Standards for Reporting EMG Data

Authors are advised that the following protocols must be observed and supplied in the Methods section of all submitted manuscripts. To avoid delay or return of manuscripts, the requirements below should be considered when preparing the manuscript.

Electrodes:
Reports on *surface recording* of EMG should include:
- –electrode material (e.g., Ag/AgCl)
- –electrode geometry (discs, bars, rectangular)
- –size (e.g., diameter, radius, width × 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 fibers direction.

Intramuscular wire electrodes should be described by:
- –wire material (e.g., stainless steel)
- –if single- or multi-strand
- –insulation material
- –length of exposed tip
- –method of insertion (e.g., hypodermic needle)
- –depth of insertion
- –if single or bipolar wire
- –location of insertion in the muscle
- –interelectrode distance
- –type of ground electrode used, location.

Needle electrodes and their application should be described and include material, size of conductive contact points at the tip, depth of insertion and accurate location in the muscle.

Amplification:
Amplifiers should be described by the following:
- –if single, differential, double differential, etc.
- –input impedance
- –Common Mode Rejection Ratio (CMRR)
- –signal-to-noise ratio
- –actual gain range used.

Filtering of the raw EMG should be specified by:
- –low and/or high pass filters
- –filter types (e.g., Butterworth, Chebyshev, etc.)
- –low and/or high pass cut-off frequencies.

Since the power density spectra of the EMG contains most of its power in the frequency range of 5–500 Hz at the extremes, the journal will not accept reports in which surface EMG was filtered above 10 Hz as a low cut-off, and below 350 Hz as the high cut-off; e.g., 10–350 Hz is preferred for *surface* recording. Filtering in the band of 10–150 Hz or 50–350 Hz, for example, is not acceptable as portions of the signal's power above 150 Hz and below 50 Hz are eliminated. This should be kept in mind when designing a study's protocol. Exceptions will be made only in rare cases that carry full scientific justification.

Intramuscular recording should be made with the appropriate increase of the high frequency cut-off to a minimum 450 Hz. A bandpass filter of 10–450 Hz is therefore required.

Needle recording should have a bandwidth of 10–1,500 Hz.

Rectification: A note should be made if full or half-wave rectification was carried out.

EMG Processing: There are several methods of EMG processing. *Smoothing* the signal with a low pass filter of a given time constant (normally 50–250 ms) is best described as "smoothing with a low-pass filter of x ms". Alternatively, one can describe it as a "linear envelope" or "the Mean Absolute Value", while giving time constant type and order of the low-pass filter used.

Also acceptable is determination of the "Root Mean Square" or RMS. Authors should include the time period over which the average RMS was calculated.

Integrated EMG is sometimes reported, but the signal is actually integrated over time, rather than just smoothed. Such procedure allows observation of the accumulated EMG activity over time, and should be presented with information as to whether time or voltage was used to reset the integrator and at what threshold it was reset.

Power Density Spectra presentation of the EMG should include:
- –time epoch used for each calculation segment
- –type of windows used prior to taking the Fast Fourier Transform (FFT) (e.g., Hamming, Hanning, Tukey, etc.)
- –taking the algorithm (e.g., FFT)
- –number of zero padding applied in the epoch and the resultant resolution
- –equation used to calculate the Median Frequency (MDF), Mean Frequency (MNF), etc.
- –the muscle length or fixed joint angle at the time of recording.

Other processing techniques, especially novel techniques, are encouraged if accompanied by full scientific description.

Sampling EMG into the Computer:
Computer processing of the EMG is encouraged if authors observe these important factors:

1. It is advisable that the raw EMG (e.g., after differential amplification and bandpass filtering) be stored in the computer before further analysis in case modification of the protocol is required in the future. In this case, the minimal acceptable sampling rate is at least twice the highest frequency cut-off of the bandpass filter, e.g., if a bandpass filter of 10–350 Hz was used, the minimal sampling rate employed to store the signal in the computer should be 700 Hz (350 × 2), and *preferably higher* to improve accuracy and resolution. Sampling rates below twice the highest frequency cut-off will not be accepted.

2. If smoothing with a low-pass filter was performed with hardware prior to sampling and storing data in the computer, the sampling rate could be drastically reduced. Rates of 50–100 Hz are sufficient to introduce smoothed EMG into the computer.

3. It is also advisable that authors consider recording the raw EMG (prior to bandpass filtering) in the computer; in such cases a sampling rate of 2500 Hz or above could be used. Yet, to avoid aliasing of high-frequency noise, bandpass filtering (written in software) in the range prescribed above should be performed prior to any further processing of the signal. This approach allows authors to perform EMG recording with minimal hardware and maximal flexibility. Yet, it may be at the expense of computer memory space and speed.

4. Number of bits, model, manufacturer of A/D card used to sample data into the computer should be given.

Normalization: In investigations where the force/torque was 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). Authors should be aware that obtaining true MVC from subjects requires some preliminary training. Without training, the MVC could be as much as 20–40% less of that obtained after appropriate training. The journal, therefore, will not accept reports in which subjects were not properly trained to elicit true MVC.

Normalizing the force/torque with respect to its MVC is commonly performed with MVC as 100% of the force/torque, and other force levels are expressed as the appropriate percentage of MVC. Similarly, the EMG associated with 100% MVC is designated as 100%. 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/elongation, and load applied for non-isometric contractions.

Normalization of data collected from one experimental condition with respect to other contractile conditions can be performed for comparative purposes and will be accepted by the journal only if full description is given.

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

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

EMG Crosstalk:
Authors should demonstrate that significant effort was made to determine that EMG crosstalk from 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 area where many narrow muscles are tightly gathered (e.g., forearm), or when working with superficial/thin muscles (e.g., trapezius). The work of Winter *et al.*[3] and Fuglevand *et al.*[1] should be consulted if doubts exist. Care also should be employed when recording surface EMG from areas with subcutaneous adipose tissue as it is known that adipose tissue enhances crosstalk[2].

[[1]] Fuglevand AJ, Winter DA, Patala AE, Stashuk D. Detection of motor units' action potentials with surface electrodes - influence of electrode size and spacing. Biological Cybernetics 1992;67:143–153.

[[2]] Solomonow M, Baratta R, Bernardi M, Zhou B, Lu, Y, Zhu M, Acierno S. Surface and wire EMG, crosstalk in neighbouring muscles. Journal of Electromyography and Kinesiology 1994;4:131–142.

[[3]] Winter DA, Fuglevand AJ, Archer SE. Crosstalk in surface electromyography: theoretical and practical estimates. Journal of Electromyography and Kinesiology 1994;4:15–26.