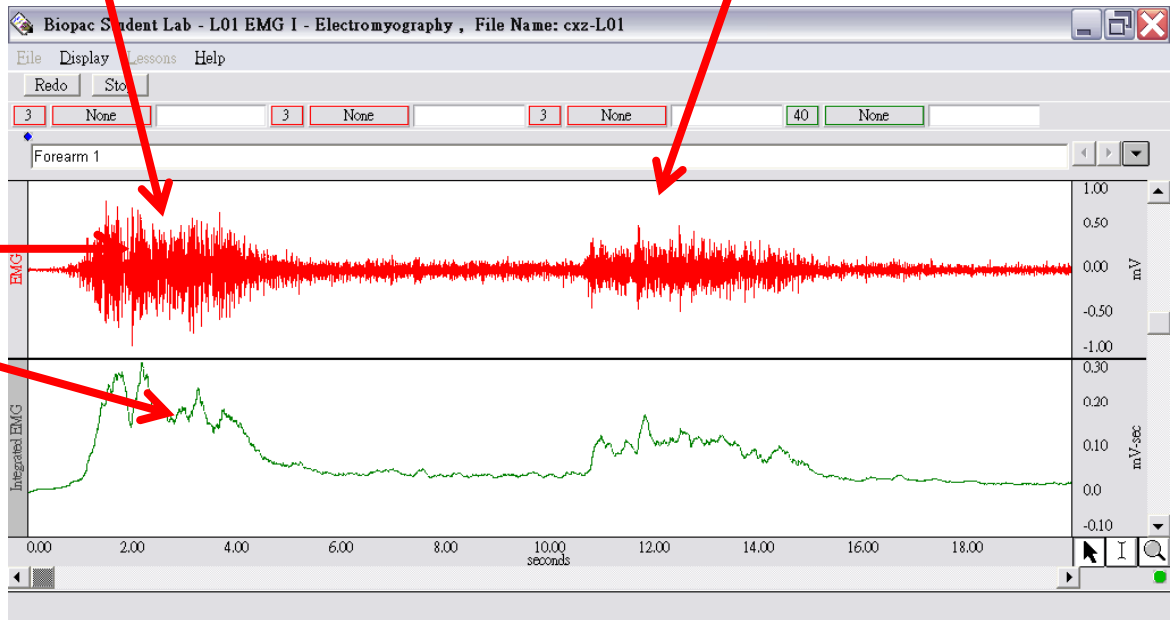


手使力彎曲

手用力放下

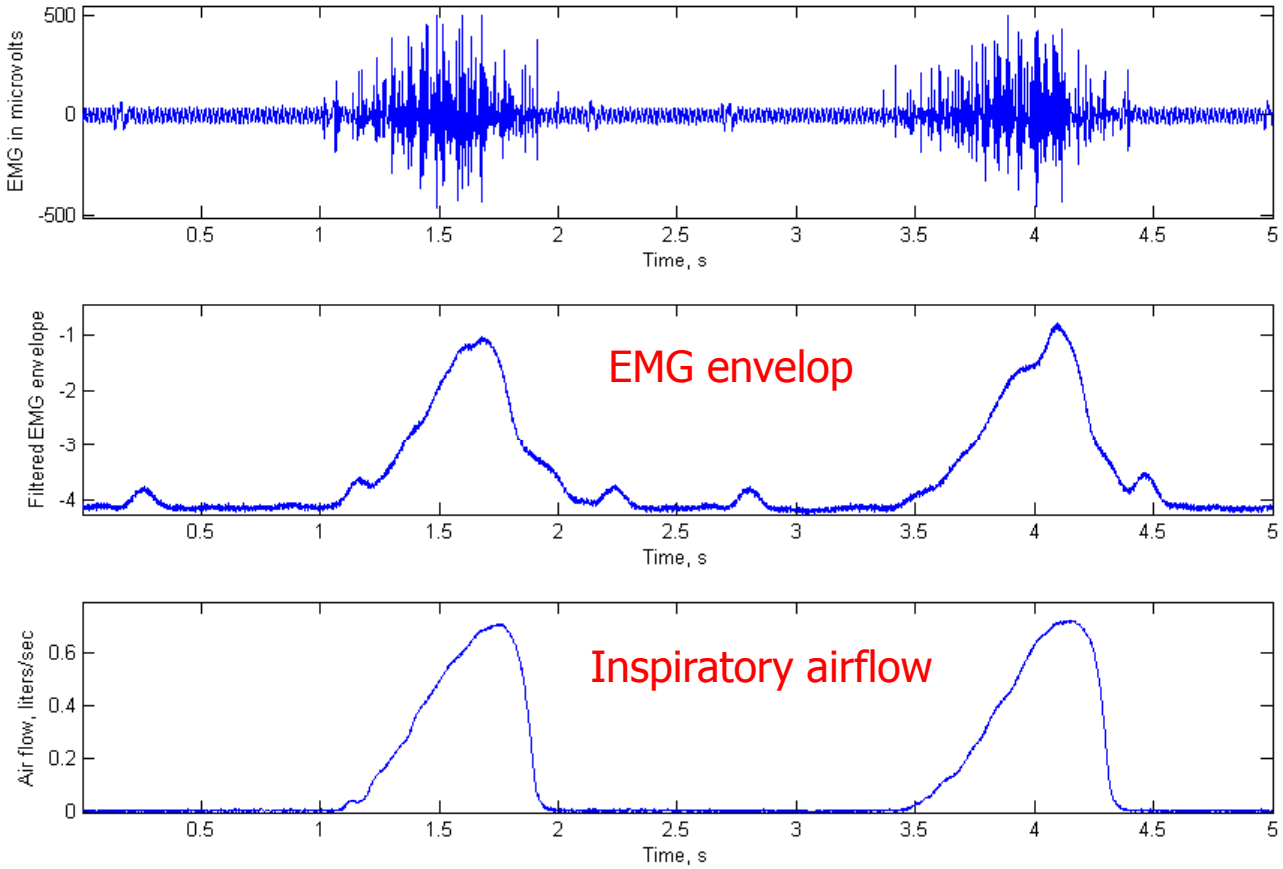
Original EMG

Integrated EMG

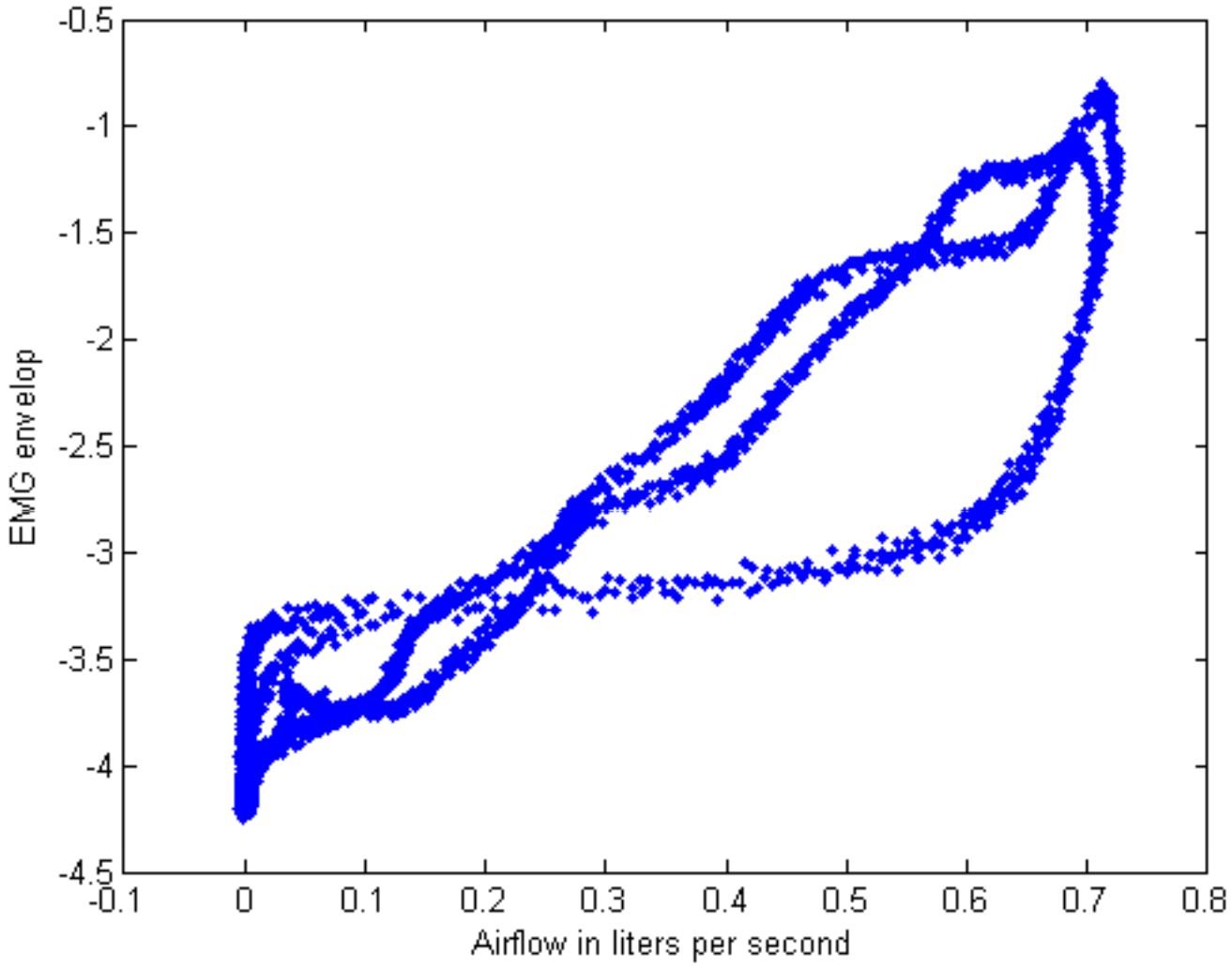


Analysis of EMG activity

EMG over two breath cycles from paraternal intercostal muscle of a dog



