ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΕΣΣΑΛΙΑΣ
ΤΜΗΜΑ ΕΠΙΣΤΗΜΗΣ ΦΥΣΙΚΗΣ ΑΓΩΓΗΣ ΚΑΙ ΑΘΛΗΤΙΣΜΟΥ

ΕΠΕΑΕΚ

MANAGING AUTHORITY OF THE OPERATIONAL PROGRAMME EDUCATION AND INITIAL VOCATIONAL TRAINING

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Co financing
European Social Fund (E.S.F.)
European Regional Development Fund (E.R.D.F.)

MINISTRY OF NATIONAL EDUCATION AND RELIGIOUS AFFAIRS

Νέες Τεχνολογίες στην Ανάλυση της Κίνησης

Διάλεξη 5

Ηλεκτρομυογραφία

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Sampling

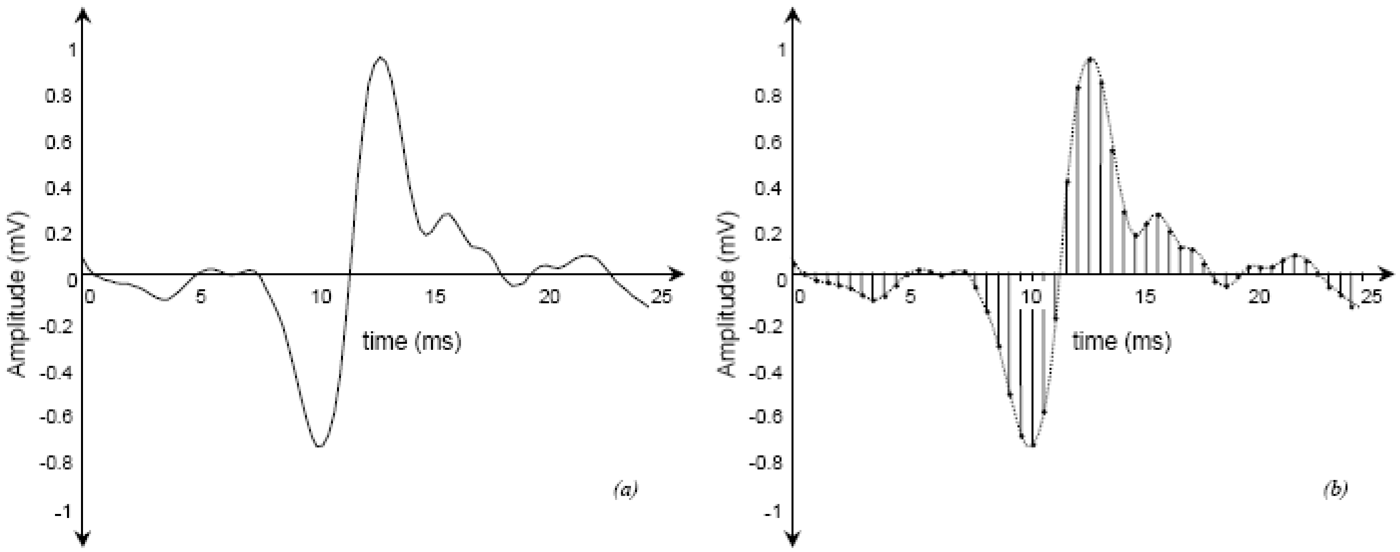


Figure 1: a) A typical analog EMG signal detected by the DE-2.1 electrode. (b) The digital sequence resulting from sampling the signal in (a), at 2 kHz (every 0.5 ms).

Sampling

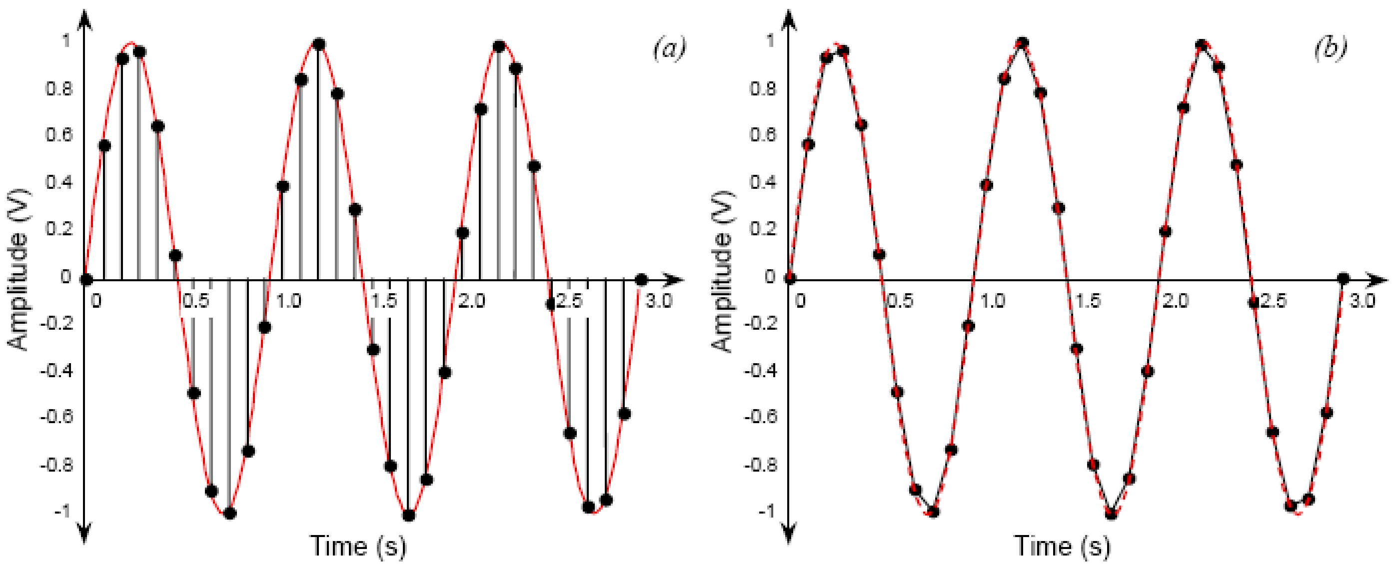


Figure 2: (a) Sampling a 1 V, 1 Hz sinusoid at 10 Hz. (b) Recreating the sinusoid sampled at 10 Hz.

Sampling

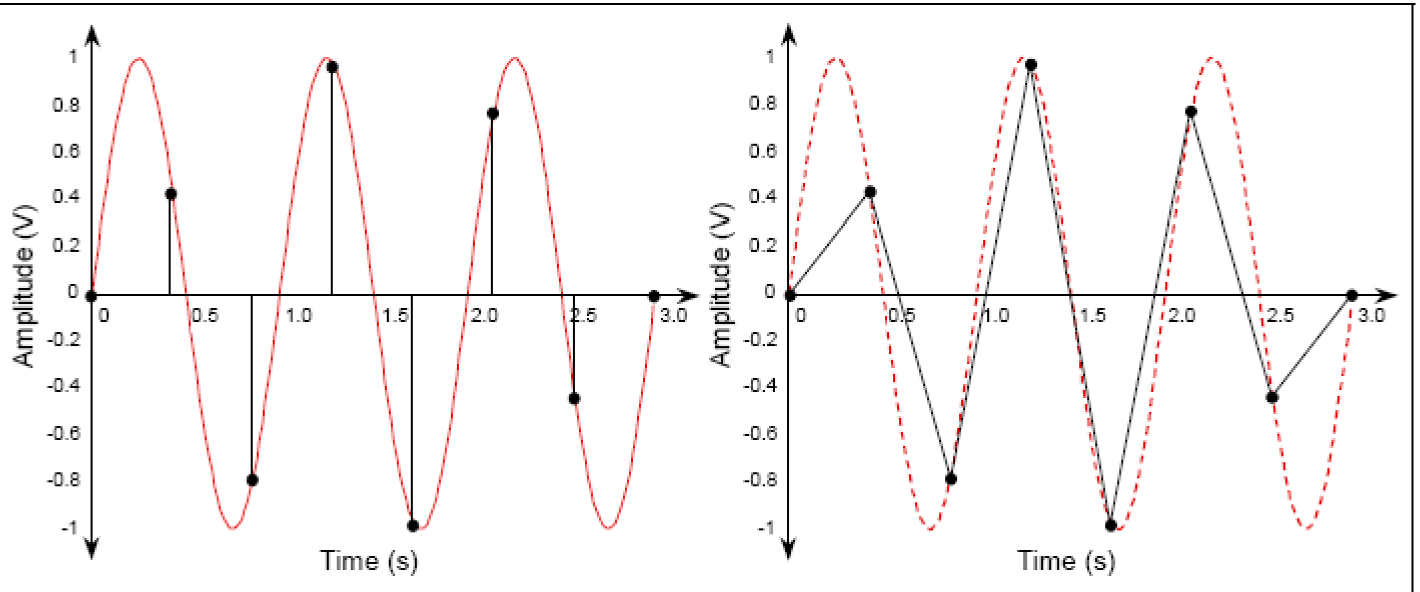


Figure 3: (a) Sampling a 1 V, 1 Hz sinusoid at approximately 2 Hz. (b) Recreating the sinusoid sampled at ~2 Hz.

Sampling

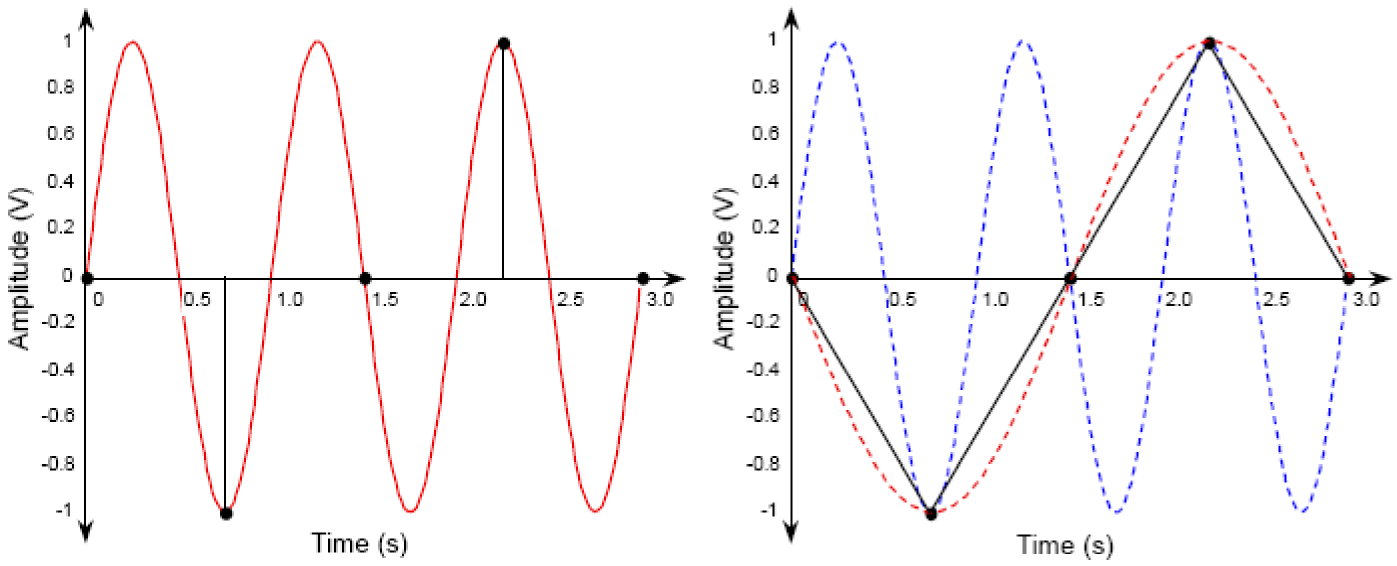


Figure 4: (a) Sampling a 1 V, 1 Hz sinusoid at 4⁄3 Hz. (b) Recreating the sinusoid sampled at 4⁄3 Hz yields the red signal at 1⁄3 Hz. The original 1 Hz signal is undersampled.

Signal Integration

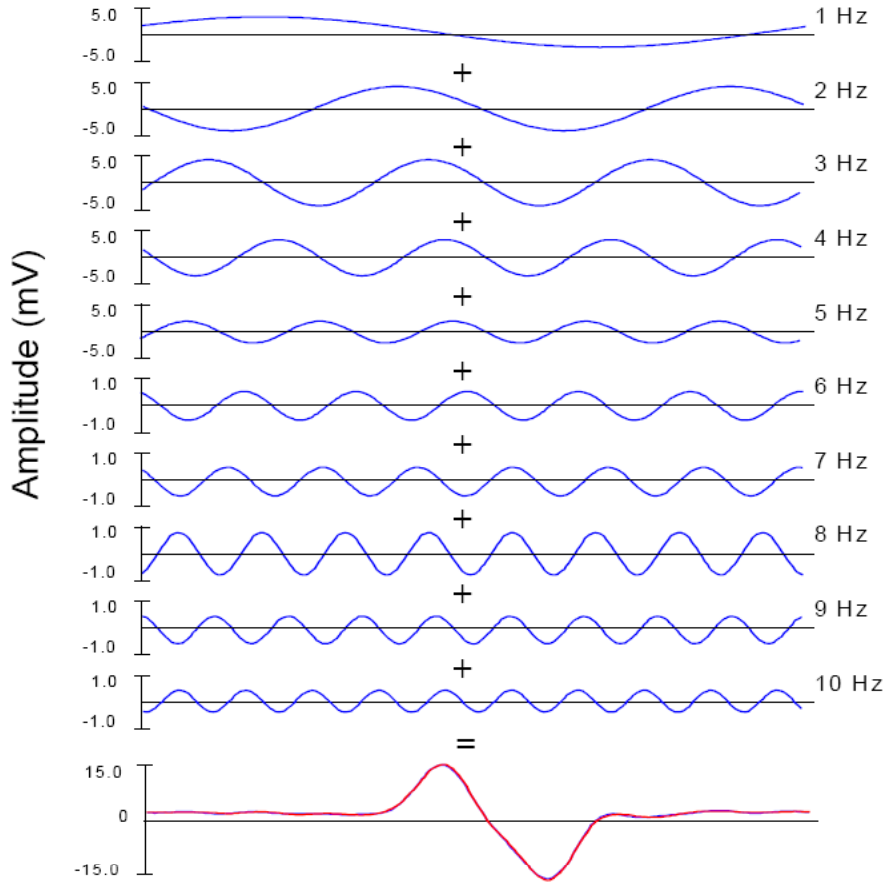
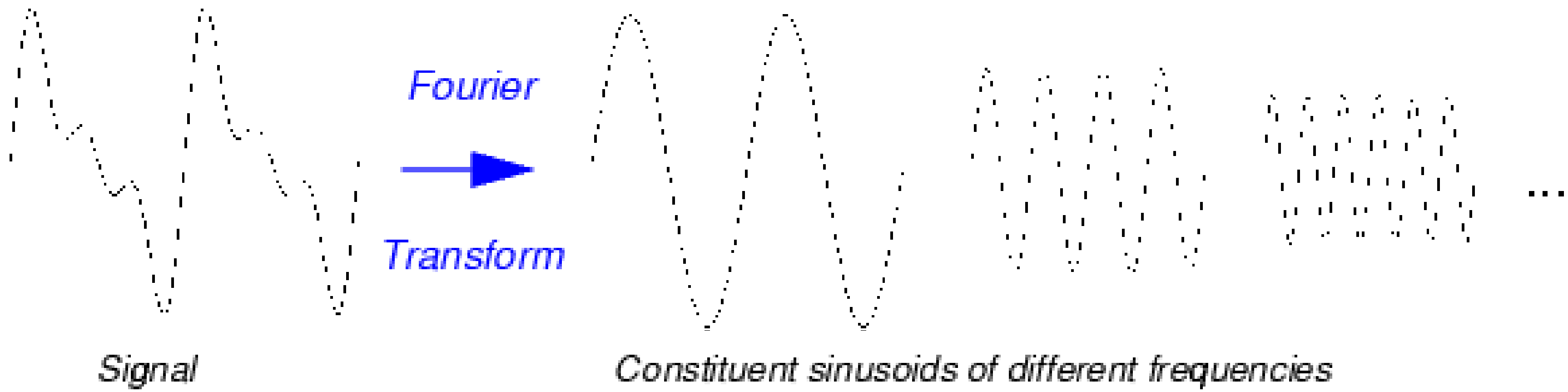


Figure 5: Fourier decomposition of a sample motor unit action potential (MUAP) recorded using a DE-2.1 electrode. The original signal is shown in red. The superposed blue signal is the mathematical summation of the 10 sinusoids above. The exact reconstruction of the red signal would require an infinite number of sinusoids, but appreciable accuracy can be achieved with only 10.

