Using Two Electromyographic Normalization Techniques in Analysis of Pushing Activity

Salam M. El-hafez
Department of Bio Mechanics, Faculty of Physical Therapy, Cairo University.

ABSTRACT

The aim of the present study is to evaluate the effectiveness of two different EMG normalization techniques. The first technique which is the most widely used for normalization is the maximum isometric voluntary contraction (MIVC). The second technique is the starting position before the activity and is referred to as the zero position. Twenty normal male subjects volunteered to participate in this study. The task required from each subject was to push a cupboard containing 30% of the subject weight with the trunk inclined 40 degrees from the vertical plane. During this task the EMG activity was recorded from the right and left erector spinae and the right and left rectus abdominis muscles. For normalization, the EMG was recorded from the specified muscles during standing with the trunk in the erect position and was referred to as "zero position" for normalization. The second normalization method was obtained by recording the EMG from the specified muscles while the subject was performing his MIVC. All EMG data were full wave rectified, integrated and then the amplitude was recorded in volts and then the data were referred as percentage from the MIVC and from the zero position. The results of this study revealed that there was a low correlation between the "zero position" normalization technique and the "MIVC" technique. It is concluded that the "zero position" technique for normalization is not preferred during studying the kinesiological surface EMG. The preferred method and previously recommended is the MIVC technique.
Keywords: *Normalization technique, Electromyography, MIVC, non-MIVC technique, Back Muscles, Abdominal Muscles.*

INTRODUCTION

The surface kinesiological electromyography (KEMG) has been used to evaluate muscle activity for function, control, and learning. Examples of specific applications that have been made include; assessing muscle function during or as a result of exercise and therapeutic procedures, providing biofeedback to patients, evaluating control by assessing muscle onset time and durations or establishing motor unit discharge rates, assessing gait and determining matters relative to fatigue[7].

Electromyography is a tool that can be very valuable in ergonomic studies. It is one of several methods used for analyzing the performance associated with the work place. It can be used for assessing the performance of a task. However, EMG is used more often to evaluate lighter, repetitive work where the activity of specific muscles is of interest. Ergonomic analyses often include use of this technique when comparing the stress in given or specific muscles associated with various work positions, postures, or activities. The use of EMG is thus appropriate when it is suspected that a specified muscle or group of muscles is affected adversely because of the design of the work place[5].

The myoelectric signal may change from one time to the next for several reasons such as; slight change in electrode location, change in tissue properties, or change in tissue temperature. The absolute values of microvolts could give an inaccurate comparison of muscle function during different activities. Therefore, a normalization procedure must be made at each specific testing time for each subject tested[3]. Because of the inherent EMG signal variability, clinical interpretation of surface EMG signals requires normalization of the signal for physiologic interpretation and for comparison between bilateral muscle and between the same muscle on different days and between different subjects[2]. Both raw and processed versions of data can be entered into the normalization module, which allows for the process of referencing the EMG data to some standard value, usually by dividing the derived EMG data by a reference value. The decision to normalize or not normalize is based on the type of descriptions or comparisons to be made. If comparisons are made between subjects, days, muscles, or studies, the process is required. Conversely, if subjects serve as their own control and contrasts are made within a day and on the same muscle, with the electrode not being removed, normalization is not thought to be necessary[4,6,7].

When normalization is performed, the user should decide whether a static effort or a dynamic effort is to be used as the reference muscle contraction. The most frequently used value is the maximum isometric voluntary contraction MIVC. There have been trends to use alternatives such as (a) a percentage of the MIVC, (b) the peak EMG value obtained during a dynamic activity, or (c) the mean EMG value obtained during a dynamic activity. Another technique very similar to the MIVC is to use a known level of force or to use the amplitude of the EMG signal when exerting a known force aginst an immovable object. Another alternative has been the use of EMG data obtained from subjects who are simply resting or passive. The resting EMG is a normalization procedure that is efficient for testing subjects who are being observed during functional tasks. Little is really known about the best standard to use for normalization. The rationale for selection has generally been based on logic or opinion[1,4,6,7]. So the purpose of this study is to apply two different normalization techniques on pushing activity to evaluate the appropriate method to be used. The two normalization techniques are the MIVC and the resting EMG which is referred to as "zero position".