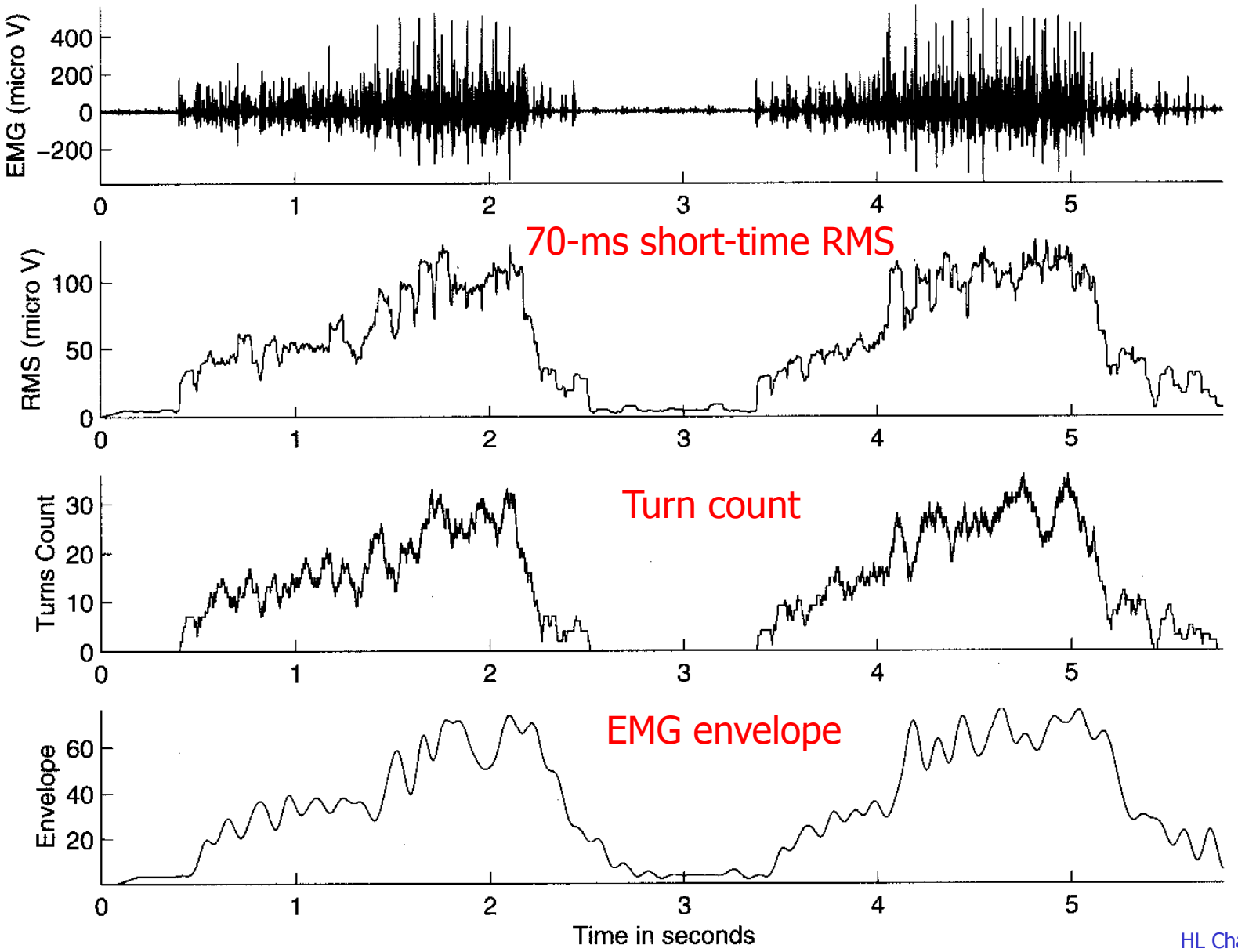
Relation between EMG activity and airflow



Methods to compute EMG envelop

- Root-mean-square (RMS) method
- Turn count
- Hilbert transform-based method
- Using a full-wave rectifier and a lowpass filter