Time domain - frequency domain (Fourier Transform)

$$\text{Signal} = \sum [a\text{Sin}x + b\text{Cos}x] + c$$



Four essential components of time-varying signal

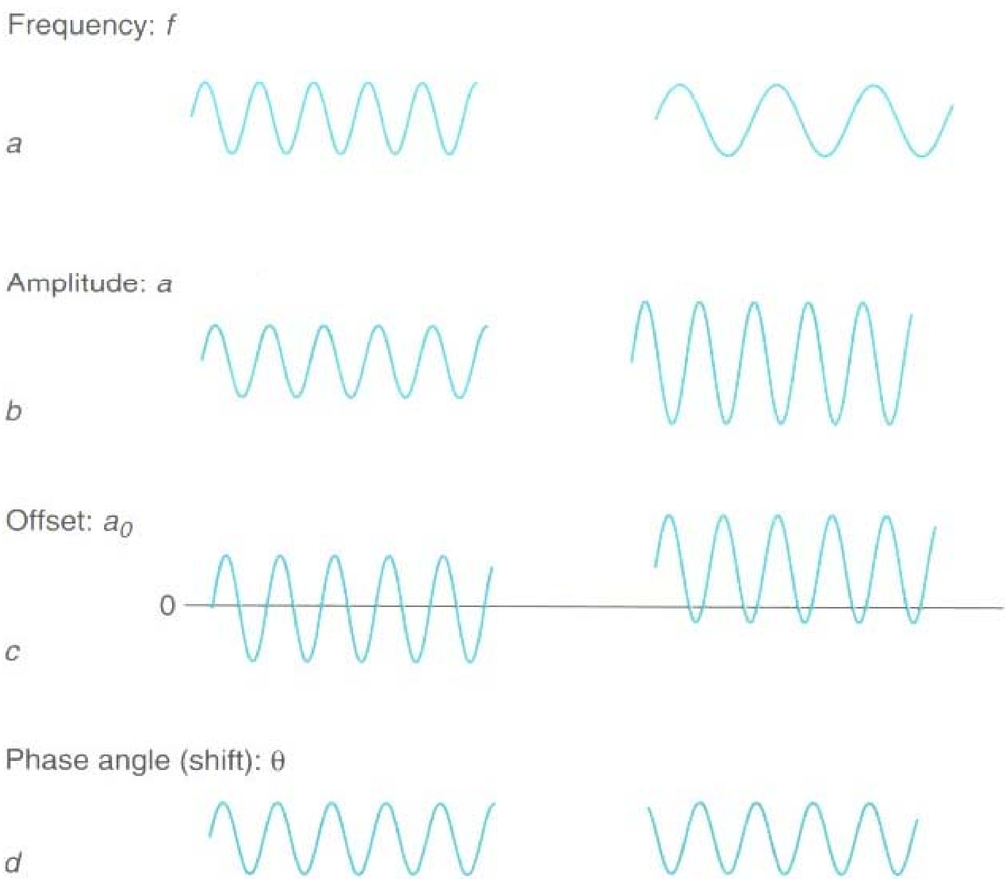
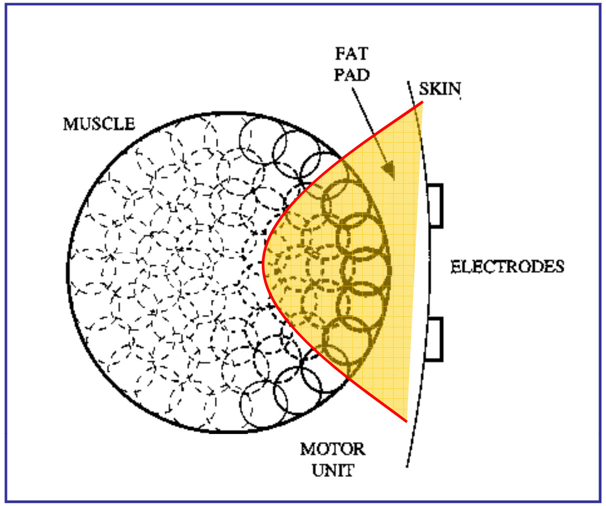
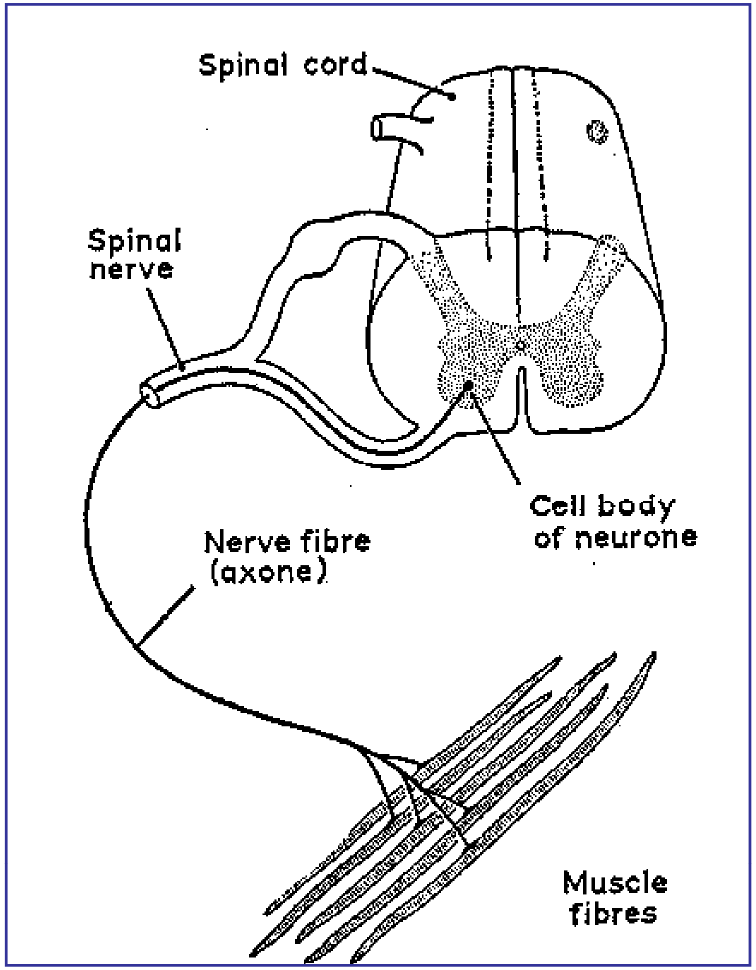


Figure 11.2 The four essential components of a time-varying signal.

Motor Units (MUs)

- Innervation ratio
  - 1:10 to 1:2000
- Neuromuscular compartments?



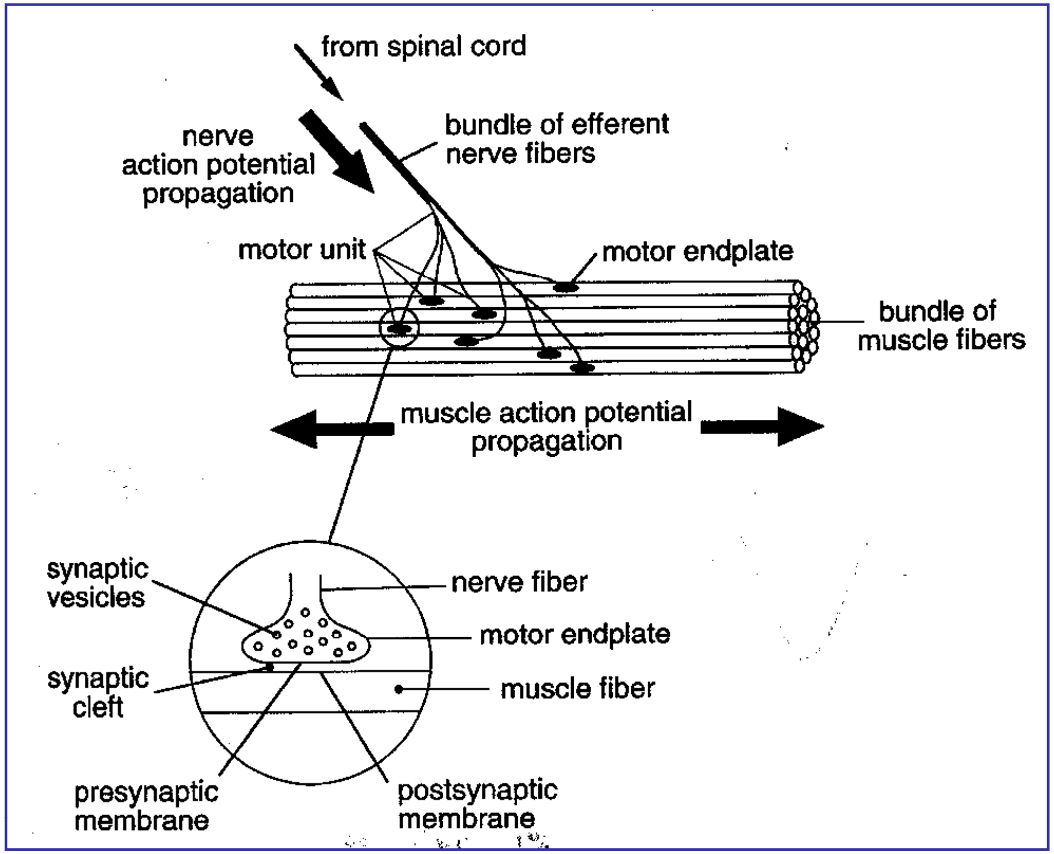


Muscle fibre action potential (MAP)

- Resting membrane potential
- Depolarisation

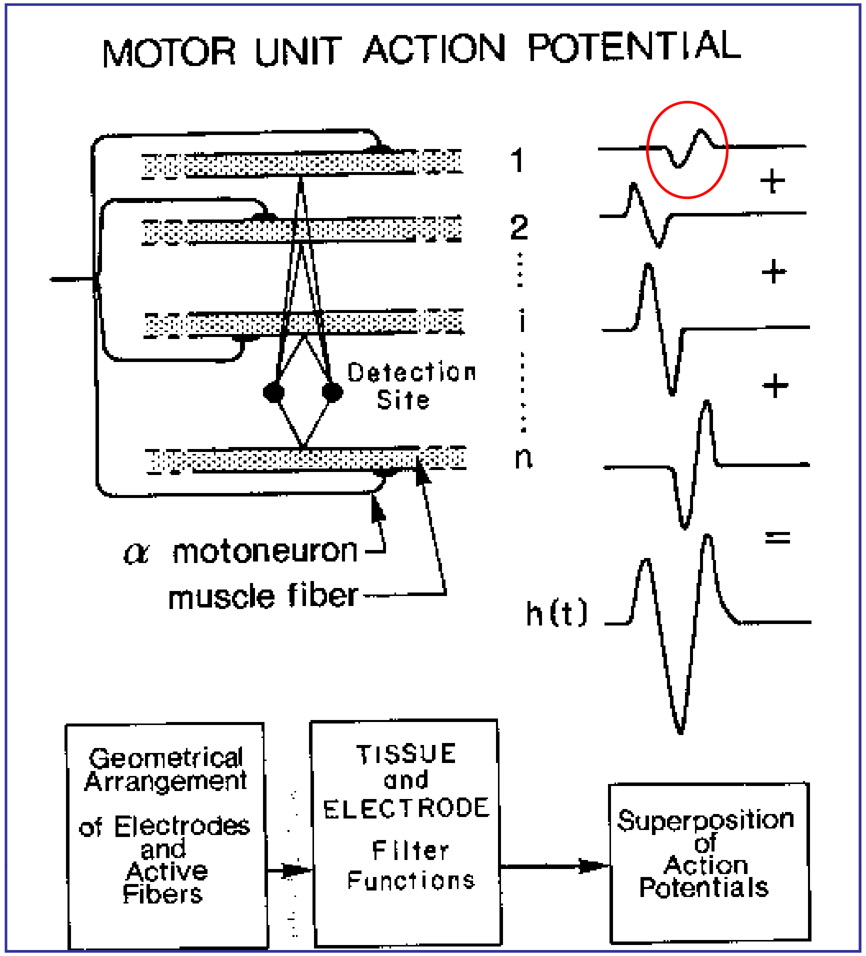
recorded

- Muscle fibre action potential (MAP)



Motor unit action potential (MUAP)

The detected waveform consisting of the spatiotemporal summation of individual MAPs from muscle fibres in the vicinity of recording electrodes

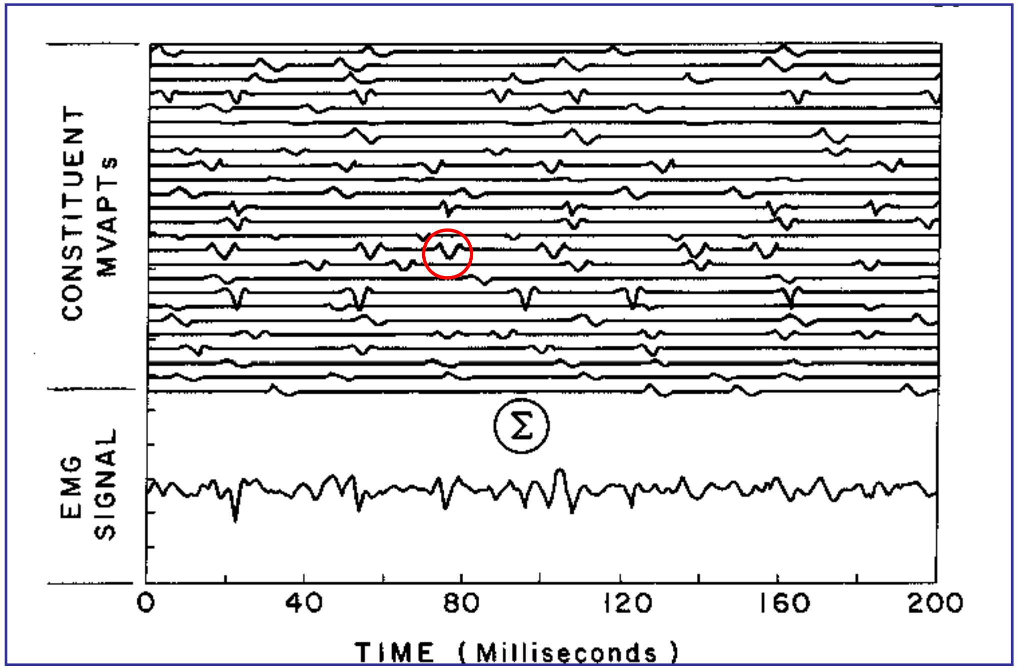


Motor unit action potential train (MUAPT)

