

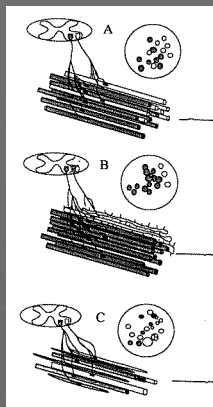
Electrophysiological Characterization of Muscle Using Quantitative EMG Measures

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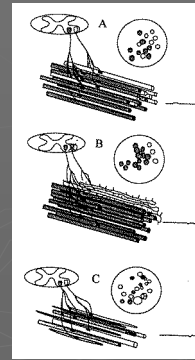
Objectives

- ▶ What is electrophysiological characterization
- ▶ Brief review of quantitative EMG
- ▶ Principles of decomposition EMG
- ▶ Basic overview of DQEMG
- ▶ How can DQEMG be used for clinical and research based electrophysiological characterization
- ▶ Validation and reliability of the method
- ▶ Application to the study of aging and NM disease
- ▶ Future plans and applications

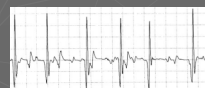
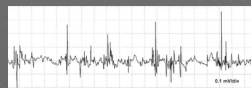
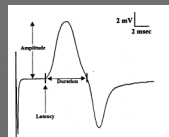
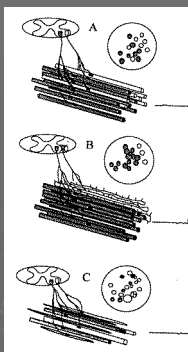


Desired Neuromuscular Information

- Numbers of MUs
- Relative sizes of MUs
- MU Innervation patterns (fiber densities)
- MU Recruitment
- MU Firing Rates
- Stability of neuromuscular junction operation



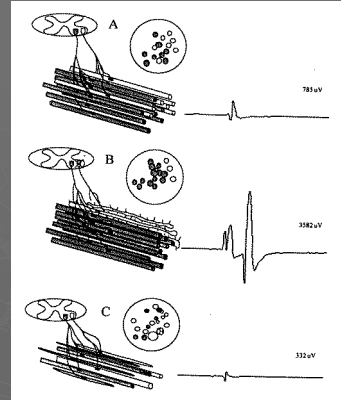
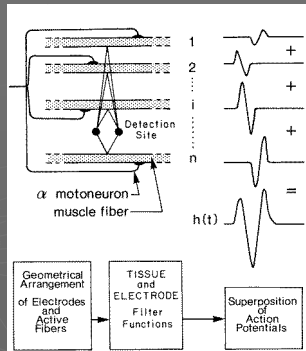
Electrophysiological Characterization



What is an EMG Signal?

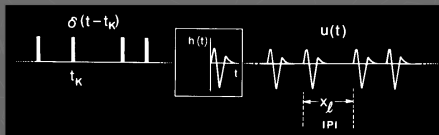
- ✦ MFP - muscle fibre potential
- ✦ MUP - motor unit potential
- ✦ MUPT - motor unit potential train
- ✦ Composite EMG

MUP Composition



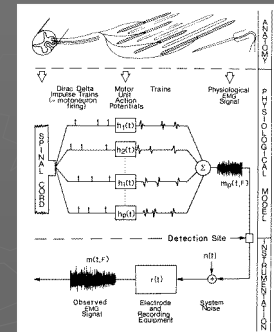
MUPT - components of a MUPT

$$\text{MUPT}_k(t) = \sum_{i=1}^{N_k} \text{MUP}_{ki}(t - \delta_{ki})$$

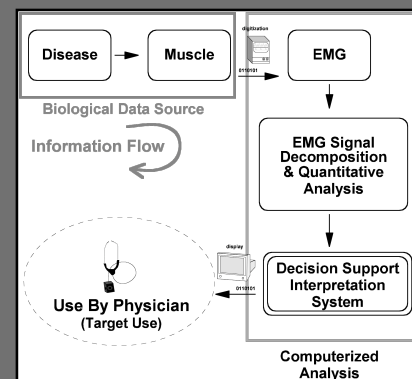


Composite EMG Signal

$$\text{EMG}(t) = \sum_{m=1}^N \text{MUPT}_m(t) + n(t)$$



Why develop/use Quantitative EMG Methods?



Why develop/use Quantitative EMG Methods?