Diaphram EMG over two breath cycles

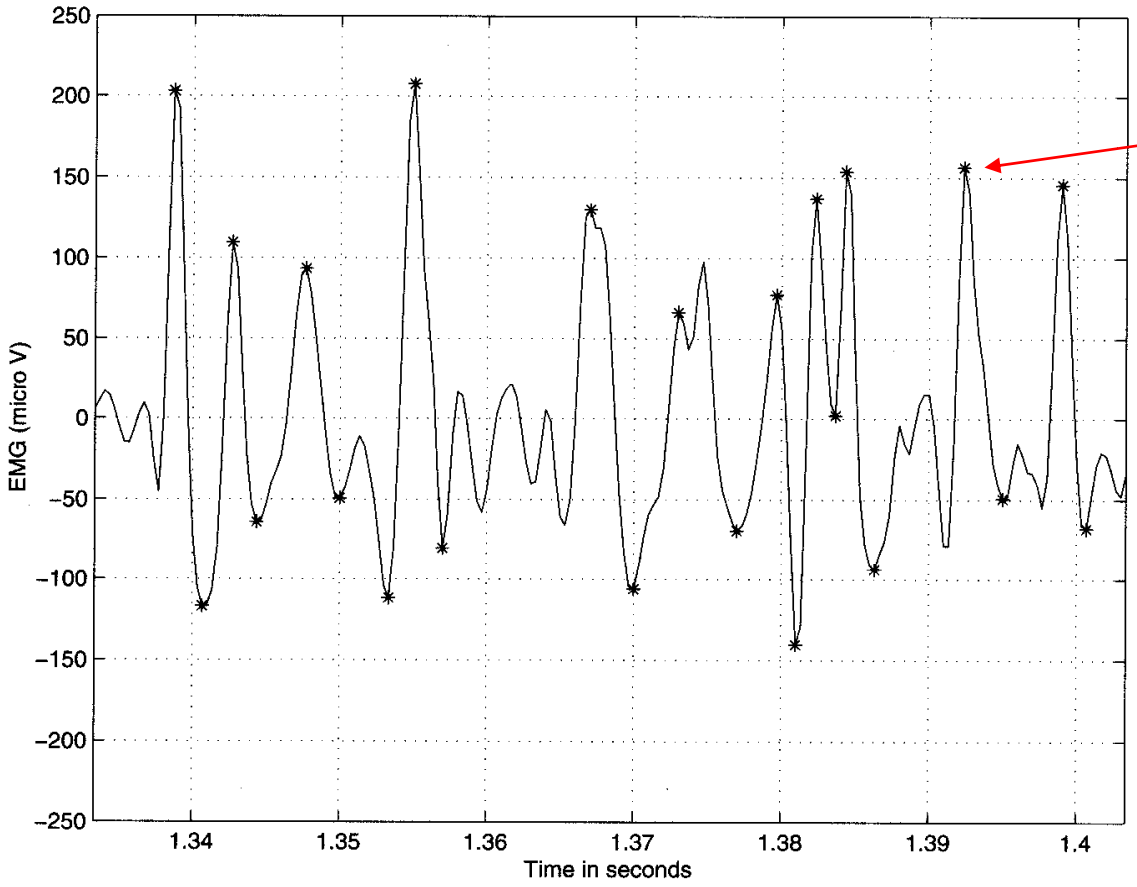


Analysis of activity by RMS

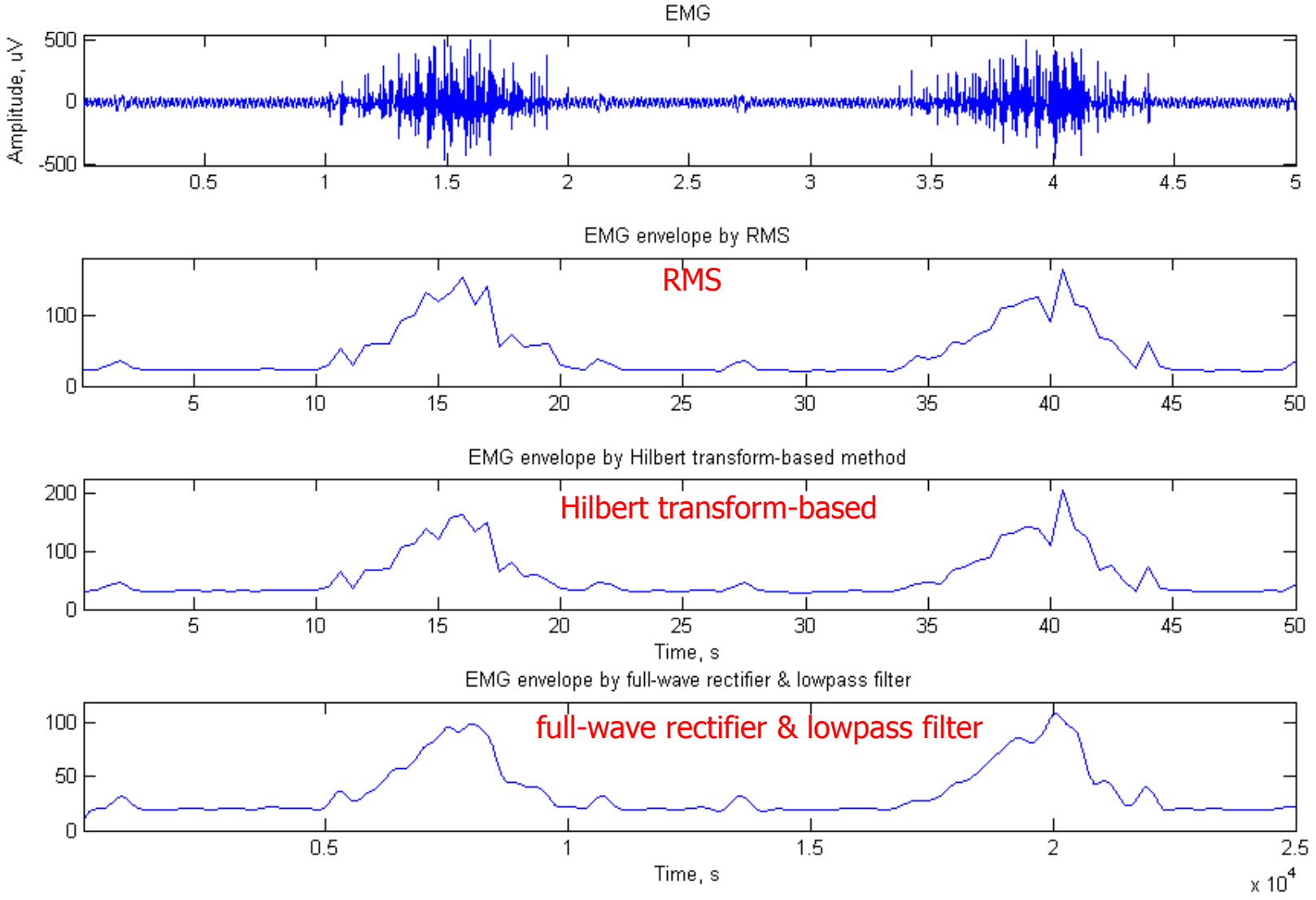
- Root mean-squared value

$$RMS(n) = \left[\frac{1}{M} \sum_{k=0}^{M-1} x^2(n-k) \right]^{1/2}$$

Turns count



*Willison define turns to have difference greater than 100μV


EMG
Amplitude, uV
500
0
-500
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
EMG envelope by RMS
RMS
100
0
5
10
15
20
25
30
35
40
45
50
EMG envelope by Hilbert transform-based method
Hilbert transform-based
200
100
0
5
10
15
20
25
30
35
40
45
50
Time, s
EMG envelope by full-wave rectifier & lowpass filter
full-wave rectifier & lowpass filter
100
50
0
0.5
1
1.5
2
2.5
Time, s
x 10^4

Hilbert transform and analytic signal

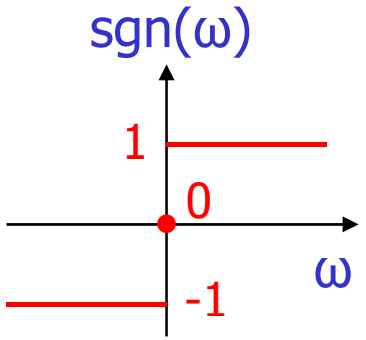
Analytic signal

$$y(t) = x(t) + jx_H(t) = |x(t)|\, e^{j\phi(t)}$$

where $x_H(t)$ is Hilbert transform of x(t)

$$x_H(t) = x(t) * \frac{1}{\pi t} = \int_{-\infty}^{\infty} \frac{x(\tau)}{\pi(t-\tau)} d\tau$$