Repetitive sequence of MUAPs from a given motor unit

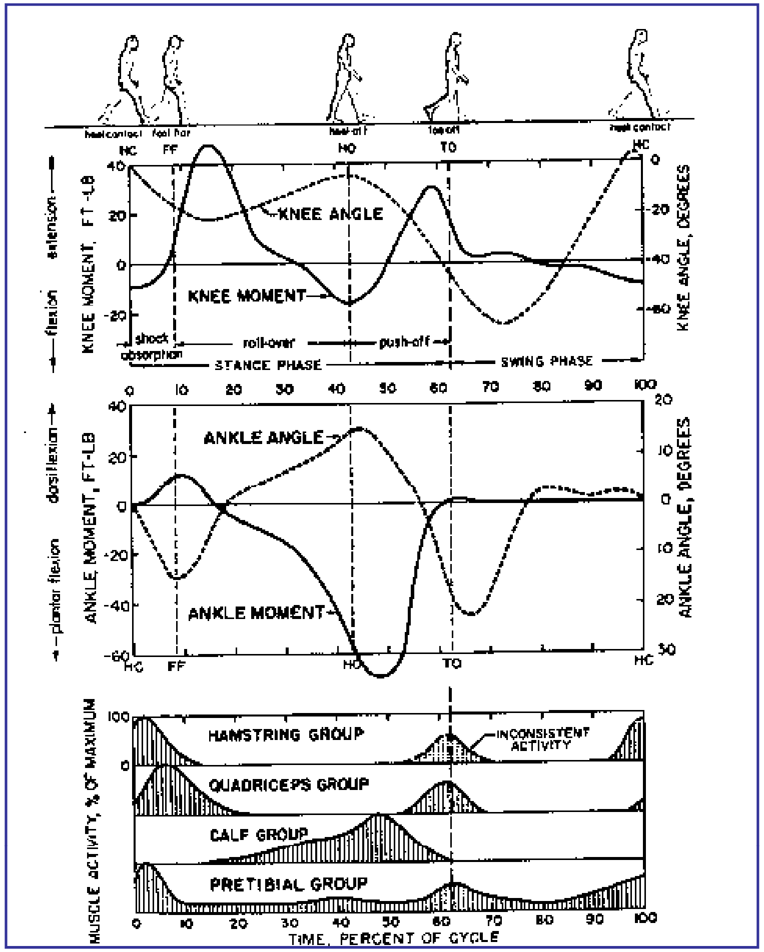
many MUs

Interference pattern (raw EMG)



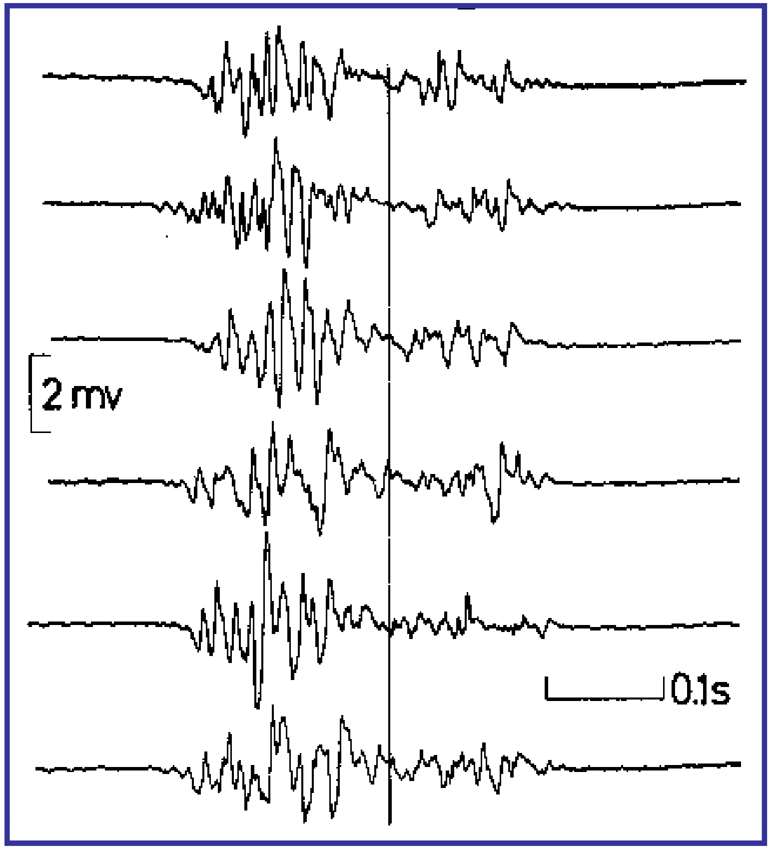
Kinesiological Electromyography

The study of muscular function and co-ordination during selected movements and postures



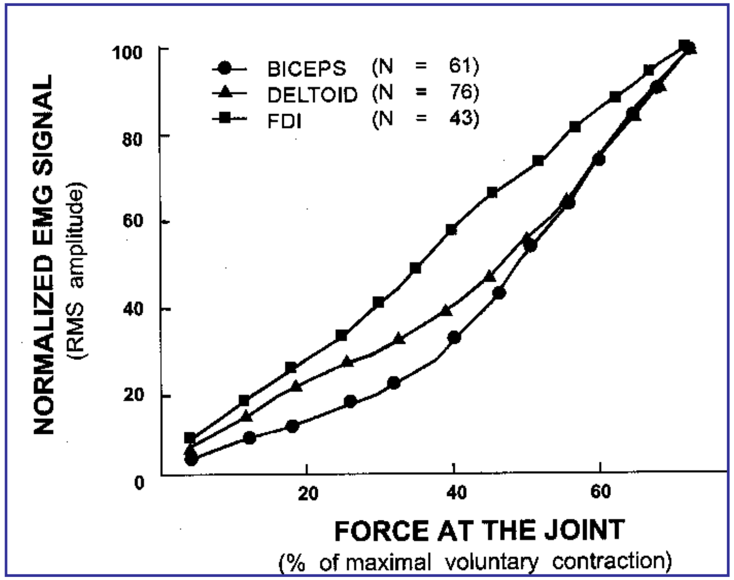
What is an Electromyogram (EMG)?

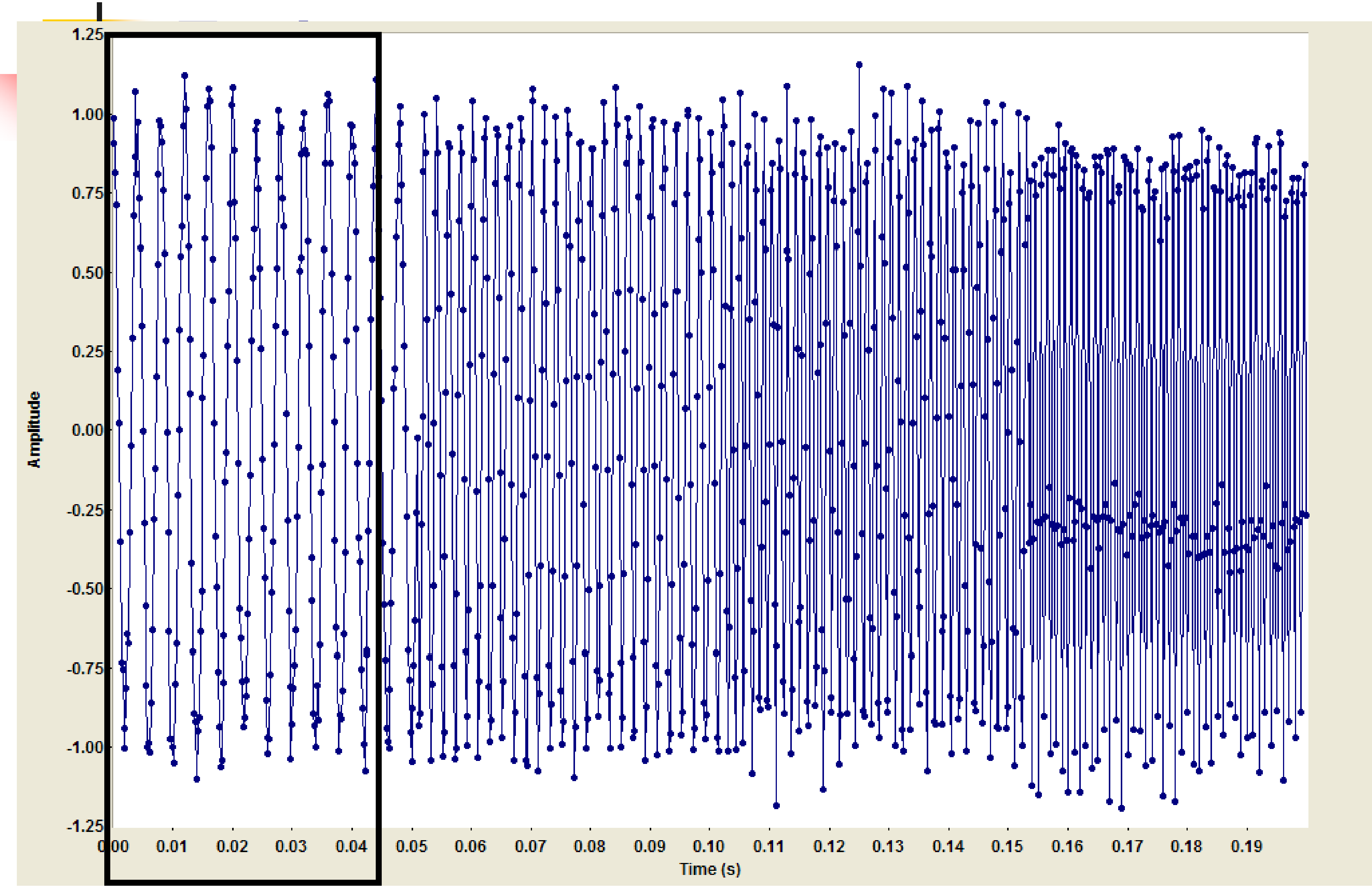
- A recording of the electrical activity associated with the contraction of skeletal muscle
  - raw EMGs usually <5 mV (peak to peak)
  - raw EMGs usually 'processed'
  - raw EMGs usually synchronised with other analysis technique(s)



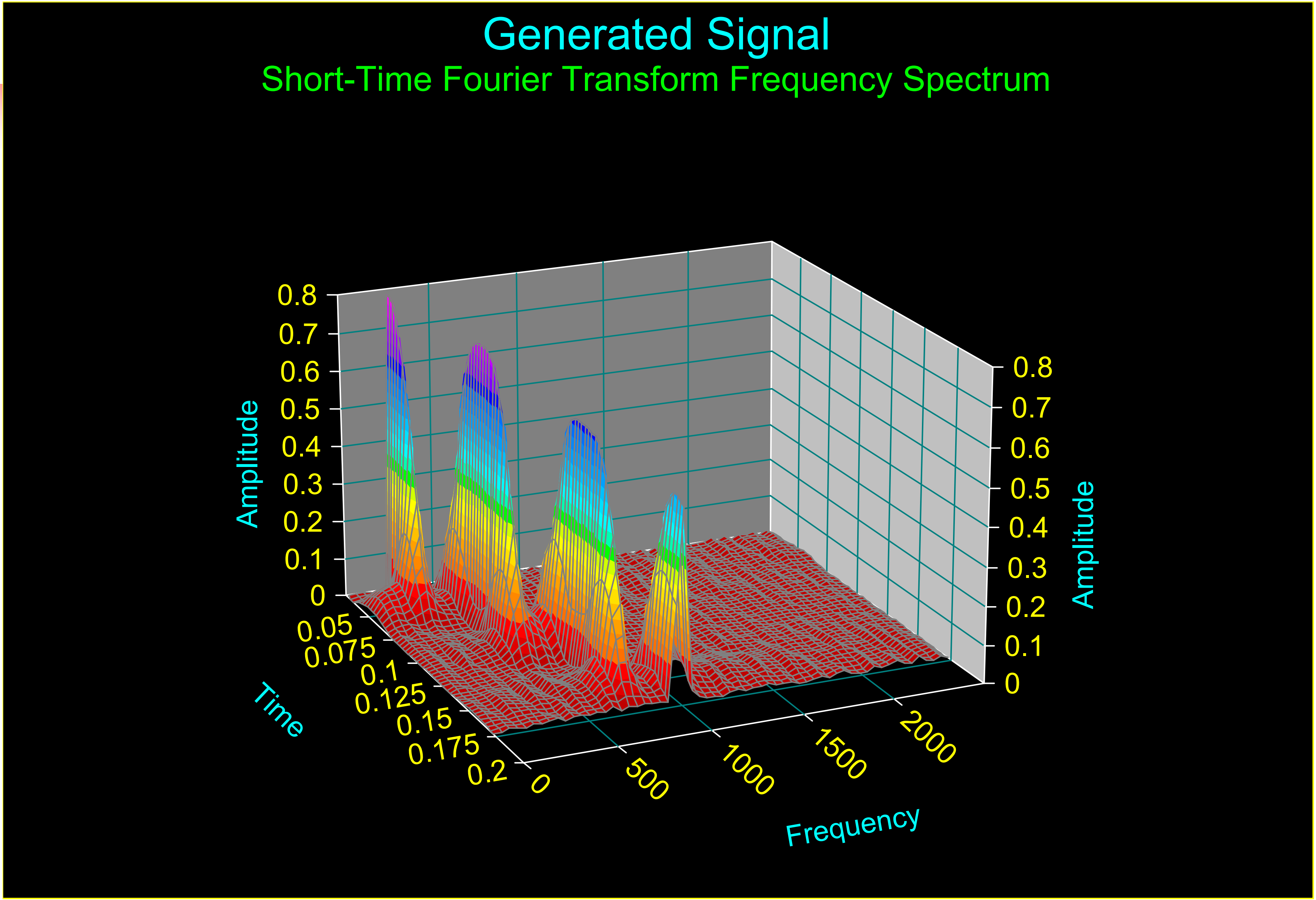
Applications of kinesiological electromyography

- Evidence of muscle activity
- Relationship with muscle force
- Indication of muscle fatigue