METHOD

Subjects

Twenty university normal male students participated in this study. Their mean age was 18.8 ±1.1 years, mean height was 174.3 ± 5.5 cm and the mean weight was 71.1 ± 6.9 Kg. They were free of any musculoskeletal pain or disorders.

Instrumentation

1) A metal cupboard with a height of 120cm, width of 40 cm and depth of 60 cm was used for the pushing activity. It was sectioned from inside to distribute the weight inside it equally.
2) Load units: rectangular sand bags are used in this study of various weights (5kg, 3kg, 1kg and ½ kg). Their dimensions and sizes vary according to their weight. Each subject was asked to push 30% of his weight.
3) EMG apparatus: A BIOPAC system was used with a MP100 data acquisition unit and CMRR of 110 dB. Four channels were used to record changes in the patterns of EMG signals of the right and left erector spinae muscle and right and left rectus abdominis muscles. Acknowledge 3.7

software was used for data analysis of the raw EMG signals.

4) Disposable surface EMG electrodes: Silver-silver chloride (Ag-Agcl) circular electrodes with active surface area of 1 cm² were used to pick up the EMG activity of the selected muscles. These metal-plate electrodes are self-adhesive and disposable. The electrode leads is snapped directly from one end to the silver-silver chloride disc and from the other end it is connected to the EMG unit. The data from each channel was collected using 3 electrodes connected to the preamplifier junction box. Two of them are active and reference electrodes and the third is ground electrode. The preamplifier junction box is in turn connected to the main EMG amplifier unit through long cable. The EMG unit was supported on the subject‘s waist.

5) Digital Goniometer (Guymon Goniometer): It was used to digitally identify the angle of the trunk at the starting position of the pushing activiy.

PROCEDURE

1- EMG Preparation

The EMG interference pattern of erector spinae muscles and rectus abdominis muscles were amplified by bioelectrical amplifier which was set with a gain of 10,000. The amplifier has input impedance of 1.0 mega Ohm while the acquisition sampling rate was set at 500 samples/second.

2- Subject Preparation

The skin resistance at the electrodes' sites was reduced by wiping the skin with alcohol over the lower thoracic region, above the umbilicus, above the lateral epicondyles of both elbows. A pair of silver-silver chloride surface electrodes (active electrodes) were jammed with adequate gel and placed 3cm lateral to the spinous process of the 3rd lumbar vertebrae over the right and left erector spinae. Another pair of electrodes (reference electrodes) were also placed 2 cm above the active electrodes. The second pair of Ag-AgCl surface electrodes was attached at the level of umbilicus, 2cm from midline, over the right and left rectus abdominis muscle. Another pair of the surface electrodes (reference electrodes) were placed 2 cm above the active electrodes. Two ground electrodes were placed over the lateral epicondyles of both elbows and the other two electrodes were placed above them by 2cm.

3- Recording the EMG activity before pushing (the two normalization techniques)

(a) Recording the EMG during resting position:

To normalize the EMG signals, the first normalization technique was the starting position before the activity (zero position). The EMG signals were recorded form the right and left erector spinae muscles and right and left rectus abdominis muscles while the subject was in the erect standing position. This resting position was taken as reference for the activity and the percentage of normalized EMG activity was calculated according to the following equation:

$$\% \text{ Normalized EMG} = \frac{(activity - resting)}{resting} \times 100$$

(b) Recording the EMG during MIVC

To record the MIVC of the erector spinae muscles, each subject was asked to assume a prone relaxed position on bed with both knees extended, ankles free from the bed edge, and hands were placed beside the trunk. Resistance was applied to the thorax and pelvis through two adjustable straps (one was just above the spines of the scapulae to allow no movement during trunk extension and the other was around the hips to prevent tilting of the pelvis or extension by gluteus maximus).

Similarly, to record the MIVC of the rectus abdominis muscles, each subject was asked to assume relaxed supine position on bed. Resistance was given by two broad straps: one across the subjects' upper trunk just above the thoracic cage to allow no movement during trunk flexion, and one around the hips to prevent tilting of the pelvis.