$$Y(\omega) = X(\omega) + X(\omega)\,\mathrm{sgn}(\omega)$$

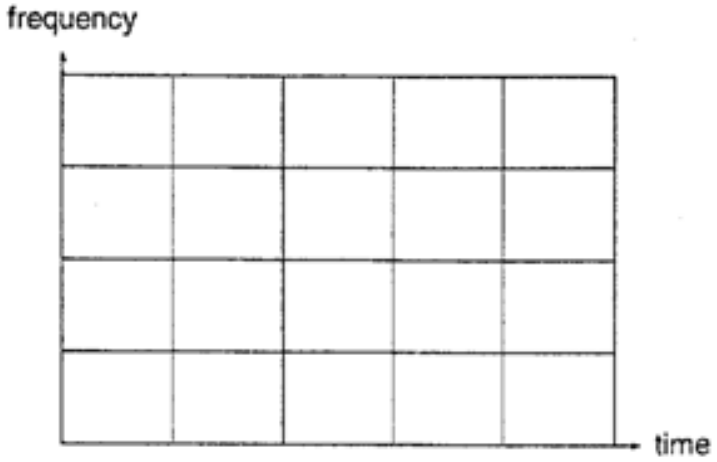


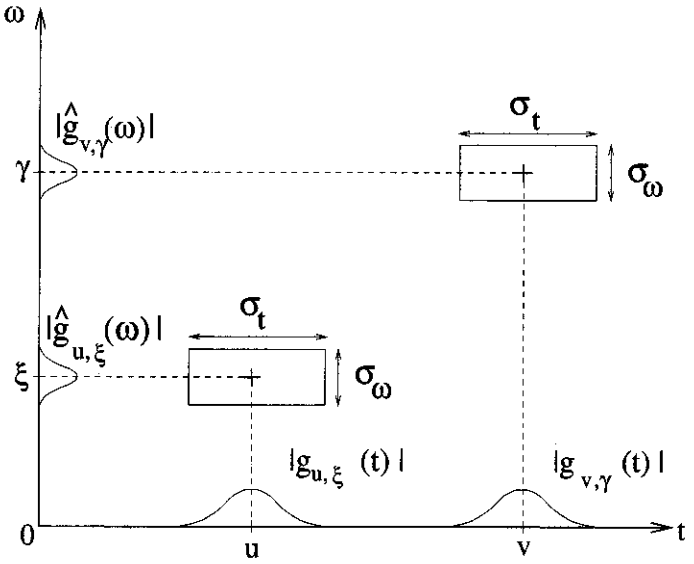
Y(ω) Contain only positive frequency components

Short-time Fourier transform (spectrogram)

- Compute time-varying spectra
- Time-frequency distribution
- Tradeoff between time resolution and frequency resolution
  - Uncertainty principle (Heisenberg inequality)

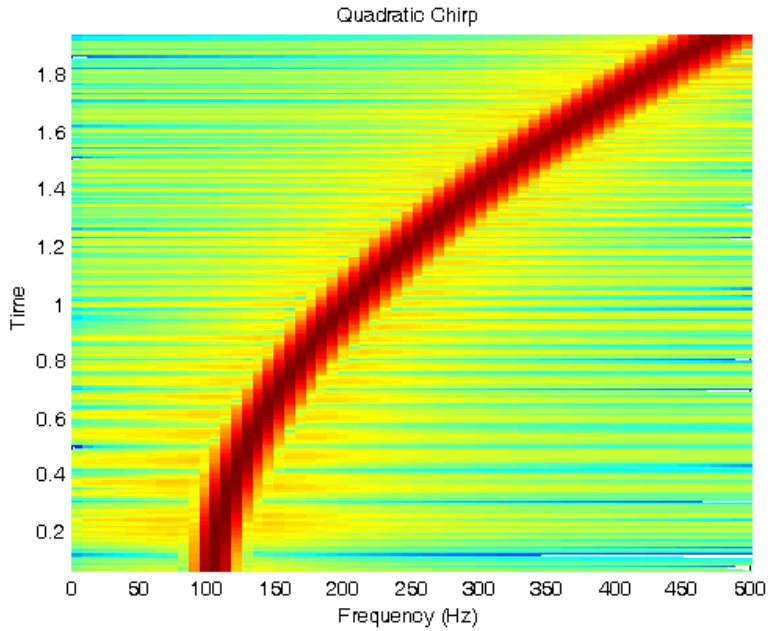
$$Time - Bandwidth\ product = \Delta t\ \Delta f \geq \frac{1}{4\pi}$$





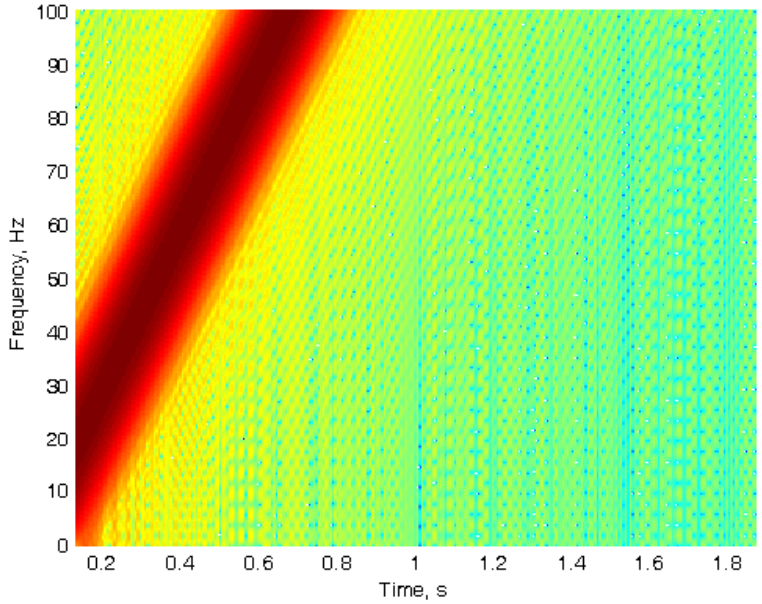
Spectrogram of chirp signal

```
T = 0:0.001:2;
X = chirp(T,100,1,200,'q');
spectrogram(X,128,120,128,1E3);
title('Quadratic Chirp');
```



Spectrogram of chirp signal (cont.)

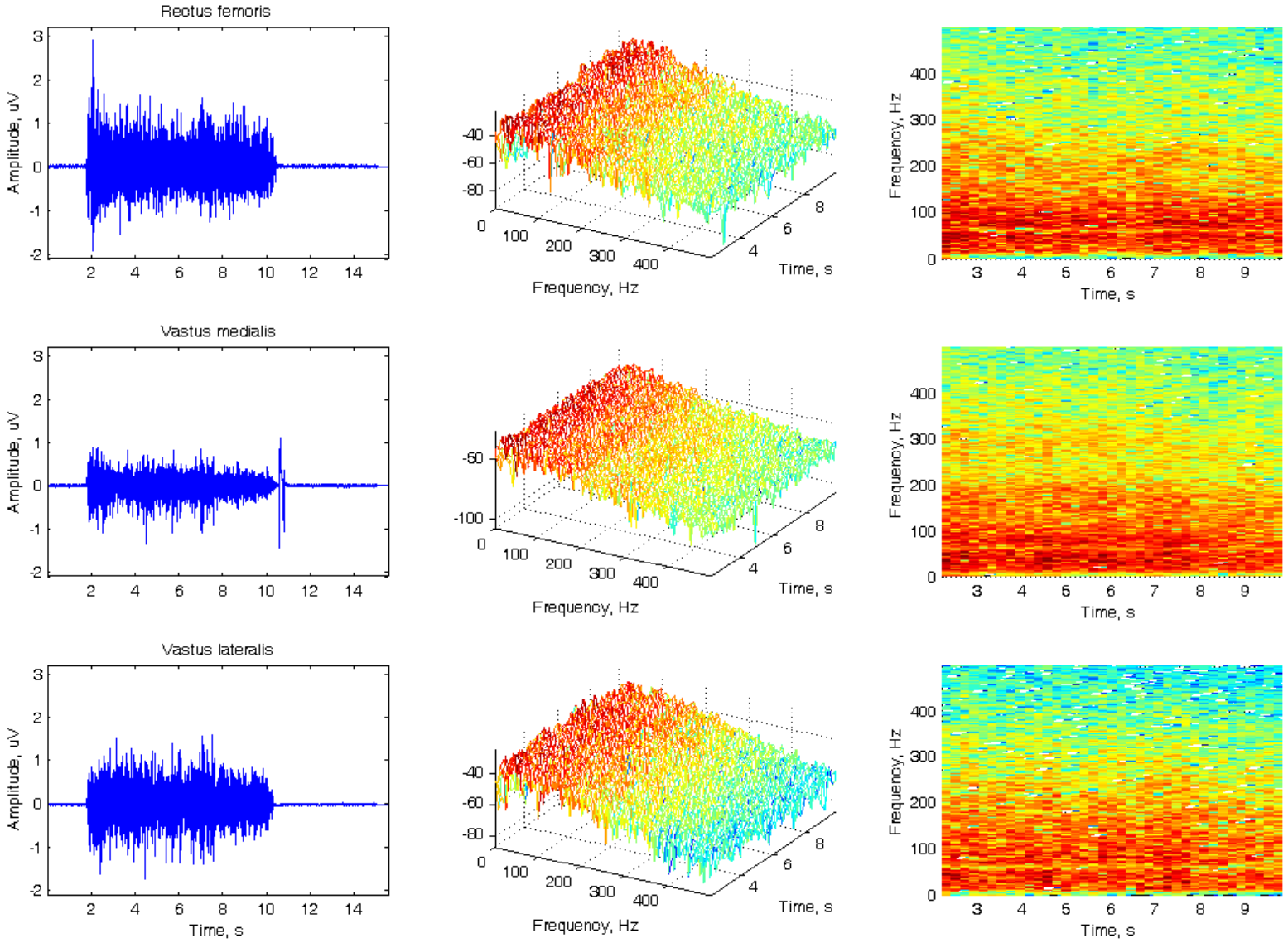
```
T = 0:0.001:2;
X = chirp(T,0,1,150);
F = 0:.1:100;
[Y,F,T,P] = spectrogram(X,256,250,F,1E3,'yaxis');
surf(T,F,10*log10(abs(P)),'EdgeColor','none');
axis xy; axis tight; colormap(jet); view(0,90);
xlabel('Time, s');
ylabel('Frequency, Hz');
```