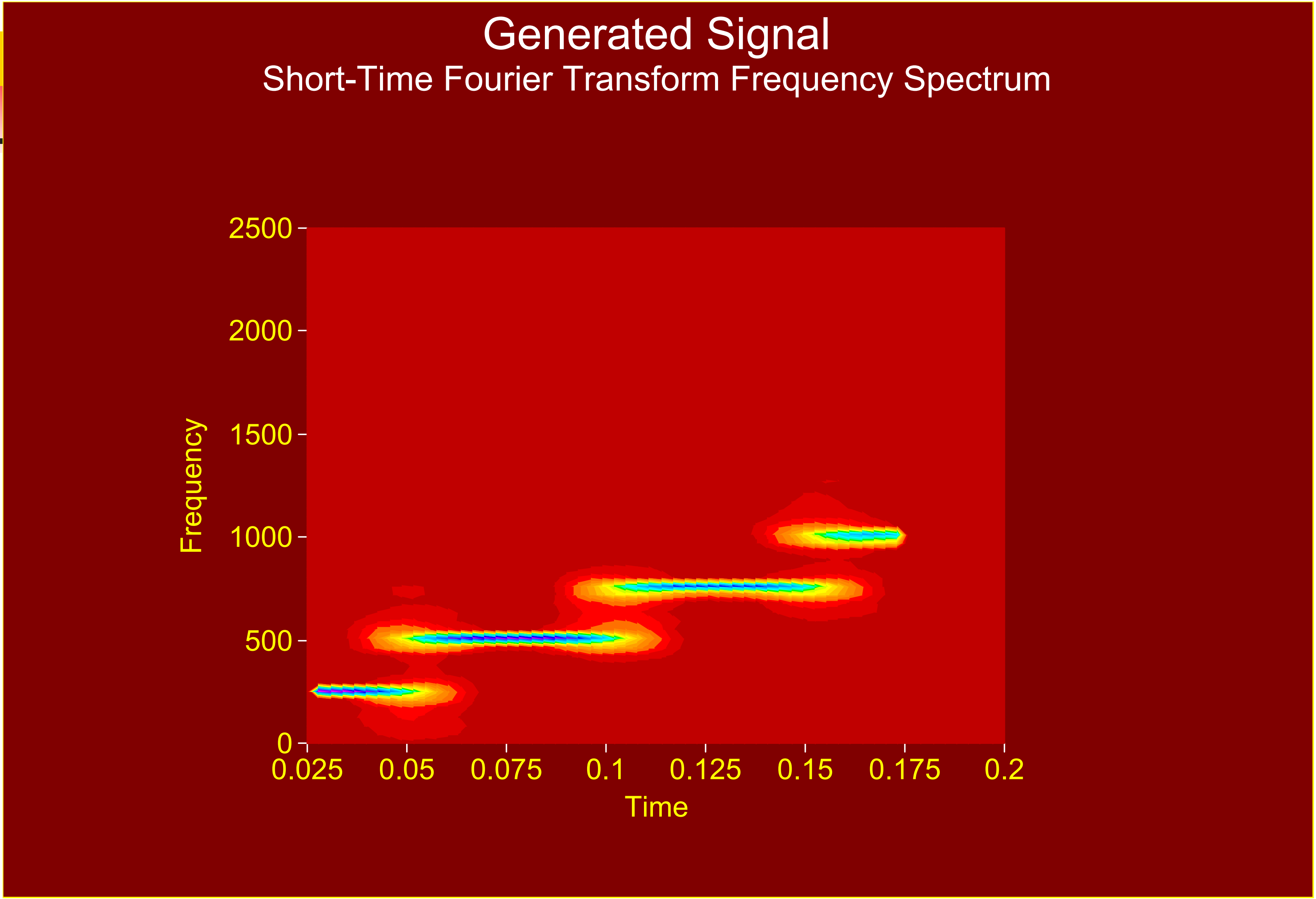


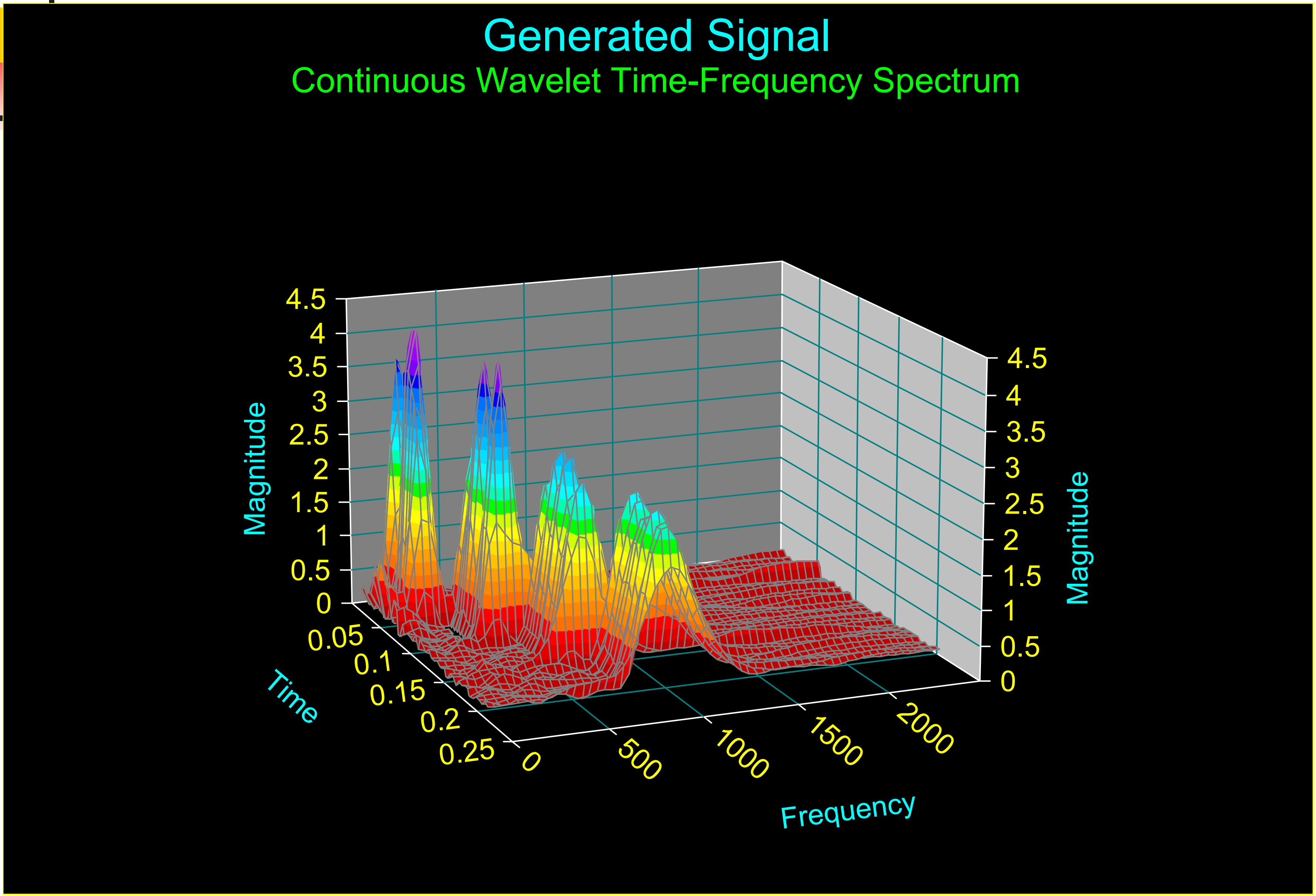


1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
Amplitude
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
0.11
0.12
0.13
0.14
0.15
0.16
0.17
0.18
0.19
Time (s)



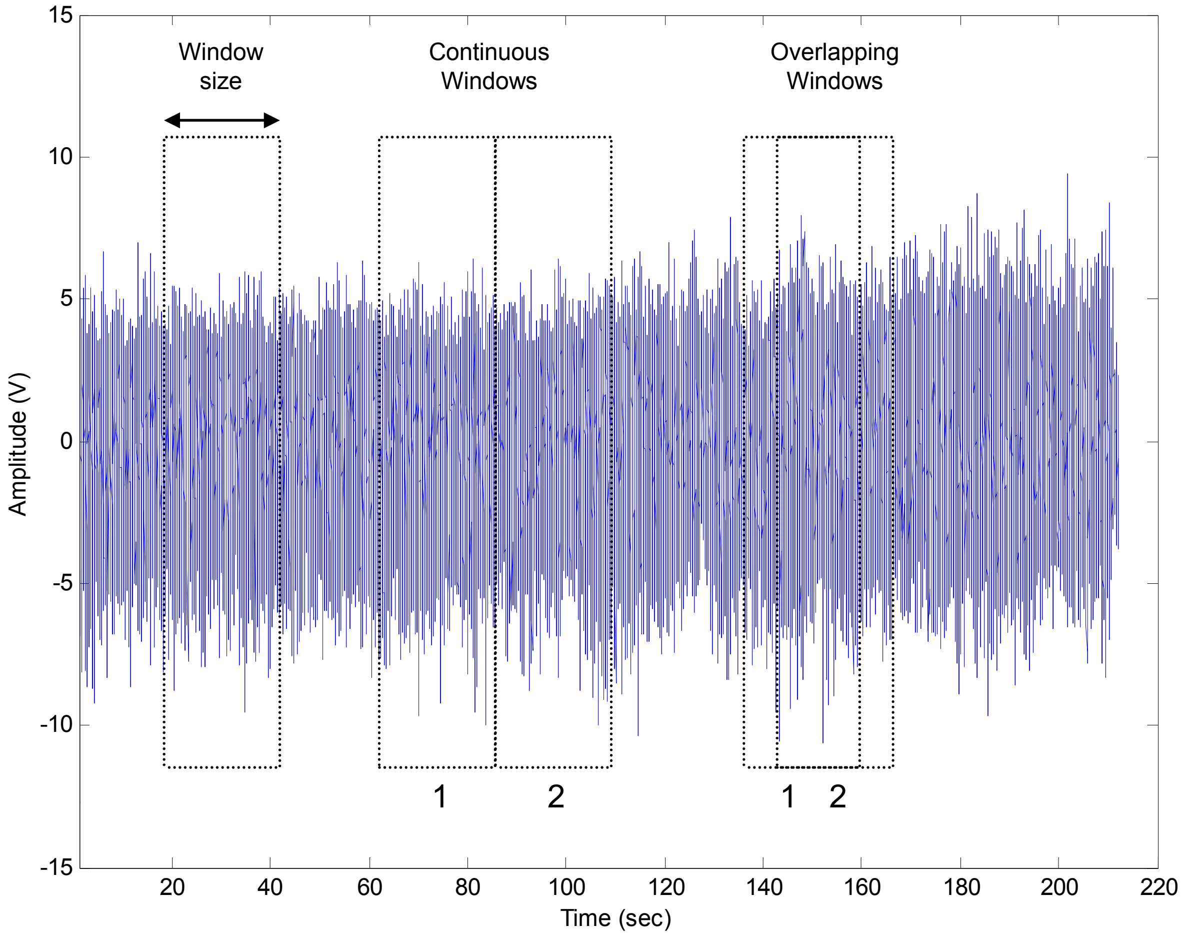
Generated Signal
Short-Time Fourier Transform Frequency Spectrum
Amplitude
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Time
0.05
0.075
0.1
0.125
0.15
0.175
0.2
Frequency
0
500
1000
1500
2000
Amplitude


Generated Signal
Short-Time Fourier Transform Frequency Spectrum
Frequency
2500
2000
1500
1000
500
0
0.025
0.05
0.075
0.1
0.125
0.15
0.175
0.2
Time

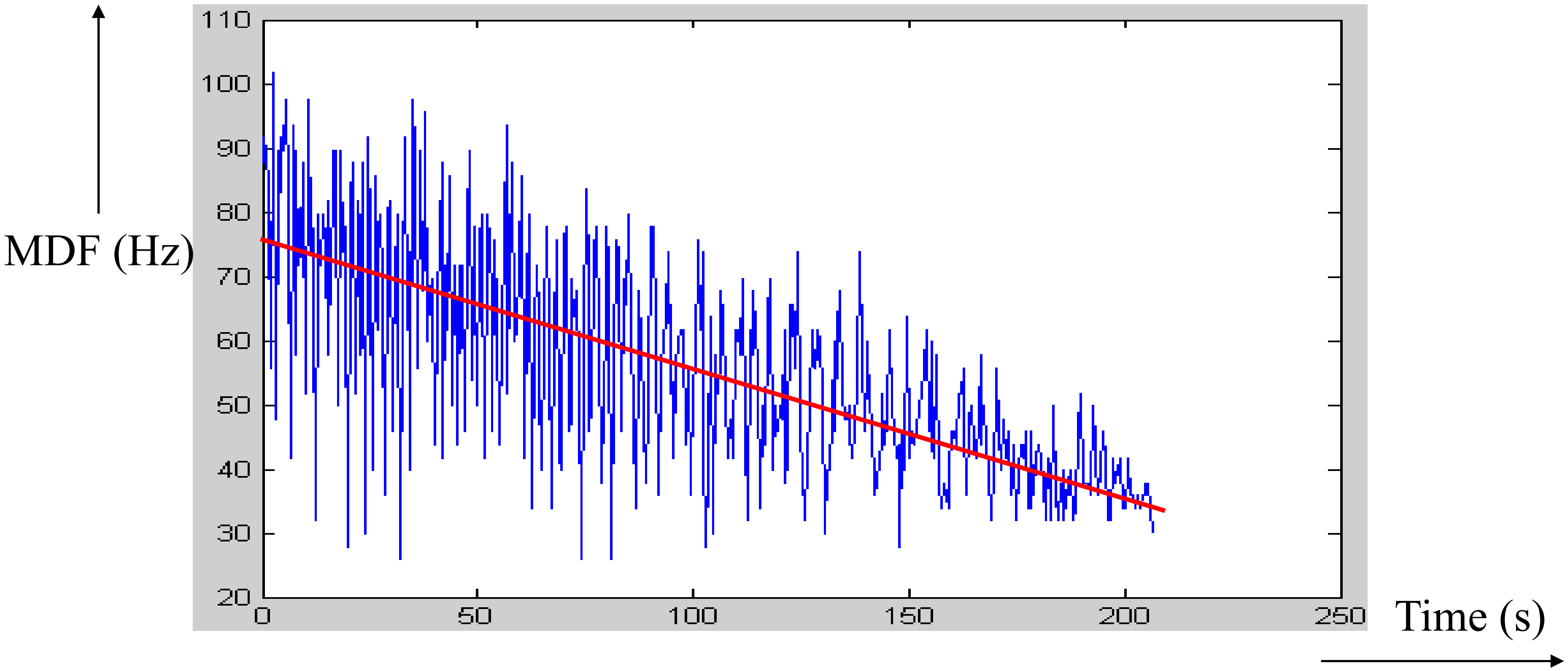


Generated Signal
Continuous Wavelet Time-Frequency Spectrum
Magnitude
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Time
0.05
0.1
0.15
0.2
0.25
Frequency
0
500
1000
1500
2000
Magnitude