- Objectivity
- Increased Sensitivity
- Increased Specificity
- Longitudinal studies

Quantitative EMG methods

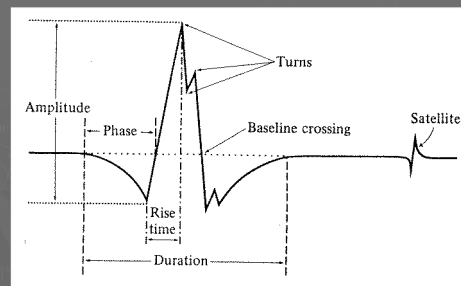
- ▶ Single Fiber EMG
- ▶ Quantitative MUP analysis
 - Semi-automated
 - Automated
- ▶ Interference pattern analysis
- ▶ Motor unit number estimation

Quantitative MUP analysis

- ▶ Buchthal method – 1950's
- ▶ Concentric needle MUPs collected one-by-one from minimally contracting muscle
 - Slow
 - ++ patient and operator interaction
 - Biased population of MUPs
 - Relatively limited information provided – only MUP parameters

Quantitative MUP Features

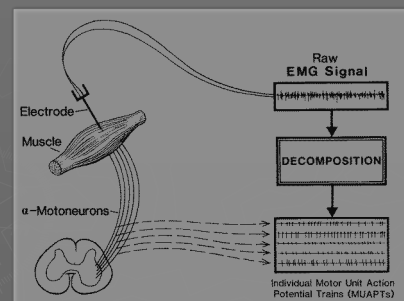
Morphological parameters - prototypical MUP of each MUPT
 • duration, number of phases, turns, V_{pp} , area, area/amplitude ratio



Example Composite EMG Signal



Concepts of EMG Signal Decomposition



How can an EMG Signal Be Decomposed?

Basic Assumptions:

- ✦ Each MUP can be detected
- ✦ Each detected MUP can be recognized

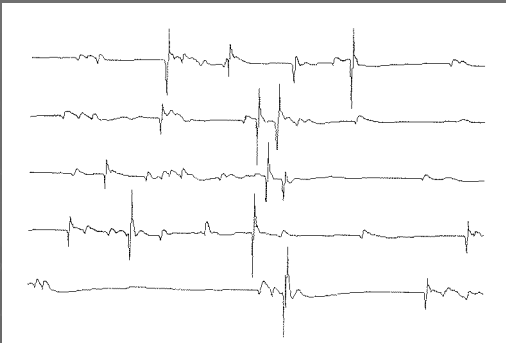
Basic Requirements:

- ✦ Common MUP feature is available for detection
- ✦ MUPs within the same MUPT are more similar than MUPs from different MUPTs
- ✦ Typical MUPs can be determined for each MUPT (i.e., MUPs must occur in isolation)

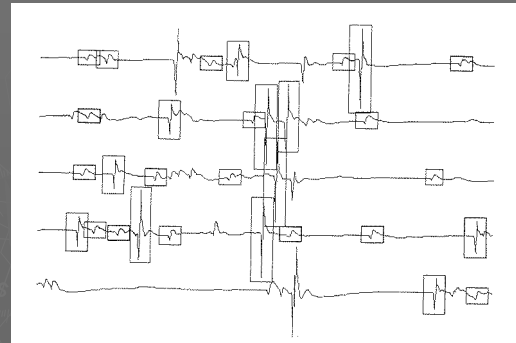
Steps in EMG Signal Decomposition

- ✦ Signal Acquisition
- ✦ Segmentation (Detecting MUPs)
- ✦ Feature Extraction
- ✦ Clustering of Detected MUPs
- ✦ Supervised Classification of Detected MUPs
- ✦ Resolving Superimposed MUPs
- ✦ Discovering MUPT Temporal Relationships

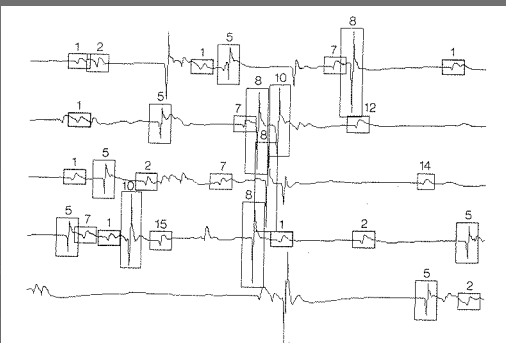
Steps In Signal Decomposition



Steps In Signal Decomposition



Steps In Signal Decomposition

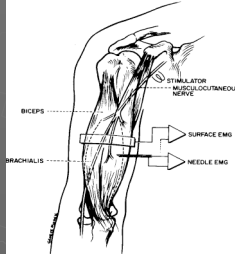


DQEMG

- Performs multiple passes through an EMG signal to complete a **partial** decomposition
- Detection pass
 - absolute or relative criteria
 - multiply and disparately detected MUPs
- Clustering pass
 - STBC (shape and temporal based clustering)
 - MUPT firing pattern classifiers used for splitting and merging trains
- Multiple Supervised Classification Passes
 - Certainty-based classification
 - Robustly and actively uses firing pattern information
 - MUPT firing pattern classifiers used for splitting and merging trains
- Temporal relationships pass
 - accounts for multiply (linked MUPTs) and disparately (exclusive MUPTs) detected MUPs
- Superimposed MUPs are **not** resolved