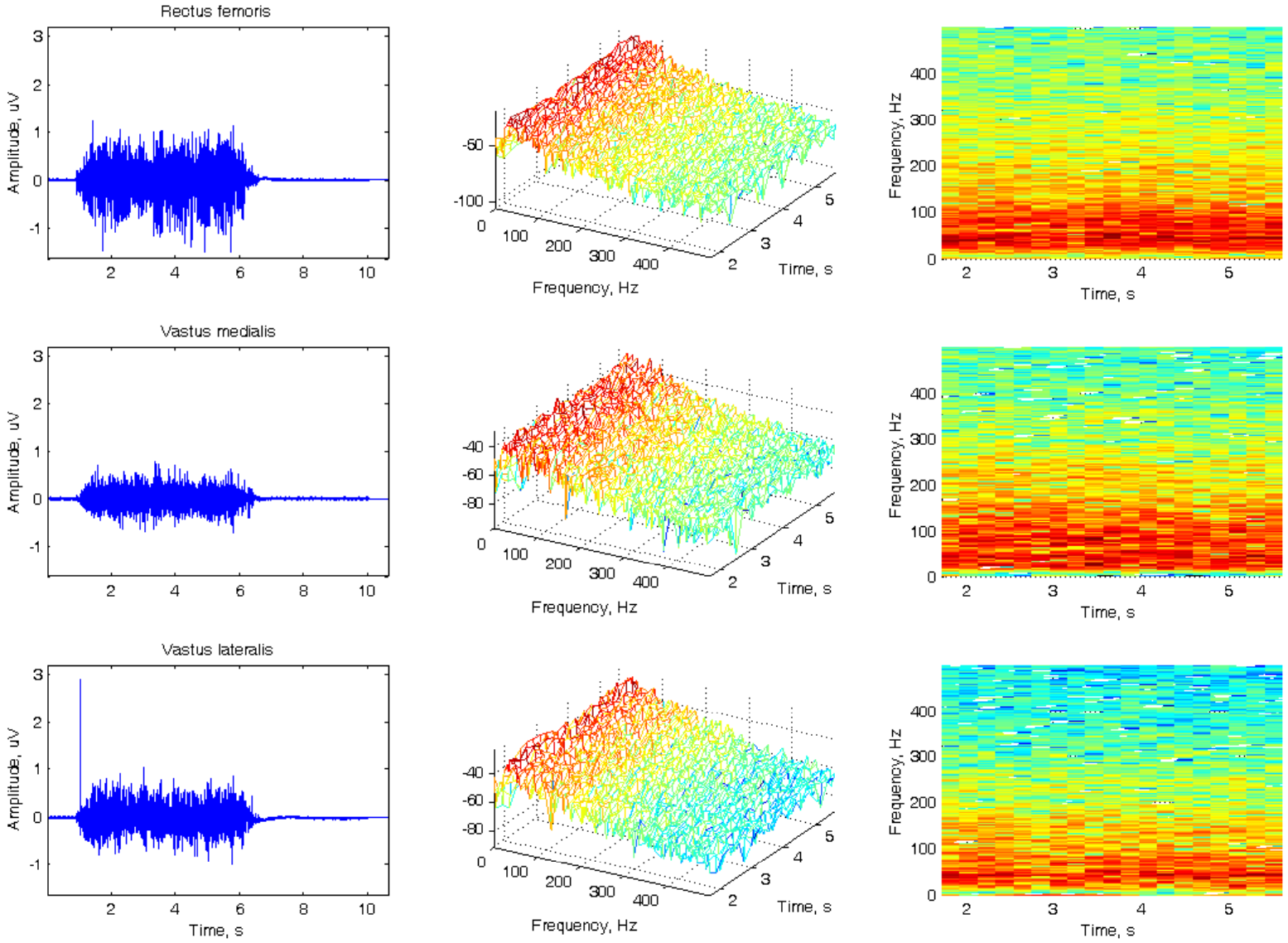
Muscle fatigue

- Nervous fatigue
  - After a period of maximum contraction, nerve's signal reduces in frequency and force generated by the contraction diminishes.
  - No sensation of pain or discomfort, muscle appears to simply 'stop listening' and gradually cease to move.
- Metabolic fatigue
  - Reduction in contractile force due to the direct or indirect effects of the reduction of substrates or accumulation of metabolites within the muscle fiber.
  - Occur through a simple lack of energy to fuel contraction, or interference with the ability of Ca^{2+} to stimulate actin and myosin to contract.

Pre-fatigue


Rectus femoris
Amplitude, uV
Frequency, Hz
Time, s
Vastus medialis
Amplitude, uV
Frequency, Hz
Time, s
Vastus lateralis
Amplitude, uV
Time, s
Frequency, Hz
Time, s
Frequency, Hz
Time, s
Frequency, Hz
Time, s