During these trials the subject was asked to exert his maximum trunk flexion and extension to produce the highest amplitudes of the muscle activity in each attempt. The MIVC was recorded for five seconds with two minutes resting period between trials to avoid fatigue. The MIVC was taken as 100% or full activation for the recorded muscle.

$$\% \text{ Normalized EMG} = \frac{recorded \cdot data}{MIVC} \times \cdot 100$$

4- Recording the EMG activity during pushing at 40 trunk inclination

Before the start of pushing activity (Fig.1), each subject was instructed to stand in front of the cupboard, assuming a step standing position with a distance of 50 cm between feet while the right foot is the preceding one, and to push at the elbow level while facing forward. At each time before initiation of the pushing activity the trunk inclination angle was adjusted at 40° trunk flexion using the digital goniometer. Its axis was placed at the most superior aspect of the iliac crest, aligned with the mid axillary line. The stationary arm is positioned in a line horizontal to the floor, while the movable arm is aligned with the mid axillary line.

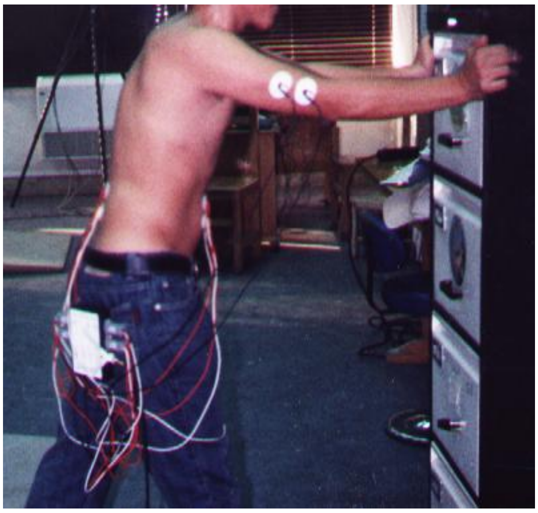

Fig. (1): The subject while assuming the position during pushing at 40 degrees trunk inclination angle. The EMG activity of the abdominal and back muscles are recorded.

RESULTS

The results of the study showed that the mean values of the normalized EMG of the upper erector spinae muscles using MIVC as a normalization technique were 65.51 % (±27.7) for the right muscles and 65.25 % (± 27.1) for the left back muscles. For the abdominal muscles the % of normalized EMG activity was 63.69 % (±26.6) and 66.08 % (±25.7) for the right and left rectus abdominis muscle respectively. Using the resting EMG as a normalization procedure indicated that the percentages of normalized EMG were 288.79 % (±11.34) and 288.33 % (±11.05) for the right and left rectus abdominis muscles and 287.51 %(12.19) and 286.88 % (11.54) for the right and left upper erector spinae muscles respectively (table 1 and fig. 2). Statistical analysis using Pearson Moment correlation coefficient indicated that there is low correlation between the normalized EMG using MIVC and using resting level of EMG. The "r" value between the two variables is 0.26 (P>0.05) for both right and left rectus abdominis muscles (fig. 3 and 4) and 0.34 (P> 0.05) and 0.31 (P> 0.05) for the right and left erector spinae muscles respectively (fig. 5 and 6).

Table (1): Correlation between the two ways of EMG normalization techniques (% from zero position and % from MIVC) for the right and left rectus abdominis and erector spinae muscles during pushing activity.

	Rt Abdominal		Lt Abdominal		Rt back		Lt back	
	% Resting	% MIVC	% Resting	% MIVC	% Resting	% MIVC	% Resting	% MIVC
$\bar{X}$	288.79	63.69	288.33	66.08	287.51	65.51	286.88	65.25
SD	11.34	26.6	11.05	25.7	12.19	27.7	11.54	27.1
r	0.26		0.26		0.34		0.31	
P value	0.25		0.26		0.13		0.18	