Signal analysis - Fatigue

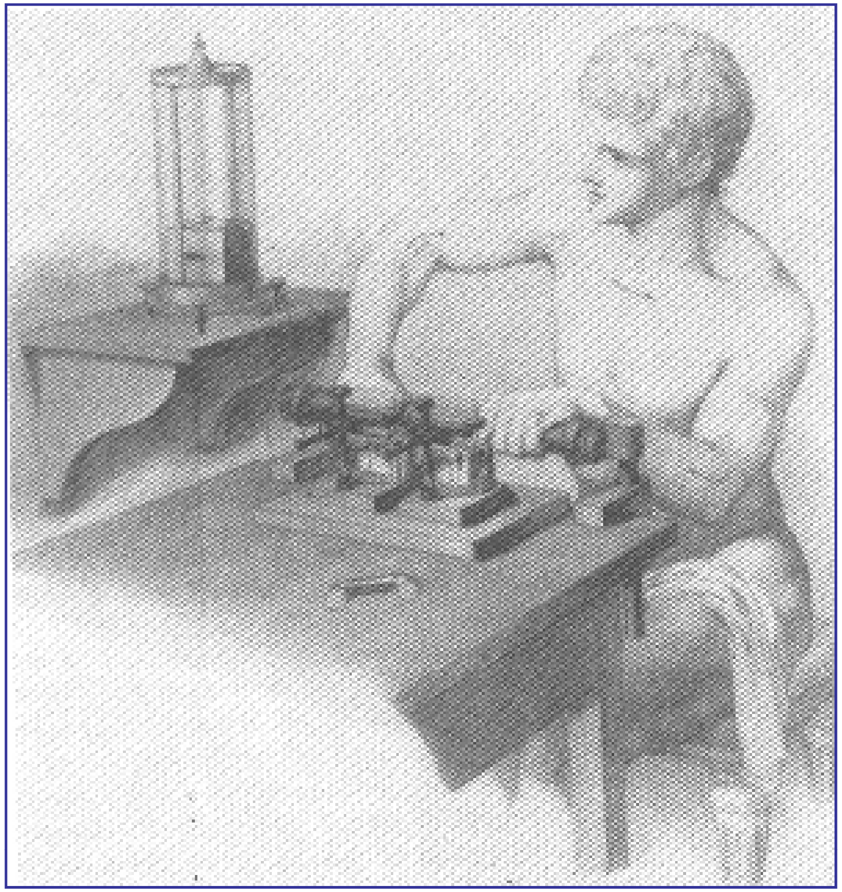


Signal analysis - Fatigue



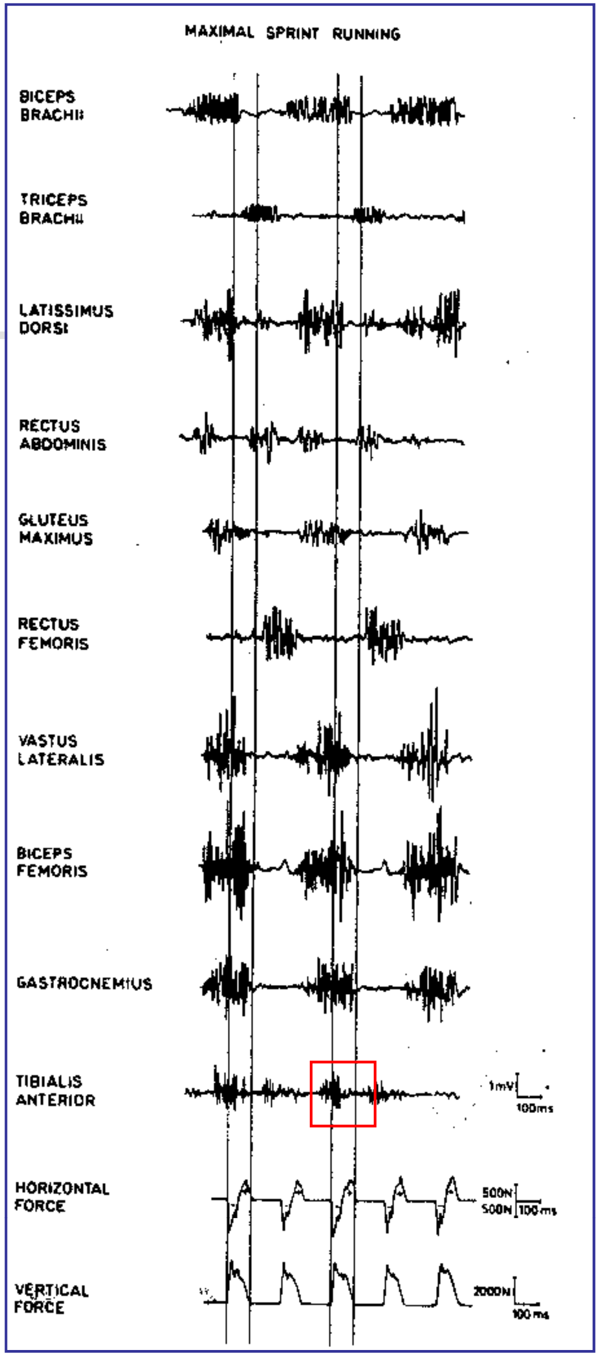
A brief history of kinesiological electromyography

- DuBois-Reymond, 1849
- International Society of Electrophysiology and Kinesiology, founded in 1965
  - http://shogun.bu.edu/isek/index.asp
- 'Muscles Alive' by Basmajian and De Luca, 1985 (final edition)
- *Journal of Electromyography and Kinesiology*, 1991
- SENIAM, 1999

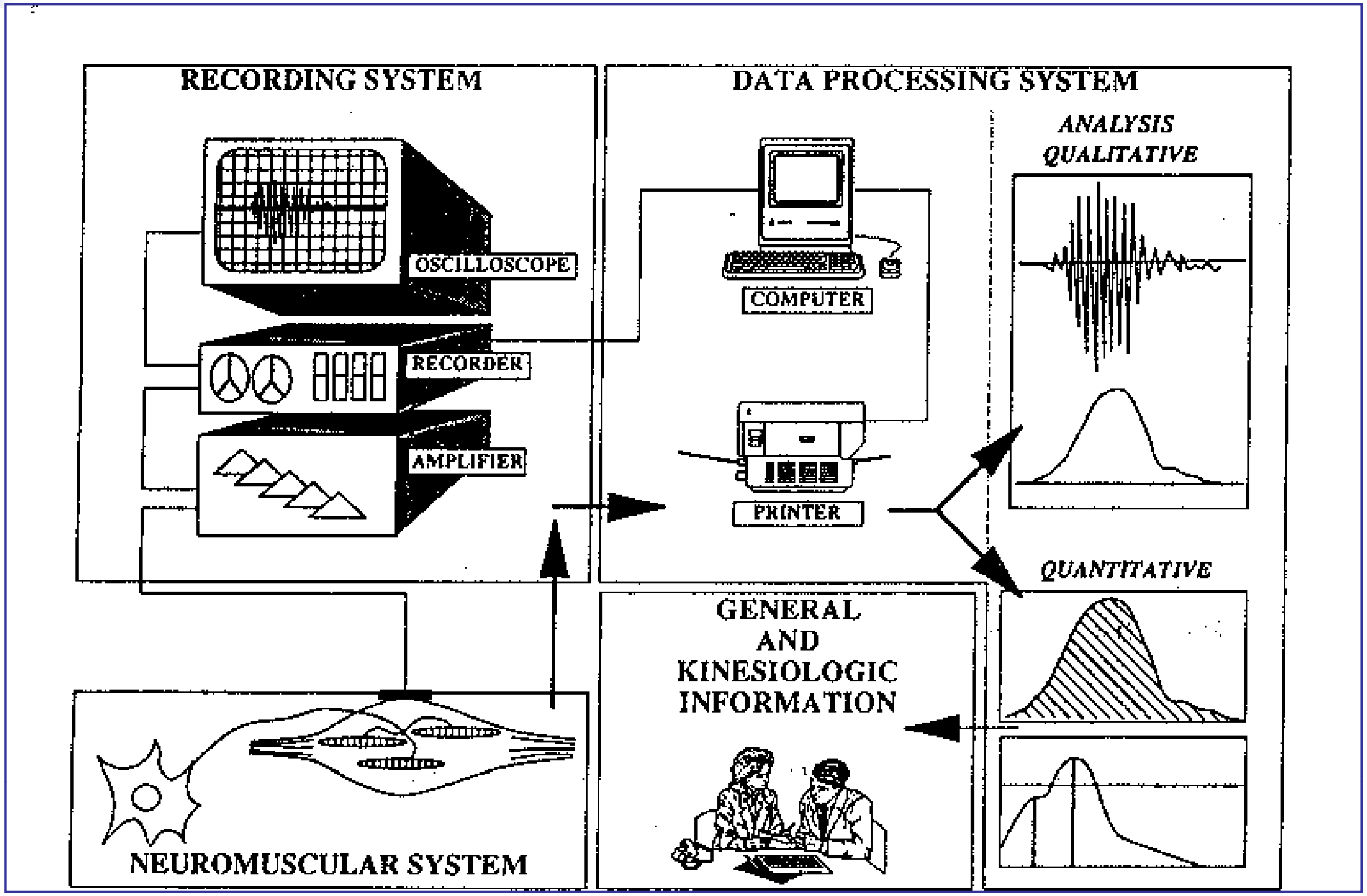


Electromyography in Sport and Exercise

- First Study
  - Broer and Houtz, 1967
    - 1 subject, 32 muscles,
    - 6 sports
- Reviews
  - Clarys *et al.*, 1988
    - Swimming and skiing
  - Clarys and Cabri, 1993
    - >130 studies
    - 32 sports (>100 skills)

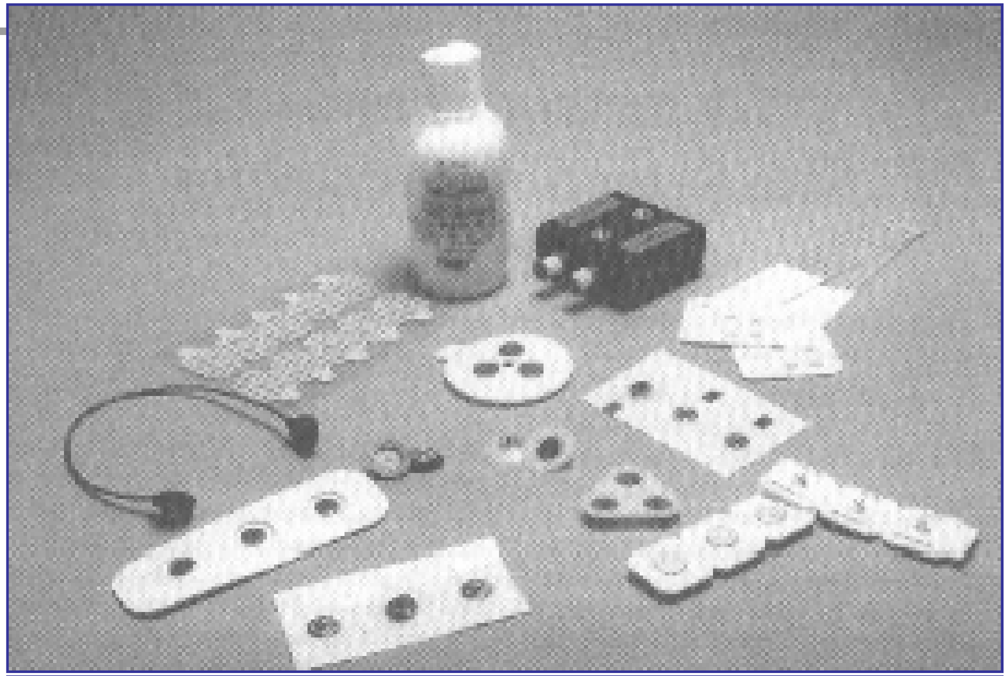


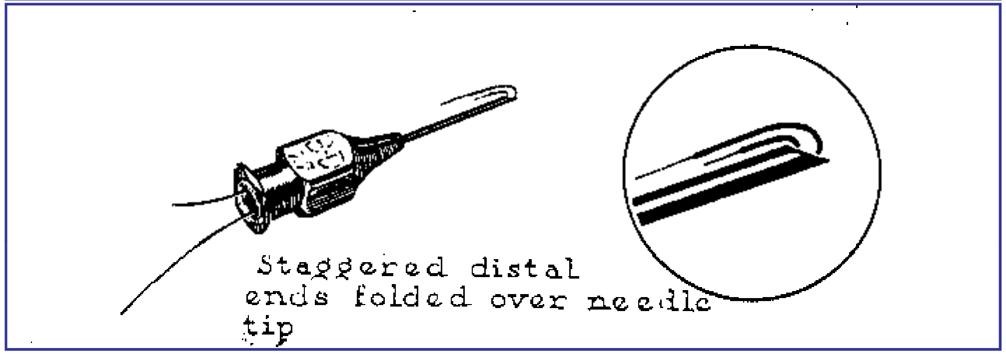
Understanding the Electromyogram (EMG)



Detection of the electromyographical signal

Surface electrodes

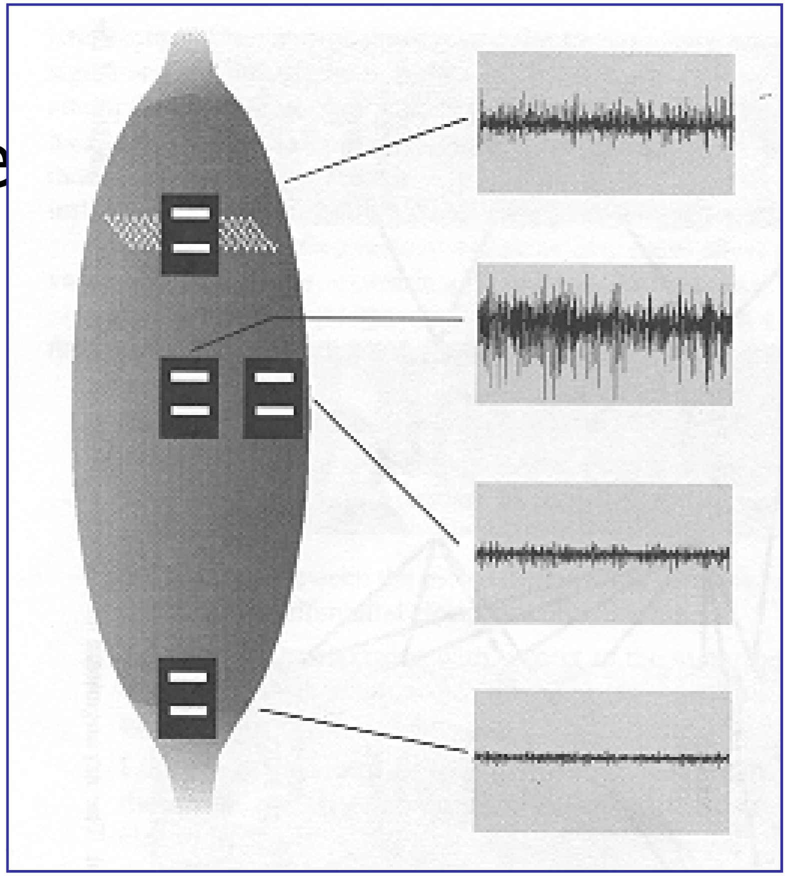




Fine-wire electrodes

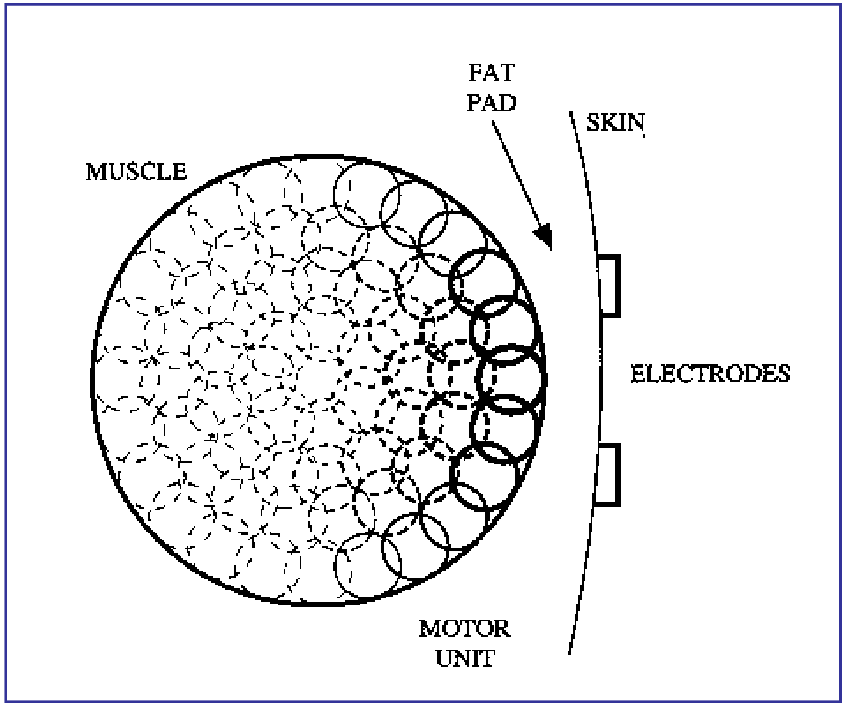
Electrode location and orientation

- LOCATE in the middle of the muscle between the origin and insertion
- ORIENTATE on a line parallel to that of the underlying muscle fibres