Post-fatigue



Measures derived from spectrum

- Mean frequency
  - Measurement of concentration of signal power

$$TP = \sum_{k=0}^{N/2} S_{xx}(k)$$

$$\bar{f} = \sum_{k=0}^{N/2} \left(f(k) \times \frac{S_{xx}(k)}{TP} \right)$$

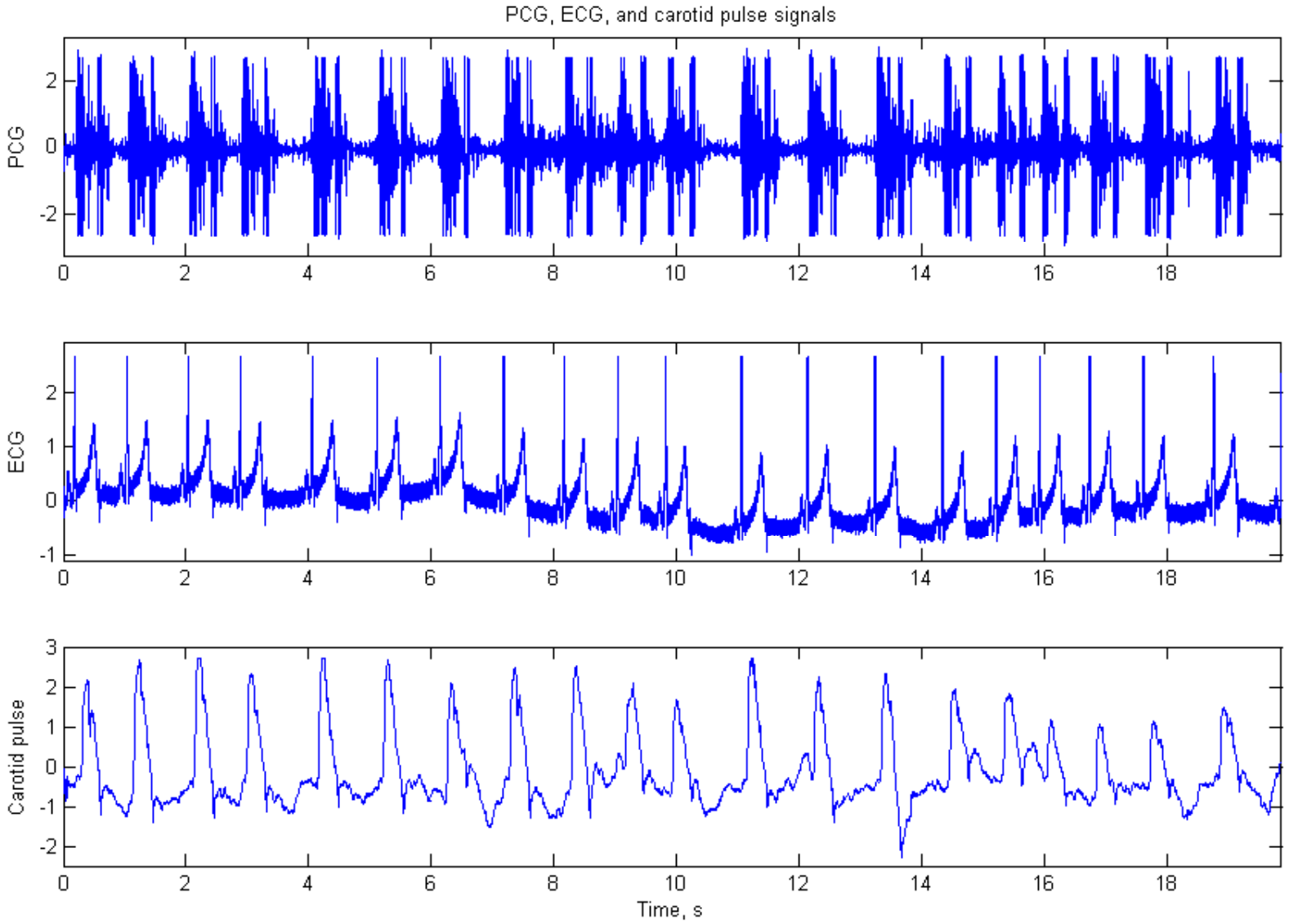
Measures derived from spectrum (cont.)

- Median frequency
  - The frequency that divides spectrum into two parts with the same total energy
- Matlab function

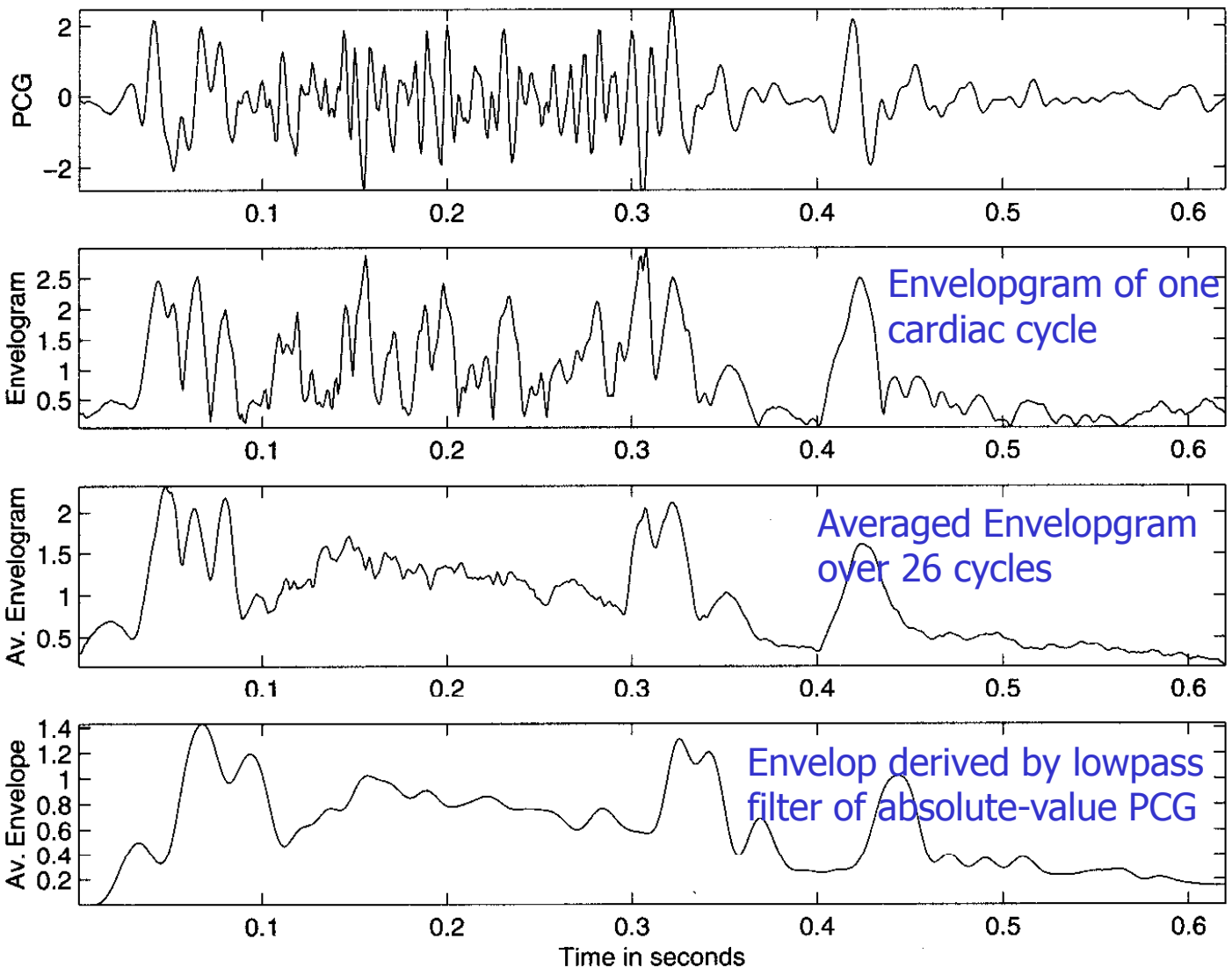
```
function [f]=medfre(Sxx,NFF,fs)
  index=1:NFFT/2;
  tp=sum(Sxx(index));
  lfp=0;
  k=0;
  while lfp<tp/2
    lfp=lfp+Sxx(k);
    k=k+1;
  end
  f=(k-1)*fs/NFFT;
```

mf=medfre(Sxx,512,5000);

