

NORMALIZATION OF SURFACE EMG SIGNALS - COMPARISON AMONG EFFORTS, JOINT POSITIONS AND PROCESSING METHODS

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INTRODUCTION

EMG signals have been used for diagnosis of disease, evaluation of different exercises, and estimation of muscle forces (Zheng, N et al, 1997). EMG results are affected by numerous factors during data detection and processing (De Luca, C. 1997), however these factors are often ignored and/or not reported when normalizing EMG. The objective of this study was to evaluate the effects of contraction effort, joint angle, and data processing method on EMG signal normalization. EMG signals were recorded during isometric contraction of the quadriceps muscles.

METHODS AND MATERIALS

Ten healthy subjects (5 male, 5 female) with no history of knee injury volunteered and signed consent forms approved by the IRB. The dominant leg was tested with the subject seated. Three pairs of surface electrodes (Medicotest Marketing, Inc. Ballwin, MO) were placed on the muscle belly of the vastus medialis (VM), vastus lateralis (VL), and rectus femoris (RF). A load cell (Omega Engineering) was installed to directly measure force applied by the dominant leg near the ankle. The force signal was collected at 1000 Hz. Synchronized EMG signals from the three muscles were recorded at 1000 Hz with a Myosystem 2000 (Noraxon USA, Inc., Scottsdale, AZ). Signals were converted from analog to digital data and stored with an ADS system (Motion Analysis Corp.,

Santa Rosa, CA). Tests were conducted at 30, 60 and 90 degrees of knee flexion with maximum, 75% and 50% effort voluntary isometric contraction for 3 seconds. Each test was repeated three times. Subjects were allowed to take a 2-minute break between tests.

Data were passed through a high-pass 4th order butter filter and rectified. Four different processing methods were then used: integration (INT), low-pass filter with cut-off frequency of 25 Hz (LPS), root-mean-square (RMS) and average rectified value (ARV). For each processing method, the mean value of the middle second was calculated and averaged for the three tests each subject performed for each condition. The coefficient of variability (COV) among the three tests was also calculated. Repeated measures analysis of variance (ANOVA) was used to identify significant ($p < 0.05$) differences in mean EMG and COV among effort, knee angle, and data process for each muscle (SPSS Inc, Chicago, USA).

RESULTS AND DISCUSSION

Table 1 lists the forces recorded at different effort levels and knee flexion angles during 3 second peak (G-P), middle second peak (L-P) and the average in the middle second (L-M). Table 2 lists the mean EMG signals at different knee angles (A), effort levels (EL), data processing methods (PM), and signal origins (SO) (i.e. G-P, L-P and L-M).

The mean values and COV of EMG for the VM and VL muscles varied significantly with knee flexion angle. For the RF muscle, mean values and COV for different knee angles showed no significant differences. EMG results varied significantly among the different data processing methods. Mean values were greatest with the INT method and least with the ARV method. COV was the least with INT and no differences among others. Each of these methods has virtue and has been used in EMG analysis. The current study does not suggest that one method is superior, but that the choice of method can affect the results and should therefore be reported. Results also varied significantly due to signal origin.

EMG data is scaled commonly by the EMG magnitude of maximum voluntary isometric contraction (MVIC). While this is a common approach, Lawrence and De Luca (1983) suggested that the variability of EMG during maximum effort was high, which makes it a poor choice for normalization. As expected, the current study showed that mean values of EMG and force both were highest with maximum effort and lowest with 50% effort. However their COV were not significantly different among effort levels. Thus, the choice of effort for normalization trials would affect the magnitude but not the consistency of scaled data.

SUMMARY

Normalization is often used in EMG data analysis. MVIC has the highest magnitude and the choice of using MVIC is no better or worse than 75% or 50% effort level. The choice of joint position and processing method should also be considered and reported. Different joint angles should be considered for different muscles to obtain MVIC or other level VIC. Because of

variability, multiple trials are always a good idea. The choice of signal origins also affects results. The choices of effort levels, joint positions, and processing methods are important, not only for the quality of an individual study, but also for comparison of various studies and clinical applications of EMG testing.

REFERENCES

- De Luca, C (1997). *J. Appl. Biomechanics*, 13, 135-163.
 Lawrence, J.H. and De Luca, C. *J. Appl. Physiol.* 54:1653-9.
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Table 1 Forces recorded at different efforts and angles (mean± SD) (N)

		G-Peak	L-Peak	L-Mean
Effort Level	100%	332 ± 12	321 ± 11	301 ± 11
	75%	266 ± 11	259 ± 11	241 ± 10
	50%	203 ± 8	197 ± 8	183 ± 7
Angle (deg)	30	228 ± 8	220 ± 8	207 ± 8
	60	317 ± 14	310 ± 14	291 ± 13
	90	257 ± 10	247 ± 10	228 ± 9

Table 2 EMG Signals for RF, VM and VL (mean± SD) (mV)

		RF	VM	VL
A	30°	39.6 ± 1.5	28.9 ± 1.4	33.9 ± 1.1
	60°	43.1 ± 1.6	34.5 ± 2.2	33.7 ± 1.1
	90°	44.8 ± 1.6	56.0 ± 2.1	46.1 ± 1.4
E L	100%	54.7 ± 1.8	36.5 ± 2.1	39.2 ± 1.3
	75%	48.6 ± 1.9	39.2 ± 1.4	38.6 ± 1.3
	50%	51.3 ± 1.8	62.1 ± 2.4	52.0 ± 1.6
P M	INT	52.6 ± 2.2	51.0 ± 2.4	48.2 ± 1.7
	LPS	44.4 ± 1.9	42.2 ± 2.2	40.4 ± 1.6
	RMS	40.7 ± 1.3	37.1 ± 1.7	35.3 ± 1.1
	ARV	32.4 ± 1.3	28.9 ± 1.4	27.6 ± 0.9
S O	G-P	54.1 ± 1.8	50.1 ± 2.0	47.5 ± 1.4
	L-P	46.9 ± 1.6	44.4 ± 2.6	42.6 ± 1.2
	L-M	26.6 ± 0.9	24.2 ± 1.0	23.5 ± 0.6