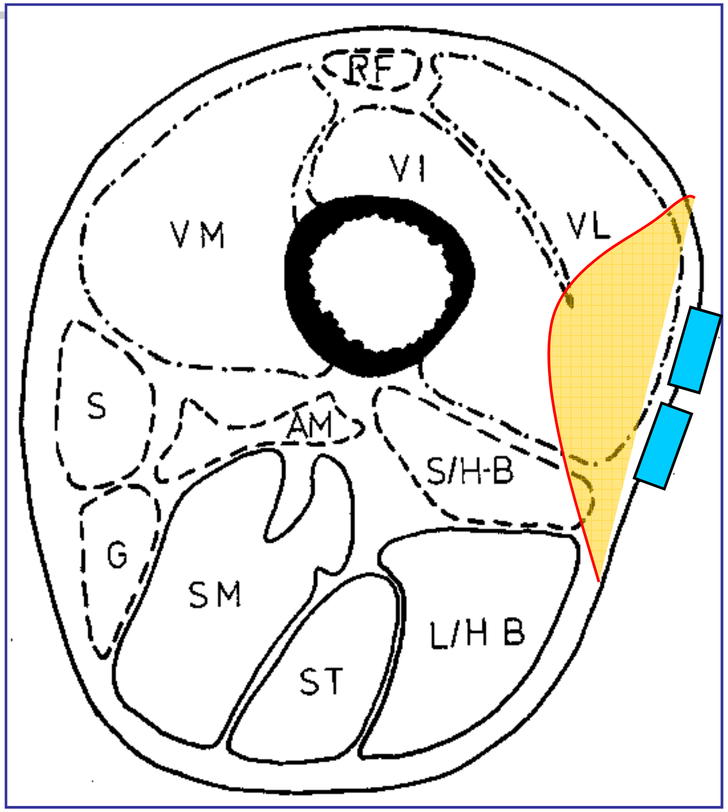
Reducing skin-electrode resistance

- The dead layer of skin, grease etc. provide a resistance to the current from the underlying muscle and should be removed
  - shaving hair
  - washing with soap and water
  - rubbing with alcohol tissue?
  - abrading with sandpaper??

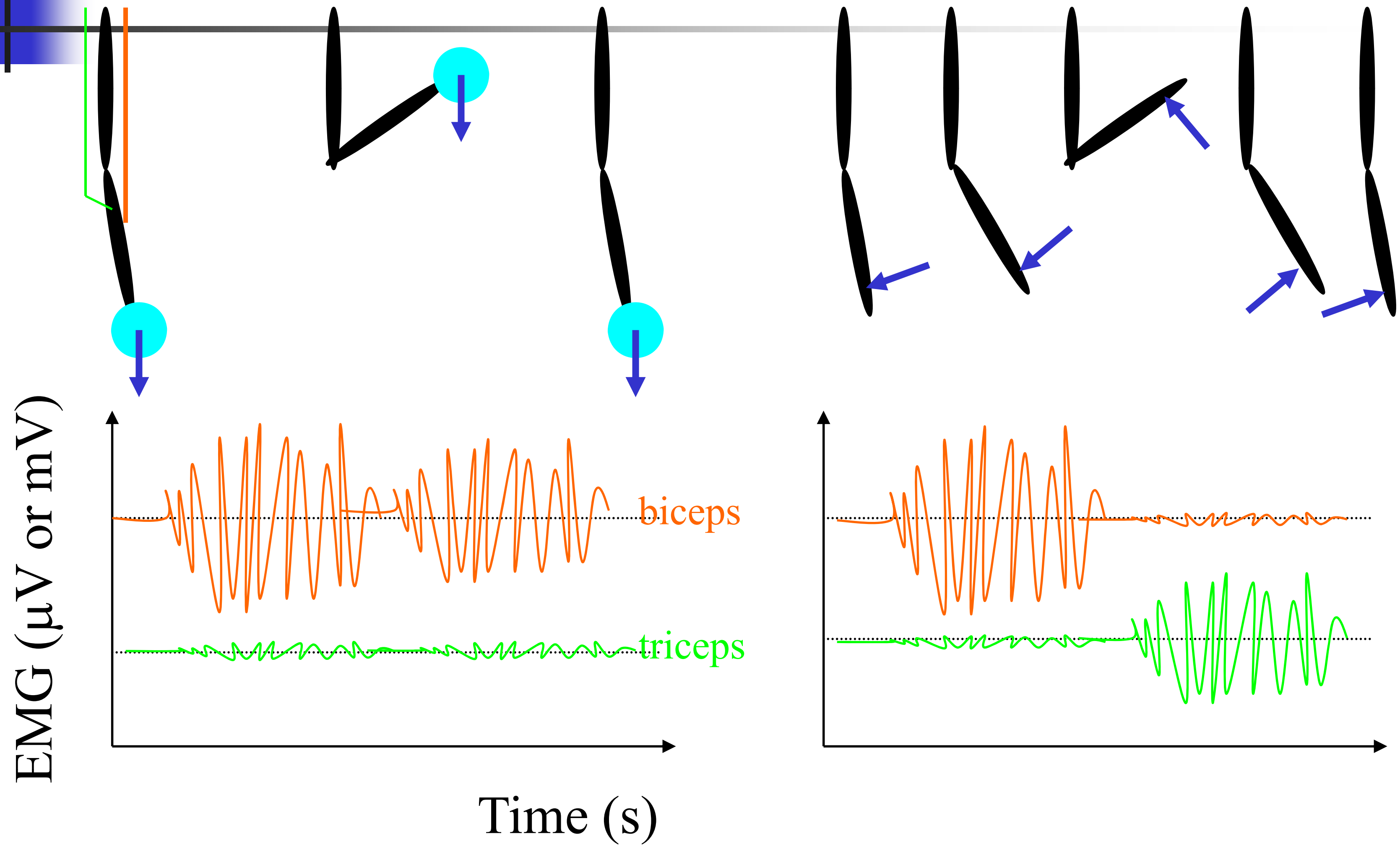


Cross-talk

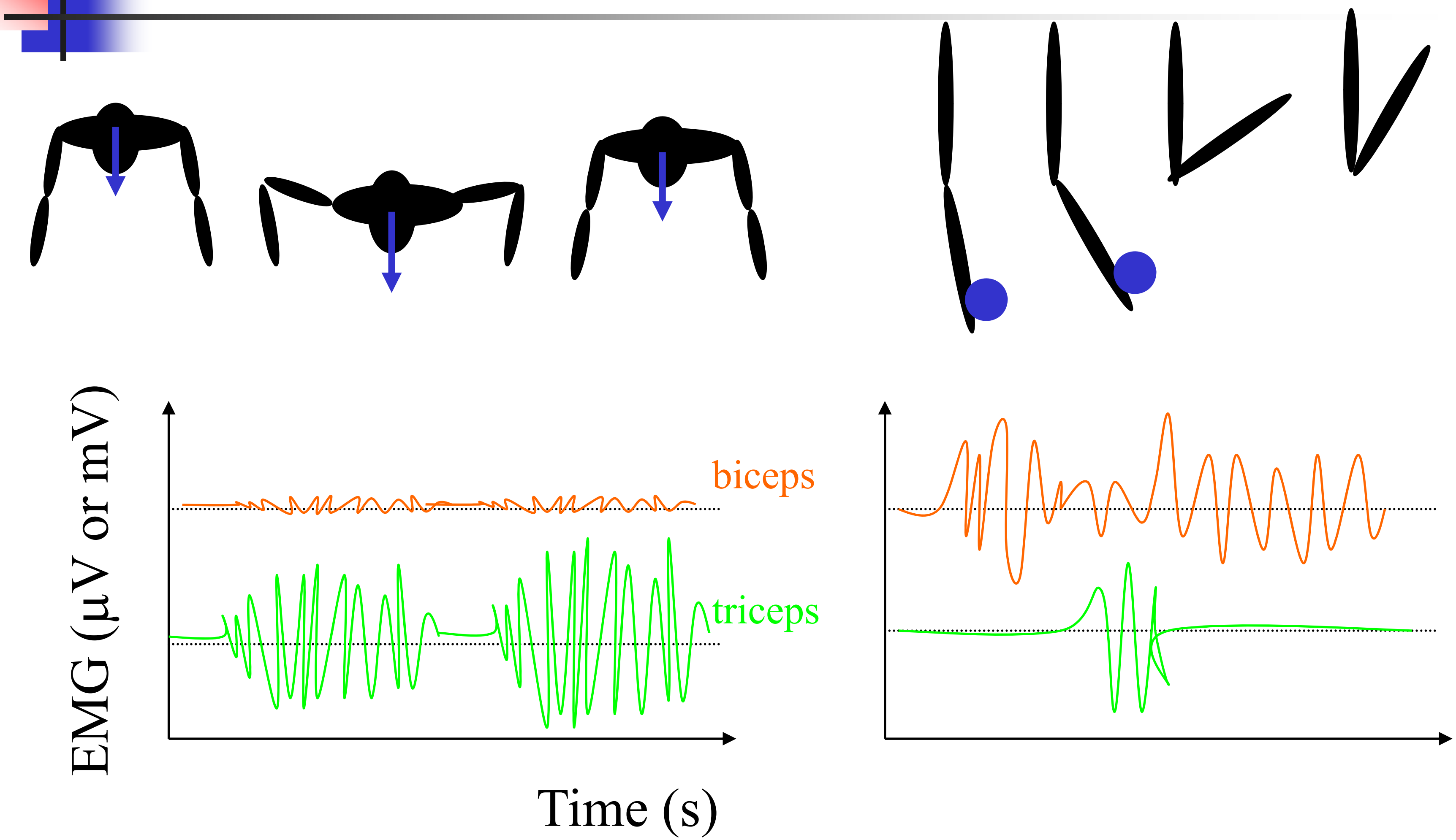
- Signals from muscles other than those that the electrodes are meant for
  - Reduced by:
    - Careful preparation and knowledge of anatomy
    - less adipose tissue
    - smaller electrodes
  - Evaluated by:
    - Muscle function testing?



What do raw EMGs reveal?

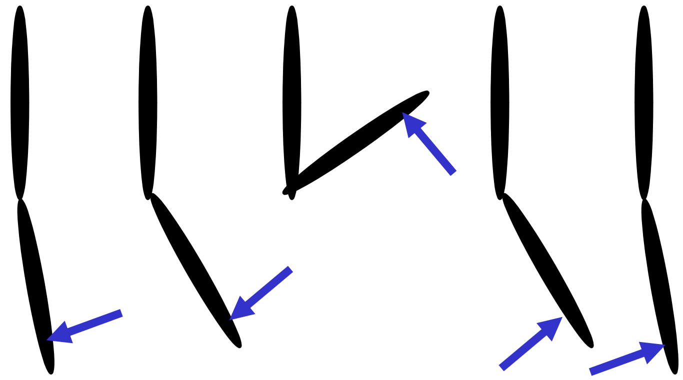


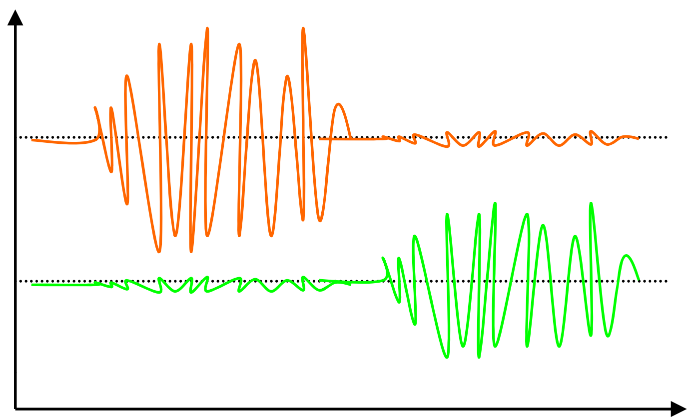
What do raw EMGs reveal?



What do raw EMGs reveal?

- How active are the biceps and triceps during flexion and extension against resistance?
  - Not sure.
    - Need to process the raw EMG to be able to quantify amount of muscle activity.