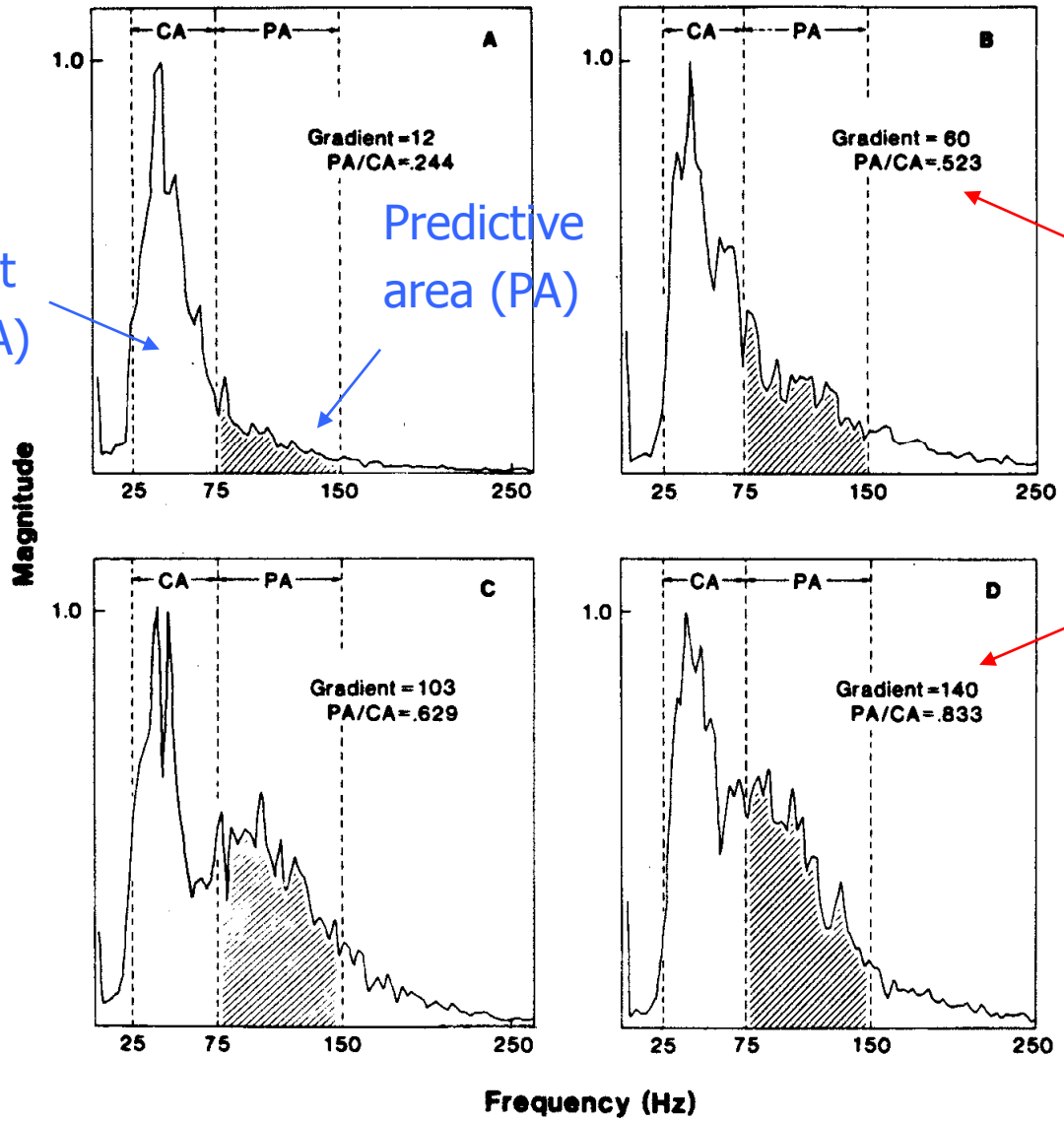
Envelope of PCG with systolic murmurs



Envelope of PCG with systolic murmurs



Spectra of systolic murmur due to aortic stenosis



Constant area (CA)

Predictive area (PA)

Spectral power ratio

Trans-valvular systolic pressure gradient

Pressure gradient

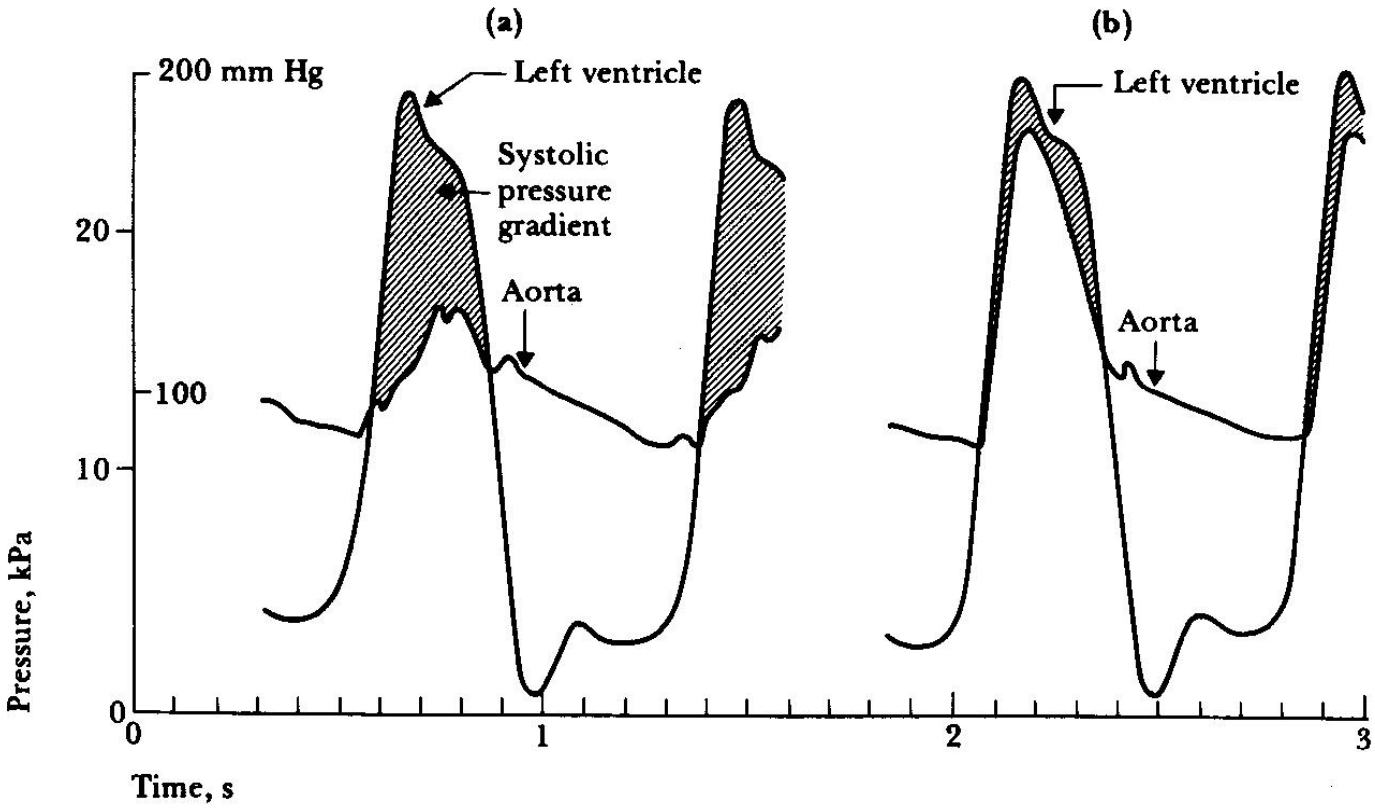
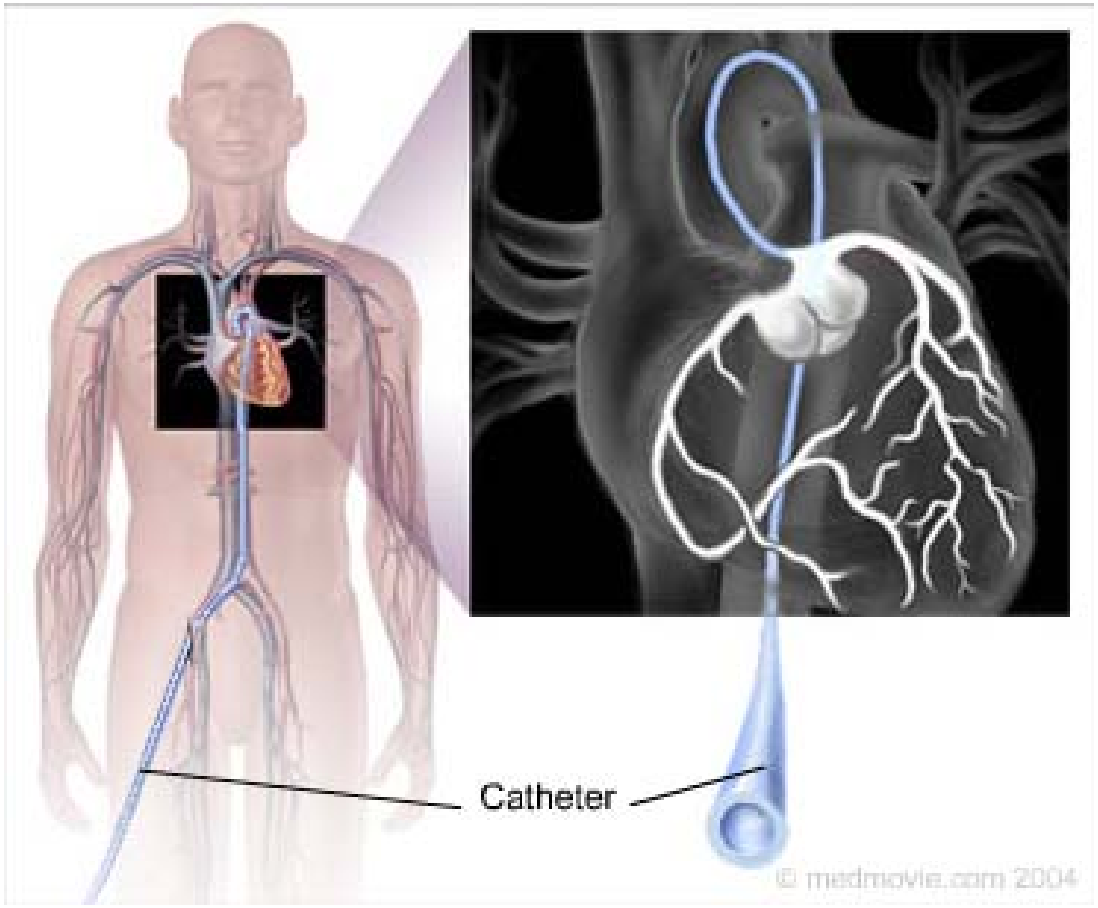
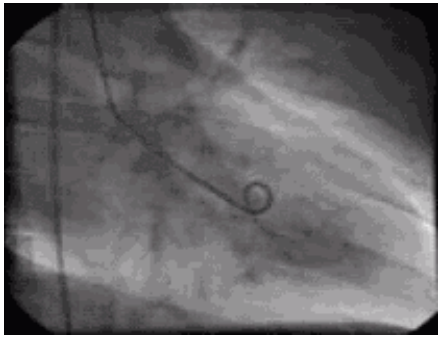
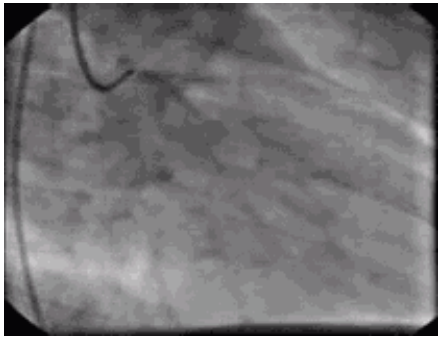