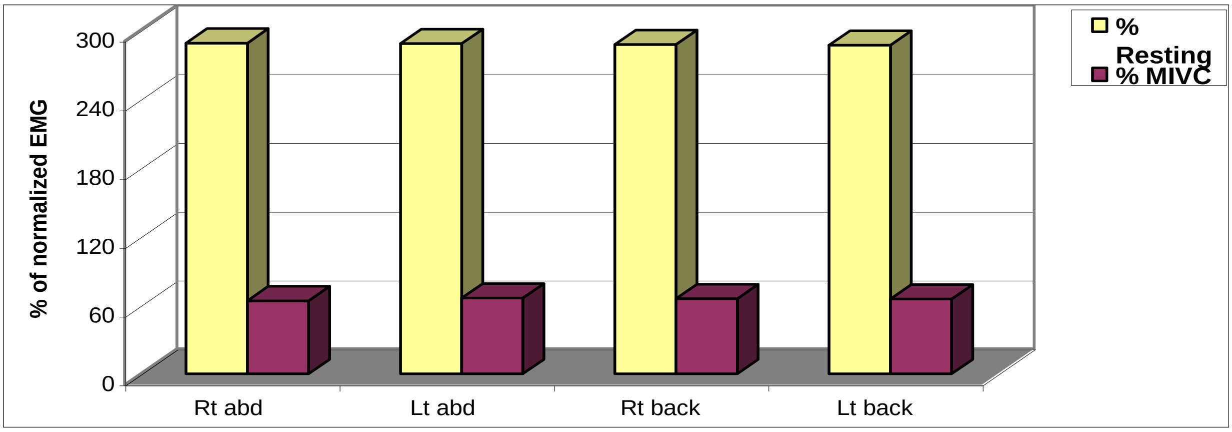

Fig. (2): Percentage of normalized EMG activity of the right and left abdominal muscles (Rt abd and Lt abd) and right and left back muscles (Rt back and Lt back) using two normalization techniques (% MIVC and % resting).

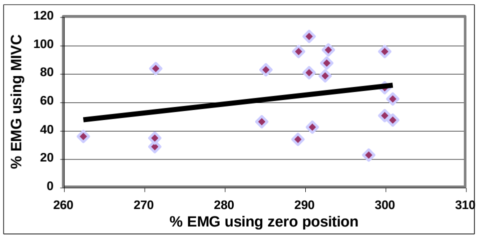

Fig. (3): Scatter diagram of the EMG recorded for the right rectus abdominis using the two normalization techniques.

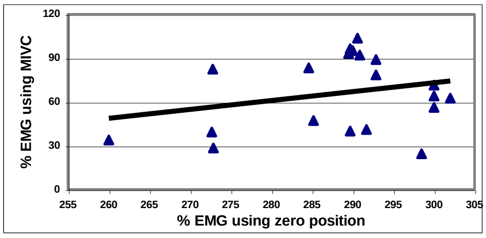

Fig. (4): Scatter diagram of the EMG recorded for the left rectus abdominis using the two normalization techniques.

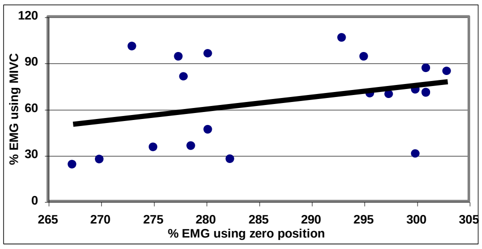

Fig. (5): Scatter diagram of the EMG recorded for the right erector spinae using the two normalization techniques.

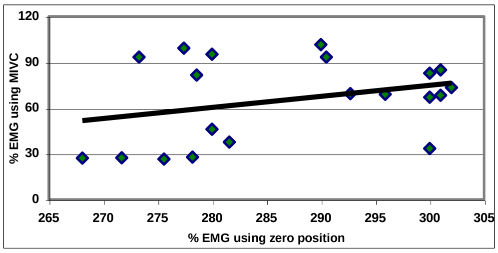

Fig. (6): Scatter diagram of the EMG recorded for the left erector spinae using the two normalization techniques.

DISCUSSION

Estimates of the amount of force exerted by a muscle using EMG rely partially upon the accuracy of the reference point used in the normalization technique[6]. Maximal isometric voluntary contractions are often subjective, and potentially limited by sensation of pain in injured individuals. The use of the MIVC as a reference contraction is based on the idea that the amount of force produced varies directly with the myoelectric output. This is not quite true, although many researchers have found a linear or near linear relationship between the myoelectric signal and the force produced. It is debatable if one can really ever obtain a true MIVC[3].