Data Collection

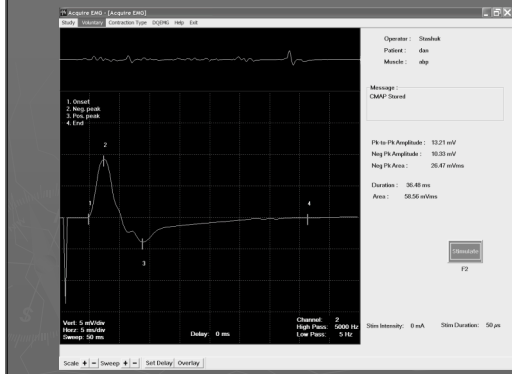
- Concentric or monopolar needle and surface "macro" EMG collected
- 20 - 30 isometric contractions
- Mild to moderate intensity
- Twenty or more MUs from 4 - 6 contractions



Acquiring EMG Signals

- Apply surface electrode configuration as per standard motor study with active electrode over motor point.
- Acquire maximal CMAP

Acquiring EMG Signals



Acquiring EMG Signals

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Acquiring EMG Signals



Acquiring EMG Signals

- Apply surface electrode configuration as per standard motor study with active electrode over motor point.
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- Perform MVC and calculate MVC RMS
- Insert needle electrode and position for sufficient signal quality (signal quality monitor V/s or kV/s²).
- Have subject isometrically contract to desired level of effort or signal intensity (%MVC RMS effort and pps intensity monitors)

Acquiring EMG Signals



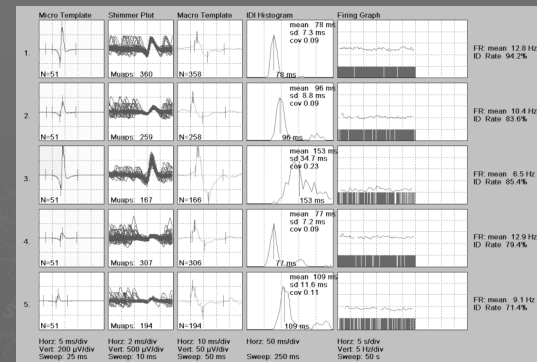
Acquiring EMG Signals

- Apply surface electrode configuration as per standard motor study with active electrode over motor point.
- Acquire maximal CMAP
- Perform MVC and calculate MVC RMS
- Insert needle electrode and position for sufficient signal quality (signal quality monitor V/s or kV/s²).
- Have subject isometrically contract to desired level of effort or signal intensity (%MVC RMS effort and pps intensity monitors)
- Decompose needle acquired signal and calculate available SMUPs
- Reposition needle and repeat during a subsequent contraction
- Continue until sufficient number of SMUPs acquired (20 –35)