Figure 7.18 (a) Systolic pressure gradient (left ventricular-aortic pressure) across a stenotic aortic valve. (b) Marked decrease in systolic pressure gradient with insertion of an aortic ball valve.

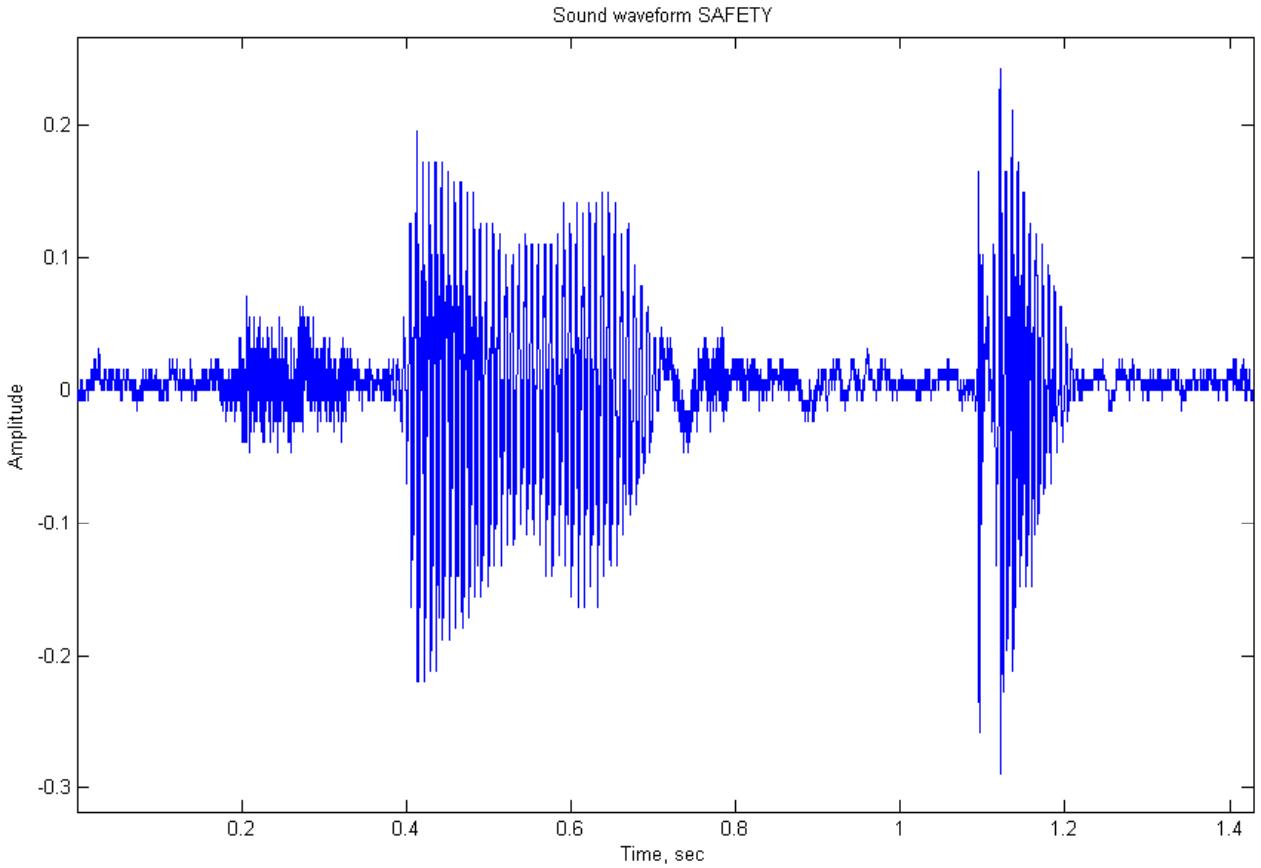
Cardiac catherterization







Speech signal



Data retrieved by safety.m

Reference

- R. Rangayyan, Biomedical Signal Analysis, John Wiely & Sons, 2002.
- John G. Webster, Medical Instrumentation, application and design, 3rd Ed., Houghton Mifflin, 2000.
- Wikipedia, the free encyclopedia