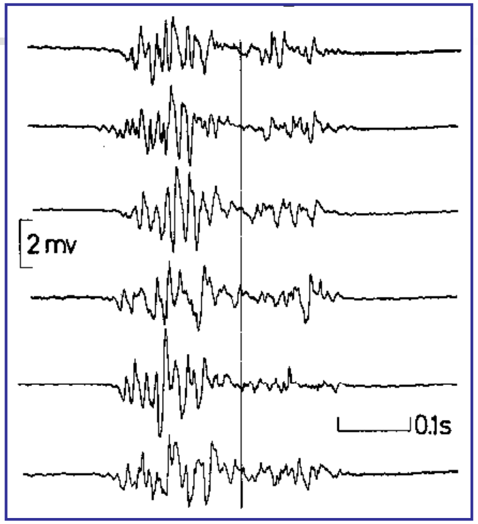


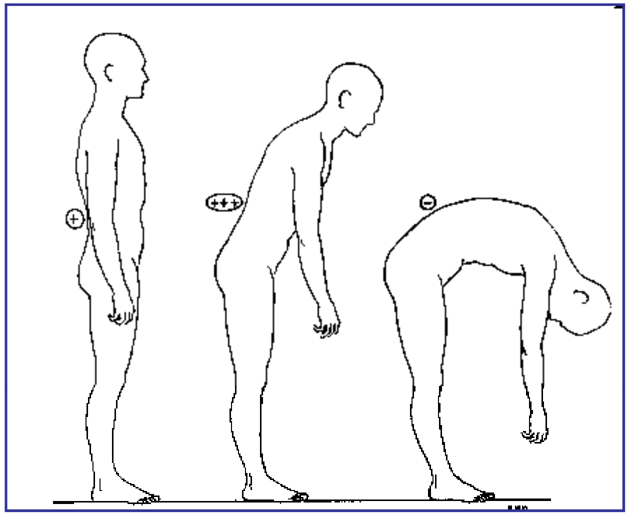


Early processing methods

- Semi-quantitative scales (e.g. Basmajian, 1978)
  - Nil 0
  - Negligible ±
  - Slight +
  - Moderate ++
  - Marked +++
  - Very marked ++++

  (equivalent to isometric maximal voluntary contraction)



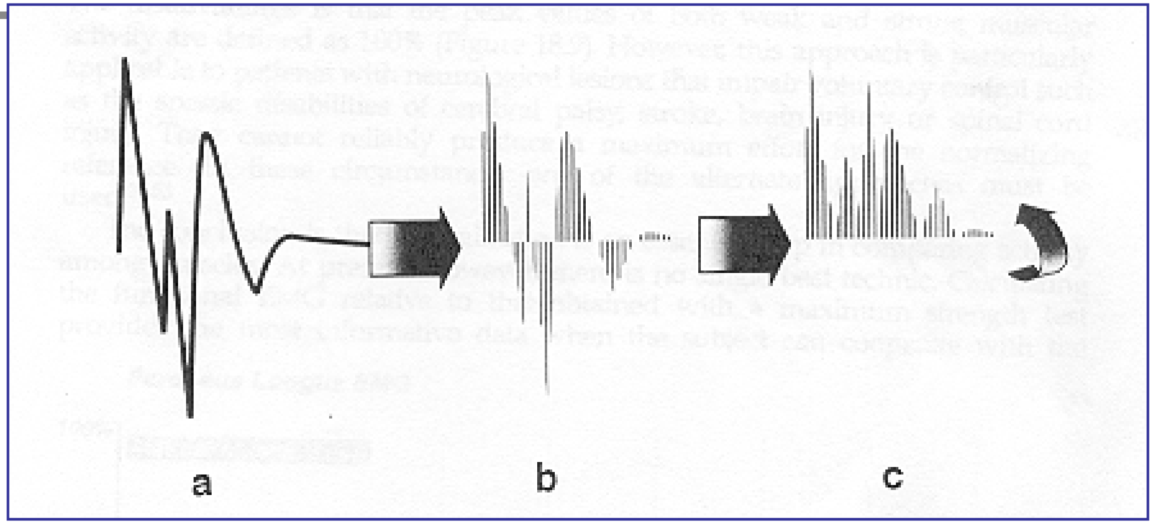


Processing I - Rectified EMG

a = raw EMG (analogue)

b = raw EMG (digital)

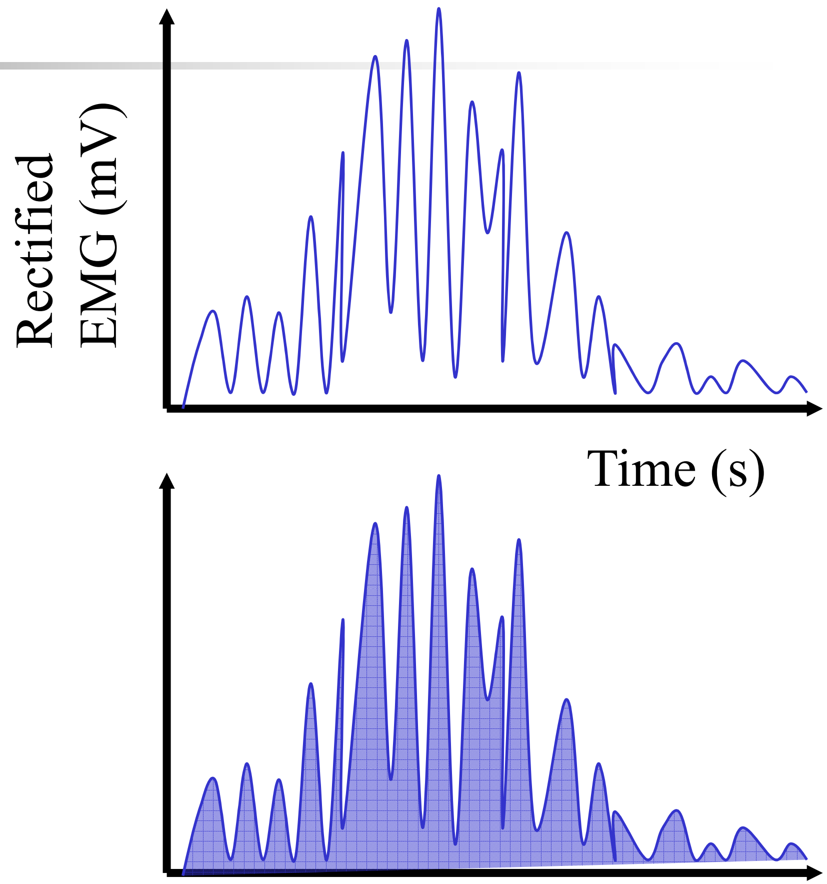
c = full wave rectified EMG



- Full Wave Rectification
  - reversal of all negative phases of raw EMG
  - required for subsequent calculation of *Average Rectified EMG*

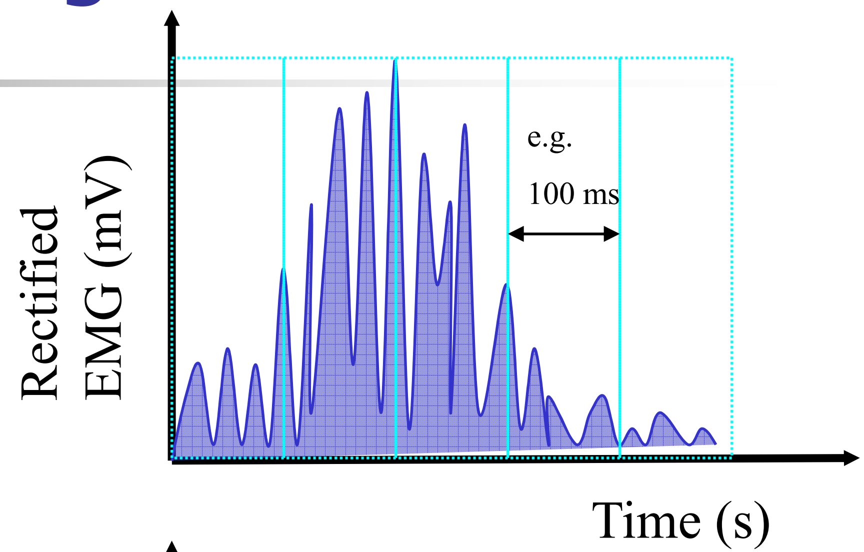
Processing II - Integrated EMG

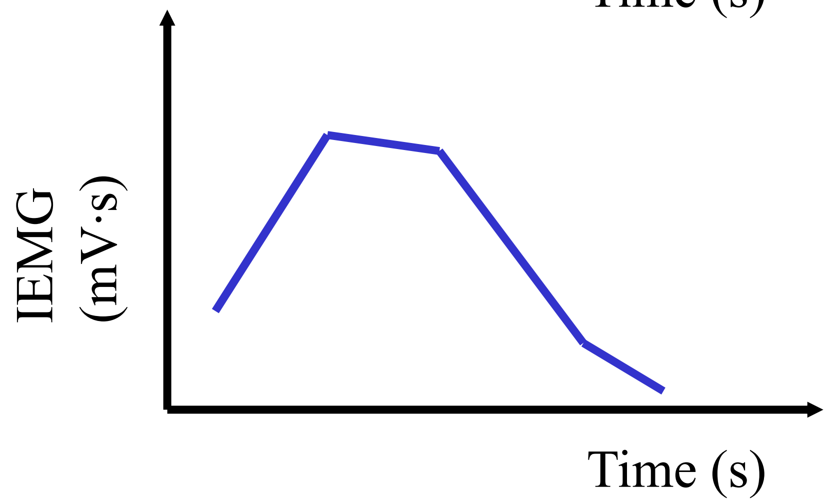
- Integrated EMG (IEMG)
  - Calculation of area underneath rectified EMG-time curve
  - Over what time is integration performed (i.e. Time Window)?
    - e.g. 1 stride
    - e.g. a specified time
  - Units = μV·s or mV·s



Processing II - Integrated EMG

- Integrated EMG often calculated over successive time intervals (usually between 50 - 250 ms)
- New Integrated EMG-time curve plotted to show trend in muscle actvity

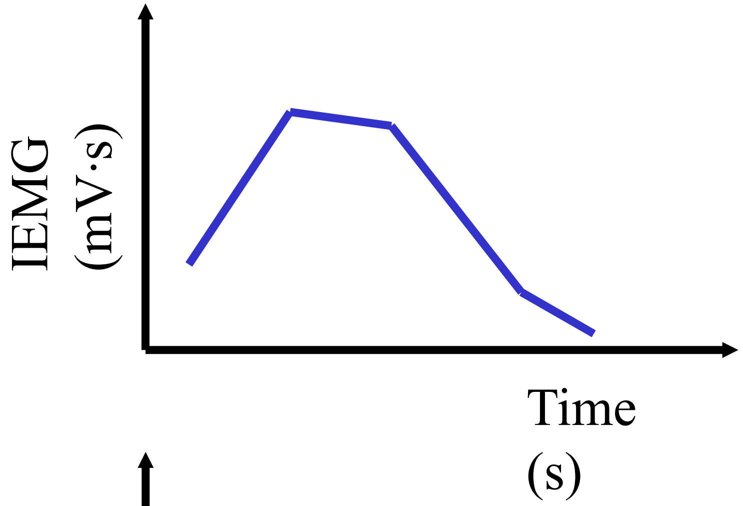


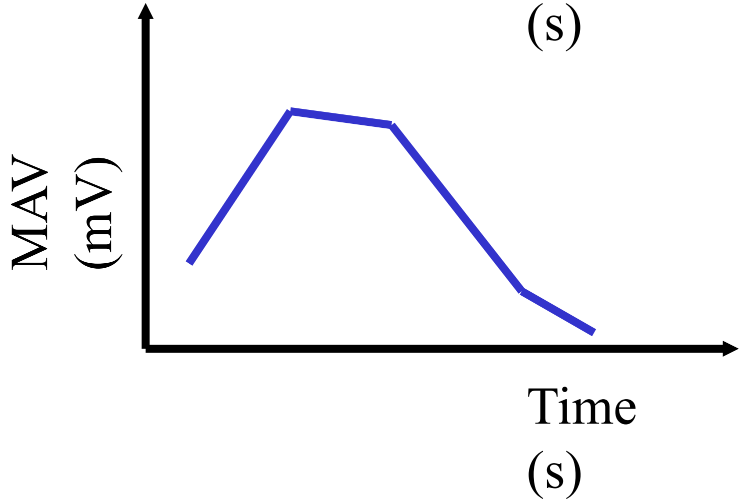


Processing III - Average Rectified EMG (AREMG)

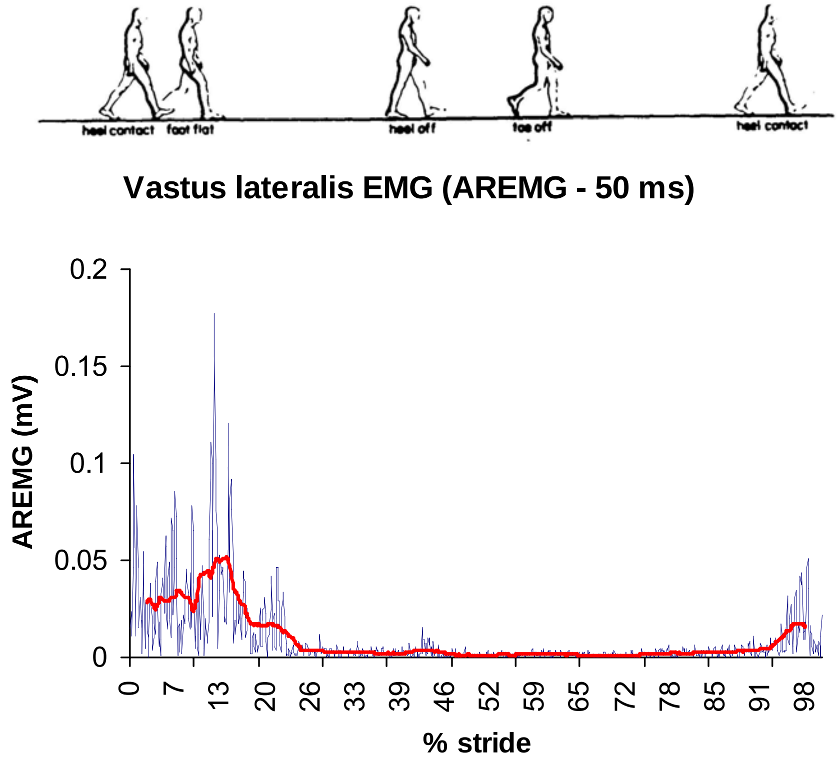
- Also referred to as:
  - Mean Absolute Value (MAV)
- Simply calculated by dividing the Integrated EMG (IEMG) by the time over which it was integrated (T), i.e.:

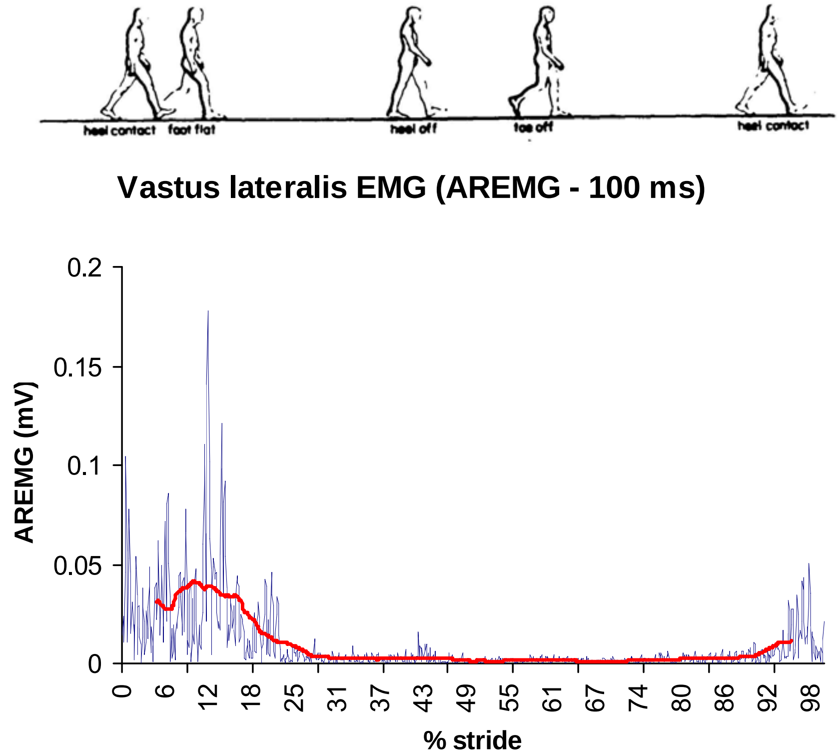
$$AREMG = \frac{IEMG}{T}$$





Effect of length of Time Window on Processed EMG

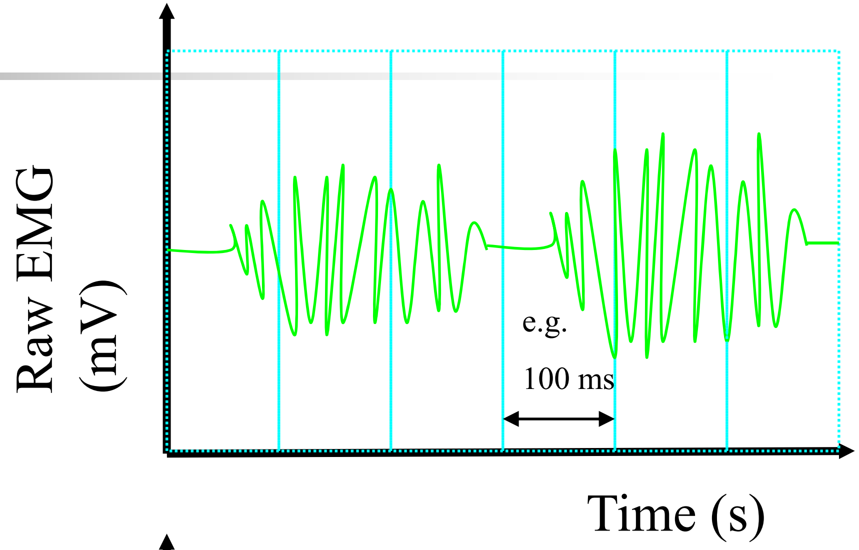


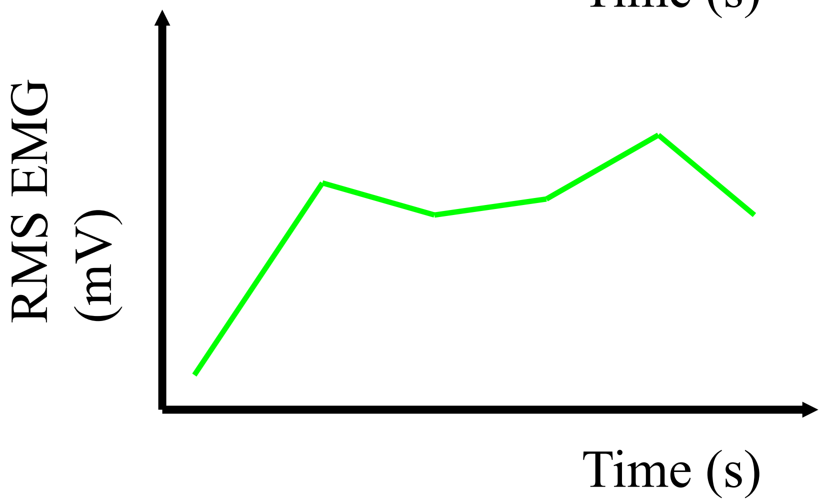


The longer the time window the smoother the processed EMG

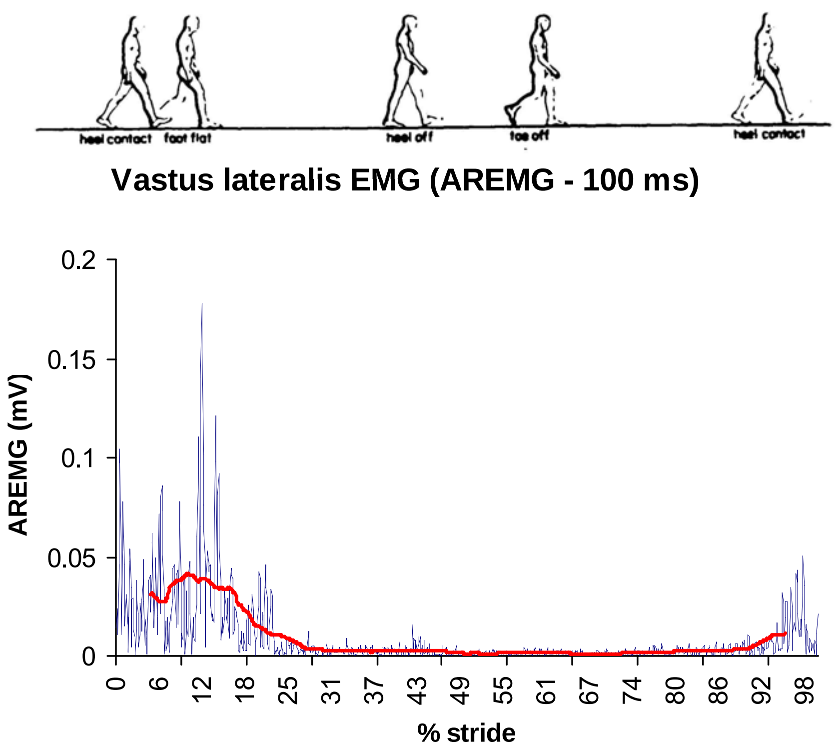
Root Mean Square (RMS) EMG

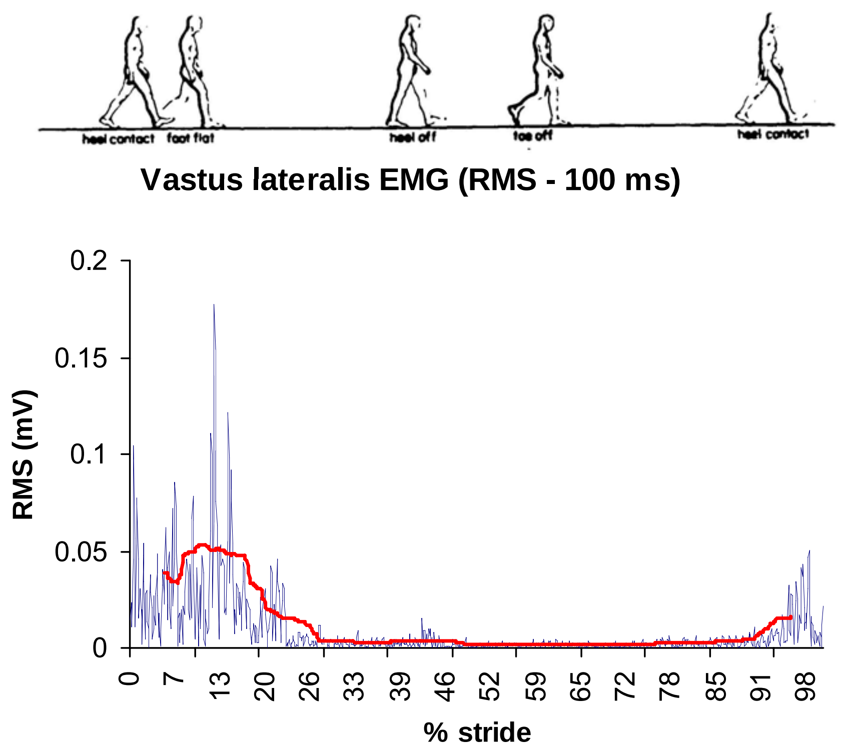
- Root Mean Square EMG
  - Select time window (e.g. 100 ms)
  - Square all rectified EMG values within each window
  - Calculate mean of each window
  - Calculate square root of each mean value
  - Plot new root mean square EMG -time curve





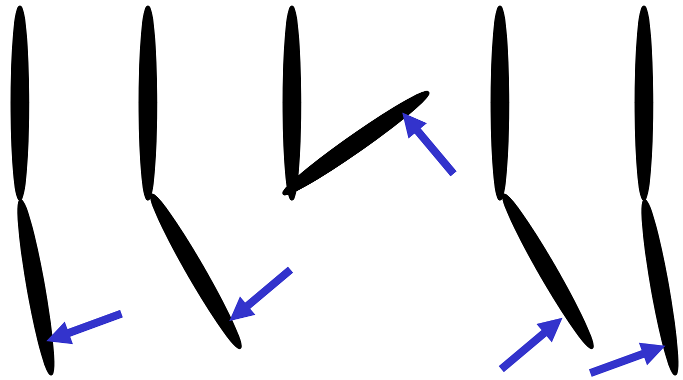
Average Rectified EMG
vs
Root Mean Square EMG

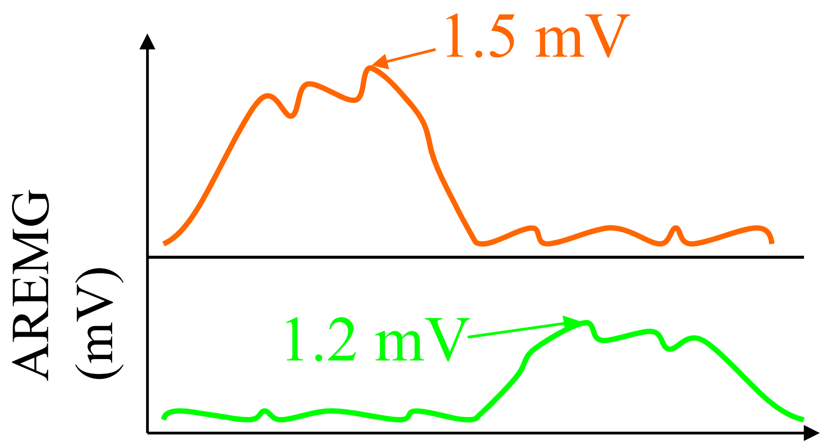




What do processed EMGs reveal?

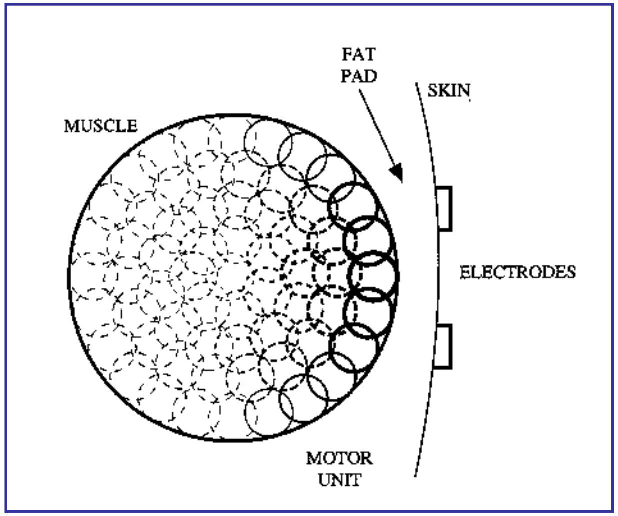
- Is biceps more active during flexion against a resistance than triceps is during extension against the same resistance?
  - Not sure.
    - Why not?





Factors affecting Processed EMGs

- Intrinsic (e.g.)
  - Number of active MUs
  - MU firing rate
  - **subcutaneous tissue**
- Extrinsic (e.g.)
  - Electrode
    - configuration
    - location
    - orientation



∴ Processed EMGs cannot be directly compared between different muscles or individuals

Normalisation of EMGs

- Express processed EMG from task as a percentage of the processed EMG from an Isometric Maximal Voluntary Contraction (MVC), i.e.:

$$\frac{EMG_{task}}{EMG_{MVC}} \times 100\ \%$$

Isometric MVC at mid-range joint angle

If peak EMG from biceps MVC = 2.72 mV

If peak EMG from triceps MVC = 2.20 mV

- Normalised biceps EMG
  = (1.5 mV/2.72 mV) x 100
  = **55 % of MVC**
- Normalised triceps EMG
  = (1.2 mV/2.2 mV) x 100
  = **55 % of MVC**

  - Provides a measure of muscle activation level during a task?
  - Allows comparison of processed EMGs between different muscles and individuals?

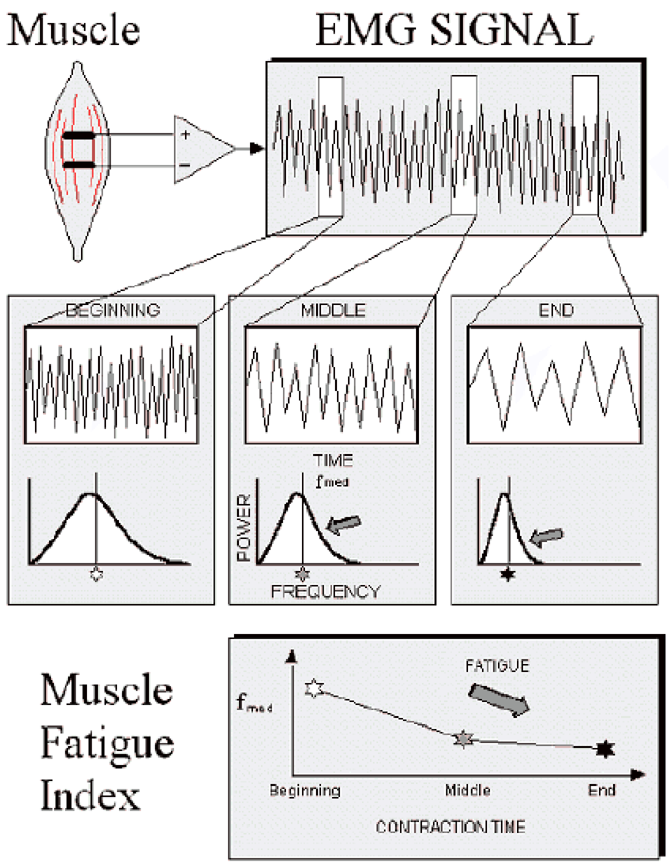


Figure 9: A diagrammatic explanation of the spectral modification which occurs in the EMG signal during sustained contractions. The muscle fatigue index is represented by the median frequency of the spectrum.

Summary

- Raw EMGs need to be processed in order to objectively quantify the level of muscle activity
  - Integrated EMG, or
  - Average rectified EMG (Mean Absolute Value), or
  - Root Mean Square EMG
- Processed EMGs need to be normalised in order to compare the level of muscle activity between different muscles and different individuals
  - Express as a percentage of the EMG from an isometric MVC
    - Do MVCs fully activate muscles?

Recommended Reading

- Bartlett, R.M. (1997). Introduction to Sports Biomechanics. London: E&FN Spon (Chapter 7).
- Clarys, J.P. and Cabri, J. (1993). Electromyography and the study of sports movements: a review. *Journal of Sports Sciences*, 11, 379-386.
- De Luca, C.J. (1997). The use of surface electromyography in biomechanics. *Journal of Applied Biomechanics*, 13, 135-163.
- Enoka, R.M. (2002). Neuromechanics of Human Movement. Champaign, IL.: Human Kinetics (pages 46-55).
- Nigg, B.M. and Herzog, W. (eds) (1999). Biomechanics of the Musculoskeletal System. Chichester: Wiley (Section 3.8, p. 352-357).