Standards for Reporting EMG Data

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The "Standards for Reporting EMG Data" have been written by Dr. Roberto Merletti and are endorsed by the International Society of Electrophysiology and Kinesiology (ISEK). The standards are also published in the Journal of Electromyography and Kinesiology (JEK).

Electrodes

Surface Electrode

Reports on surface recording of EMG should include:

- electrode material (e.g., Al/AgCl, etc.)
- electrode shape (discs, bars, rectangular, etc.)
- size (e.g., diameter, radius, width x length)
- use of gel or paste, alcohol applied to cleanse skin, skin abrasion, shaving of hair, etc.
- interelectrode distance
- electrode location, orientation over muscle with respect to tendons, motor point and fiber direction.

Intramuscular Electrodes

Intramuscular wire electrodes should be described by:

- wire materials (e.g., stainless steel, etc.)
- if single or multi strand
- insulation material
- length of exposed tip
- method of insertion (e.g., hypodermic needle, etc.)
- depth of insertion
- location of insertion in the muscle
- interelectrode distance
- type of reference electrode used, location.

Needle Electrodes

Needle electrodes and their application should be described according to standard clinical protocol. The use of nonstandard needle electrodes should be fully described and include material, size (gauge), number and size of conductive contact points at the tip, depth of insertion and location in the muscle.

EMG Detection

Detection mode and amplification should be described by the following:

- monopolar , differential, double differential, etc.
- input impedance
- Common Mode Rejection Ratio (CMRR)
- signal-to-noise ratio (SNR)
- actual gain range used

Filtering of the raw EMG should be specified by:

- filter types (e.g., Butterworth, Chebyshev, etc.)
- low and/or high pass cut-off frequencies
- slopes of the cut-offs (dB/octave or dB/decade)

The power density function of the surface EMG signals has negligeable contributions outside the range 5-10 Hz to 400-450 Hz. The bandwidth of the amplifier-filter should be within this range e.g. high pass 5 Hz, low pass 500 Hz)

Intramuscular and needle recordings should be made with the low-pass cut-off set at least at 1500 Hz.

Rectification

If analog signal rectification is carried out full or half-wave rectification should be specified.

Sampling EMG into the computer

In computer processing of the EMG it is important to consider these important factors:

1) It is advisable that the raw EMG (after amplification and bandpass filtering) is stored in the computer for digital processing. The minimal acceptable sampling is at least twice the highest frequency cut-off of the bandpass filter, e.g., if a bandpass filter of 10-400 Hz was used, the minimal sampling rate employed to store the signal in the computer should be at least 800 Hz (400 x 2), as specified by Nyquist theorem, and preferably higher to improve accuracy and resolution. Sampling rates below twice the highest frequency cut-off are incorrect unless evidence is provided that there is no noise in the frequency band between the highest signal frequency and the cut-off frequency of the lowpass filter.
2) If rectification and smoothing with a low-pass filter is performed with hardware prior to sampling and storing data in the computer, the sampling rate could be drastically reduced because of the reduced bandwidth of the linear envelope. Rates of 50-100 Hz are sufficient to introduce the EMG envelope into the computer.
3) Number of bits, model, manufacturer of A/D card used to sample data into the computer should be given.

EMG Amplitude Processing

There are several methods of EMG processing. Smoothing the rectified signal with a low pass filter of a given time constant (10-250 ms) is often described as "smoothing with a low pass filter with a time constant of x ms". Time constants higher than 25-30 ms introduce detectable delays and should be used only when interest is on the mean amplitude (moving weighted average) and not on any timing relationship with other events.

Digital non causal FIR linear phase filters are recommended

The above process can be described as "linear envelope detection" by giving the time constant value and/or the cut-off frequency and the order of the low-pass filter used, Designating the EMG resulting from this procedure as the "integrated EMG" (IEMG) is incorrect (see below).

The mean value of the rectified EMG over a time interval T is defined as Average Rectified Value (ARV) or Mean Amplitude Value (MAV) and is computed as the integral of the rectified EMG over the time interval T divided by T.

Another acceptable method of providing amplitude information is the "Root Mean Square" or RMS defined as the square root of the mean square value. Just as the ARV, this quantity is defined for a specific time interval T which must be indicated.

Smoothed, low pass filtered, average rectified or RMS values are voltages and are measured in Volt (V).

Integrated EMG (IEMG) is sometimes reported. In this case the signal is integrated (not filtered!) over a time interval, IEMG is therefore the area under a voltage curve and is measured in V/s.

EMG processing in the frequency domain

Power Density Spectra presentation of the EMG should include:

- time epoch used for each spectral estimate
- type of window used prior to taking the Fourier Transform (e.g. rectangular, Hamming, etc.)
- algorithm used (e.g. FFT)
- zero padding applied (if any) and the resultant frequency resolution
- equation used to calculate the Median Frequency (MDF) Mean Frequency (MNF) moments, etc.

Other processing techniques, especially novel techniques, must be accompanied by full scientific description.

Normalization

In investigations where the force/torque is correlated to the EMG it is common to normalize the force/torque and its respective EMG, relative to the values at maximal voluntary contraction (MVC) Obtaining the best estimate of MVC from subjects requires some preliminary training. Without training, the MVC could be as much as 20-30 % less than that obtained after appropriate training and lead to incorrect conclusions or interpretation of data. Estimates of MVC may be performed in different conditions that should be described (e.g. with/without biofeedback, position of the subject, condition of the joint proximal to the one of interest, etc.)

Normalising the force/torque with respect to its MVC value is commonly performed with MVC as 100 % of force/torque, and other force levels are expressed as the appropriate % of MVC. Similarly, the EMG associated with 100 % MVC is designated as 100 % and fractions thereof. Both force/torque and EMG normalization should include other relevant information such as joint angle(s) and/or muscle length(s) in isometric contractions, and range of joint angle, muscle length, velocity of shortening or lengthening and load applied for non-isometric contractions.

In sum, the following information should be provided when normalizing data:

- how subjects were trained to obtain MVC
- joint angle and/or muscle length
- conditions and angles of adjoining joint, e.g., for studies on elbow flexion, the condition of the wrist and shoulder joints should be provided
- rate of rise of force
- velocity of shortening or lengthening
- ranges of joint angle or muscle length in non-isometric contraction
- load applied in non-isometric contractions

EMG processing for estimation of muscle fiber conduction velocity

Estimates of muscle fiber conduction velocity (MFCV) should include:

- electrode size, type, location (see above)
- interelectrode distance
- signals used (e.g. two single or two double diff. signals, multiple signals from a linear array, etc)
- algorithm used for delay estimation (e.g., delay between reference points such as zero crossings, cross-correlation in the time domain, estimates in the frequency domain, etc.)
- delay resolution obtained

EMG Crosstalk

Effort should be undertaken to determine that EMG crosstalk form muscles near the muscle of interest did not contaminate the recorded signal. Selecting the appropriate electrode size, interelectrode distance and location of recordings over the muscle should be carefully planned, especially when working on areas where many narrow muscle are tightly gathered (e.g., forearm), or when working with thin muscles (e.g., trapezius). Care also should be employed when recording surface EMG from areas with subcutaneous adipose tissue (e.g., abdomen, buttocks, chest, etc.).