Acquiring EMG Signals



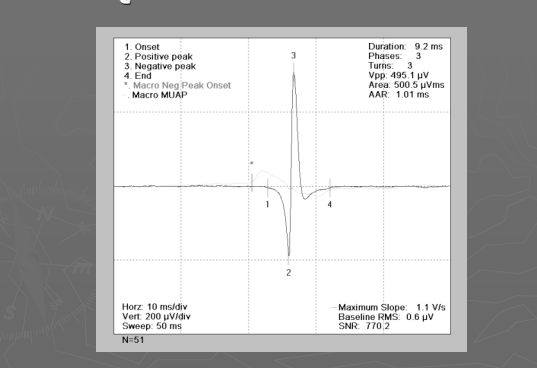
Decomposition Summary



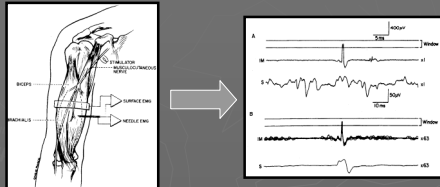
Quantitative Needle EMG



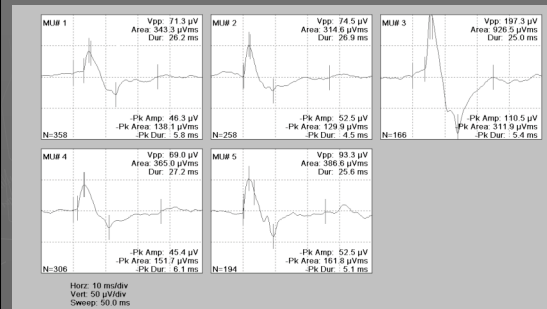
Quantitative Needle EMG



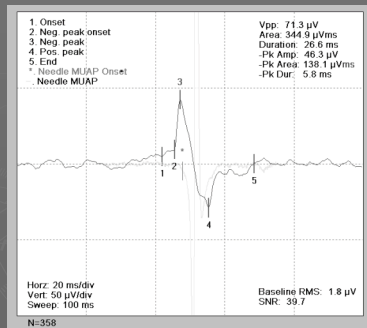
Spike-triggered Averaging



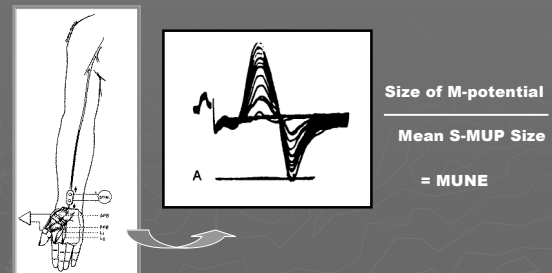
Decomposition-Based S-MUPs



Decomposition-Based S-MUPs

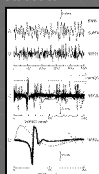
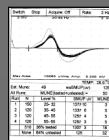
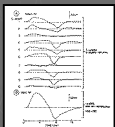
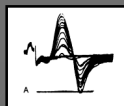


Motor Unit Number Estimation



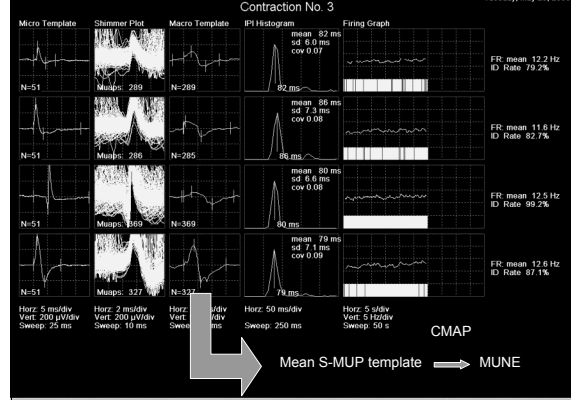
McComas et al. 1971

Methods of acquiring sample of S-MUPs

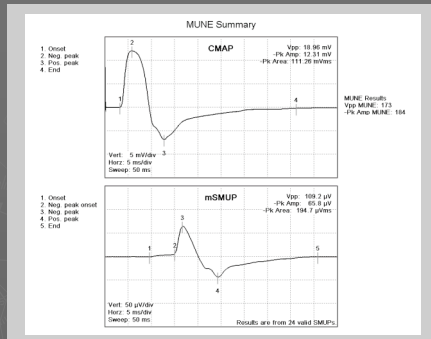


Decomposition Summary

Contraction No. 3



Decomposition-based mS-MUAP



Muscle Study Results				
Group	Parameter Type	Mean	Std. Dev	# of Samples
Contraction	Percent MVC RMS	7.29 %	0.64	5
Micro	Peak to peak voltage	663.86 μ V	577.70	29
	Duration	13.69 ms	4.05	29
	Phases	2.79	1.01	29
	Turns	3.69	1.68	29
	Area to Amplitude Ratio	1.89 ms	0.64	29
Macro	Peak to peak voltage	111.31 μ V	68.74	29
	Area	497.11 μ Vms	304.54	29
	Neg. peak amplitude	53.53 μ V	30.92	29
	Neg. peak area	193.66 μ Vms	121.76	29
	Neg. peak duration	23.46 ms	7.87	29
IDI	Mean IDI	89.37 ms	15.12	26
	IDI Standard deviation	9.88 ms	3.67	26
	IDI Coefficient of Variation	0.11 ms	0.00	26
FR	Mean firing rate	11.43 Hz	1.53	26
	FR Mean consecutive difference	0.13 Hz	0.00	26
	%Blocking	0.00 %	-----	0
Misc.	Identification rate	66.89 %	22.95	26
	Number of muaps	190.62	105.03	29
	MU Mean Voltage	5.96 μ V	3.16	26
	Peak to peak Amp MUNE	148.00	-----	1
	Neg. peak Amp MUNE	163.00	-----	1
	Neg. peak Area MUNE	207.00	-----	1
Results are from 5 contractions containing 29 valid motor units.				

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- ✓ Numbers of MUs
- ✓ Relative sizes of MUs
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