The objective of the study done by Marras and Davis[4] was to develop a normalization technique that predicts an electromyographic (EMG) reference point from sub-maximal exertions. Regression equations predicting maximum exerted trunk moments were developed from anthropometric measurements of 120 subjects. In addition, 20 subjects performed sub-maximal and maximal exertions to determine the necessary characteristic exertions needed for normalization purposes. For most of the trunk muscles, a highly linear relationship was found between EMG muscle activity and trunk moment exerted. This analysis determined that an EMG-moment reference point can be obtained via a set of sub-maximal exertions in combination with a predicted maximal exertion (expected maximum contraction or EMC) based upon anthropometric measurements. This normalization technique overcomes the limitations of the subjective nature for the MVC method providing a viable assessment method of individuals with a low back injury or those unwilling to exert an MVC as well as could be extended to other joints/muscles.

Completing their work, Marras et al.,[6] studied the validation and use of a non-MVC normalization technique for the trunk musculature to predict spinal loads. They stated that estimates of the amount of force exerted by a muscle using electromyography (EMG) rely partially upon the accuracy of the reference point used in the normalization technique. Accurate representations of muscle activities are essential for use in EMG driven spinal loading models. The expected maximum contraction (EMC) normalization method was evaluated to explore whether it could be used to assess individuals who are not capable of performing a maximum exertion such as a person with a low back injury. Hence, their study evaluated the utility of an EMG normalization method that draws upon sub-maximal exertions to determine the reference points needed for normalization of the muscle activities. The EMC normalization technique was compared to traditional MVC-based EMG normalization by evaluating the spinal loads for 20 subjects (10 males and 10 females) performing dynamic lifts. The spinal loads estimated via an EMG-assisted model for the two normalization techniques were very similar with differences being <8%. The model performance variables indicated that both normalization techniques performed well ($r^2 > 0.9$ and average error below 6%) with only the muscle gain being affected by normalization method as a result in different reference points. Based on these results, the proposed normalization technique was considered to be a viable method for EMG normalization and for use in EMG-assisted models. This technique should permit the quantitative evaluation of muscle activity for subjects unable to produce maximum exertions.

The results obtained from the present study are supported by Soderberg and Knutson[7] who indicated that the disadvantage of using resting EMG as normalization method is that the data provide no information for considering data relative to maximal exertion. This is evident in this study as there was low correlation between the normalization using MIVC and using resting level of EMG. On the other hand this technique (resting EMG) can be modified and used as normalization procedure for stroke patients or patients with neurological disorders[7]. Similarly, LeVeau and Andersson reported that the resting EMG is not considered essential by many because this same signal component is included in all of the tasks evaluated.

Conclusion

The results obtained from this study support that when using a normalization technique to interpret the EMG data, one can not rely on the resting level of EMG activity of the tested subject. Another mean of normalization is preferred to be used whether the MIVC or the sub maximal activity or EMC or known level of force. The reliability of using resting level of EMG as a normalization procedure in neurological cases needs to be investigated.

REFERENCES

1- Barr, A.E., D., Ozkaya N. and Nordin, M.: Testing apparatus and experimental procedure for position specific normalization of Electromyographic measurements of distal upper extremity musculature. J. Clin Biomech. Aug. 16(7): 576-585, 2001.
2- Lehman, G.J. and Mc Gill, S.M.: The importance of normalization in the interpretation of surface electromyography: a

proof of principle. J., Manipulative Physiolo. Ther Sep., 22(7): 444-446, 1999.

3- Leveau, B. and Andersson, G.: Output forms data analysis and application, interpretation of the electromyographic signal, In: Selected topics in surface electromyography for use in the occupational setting: expert perspective, edited by Soderberg, G.L, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, 2002.

4- Marras, W.S. and Davis K.G.: A non-MVC EMG normalization technique for the trunk musculature: part1. Method development Journal of Electromyography and Kinesiology. Feb., 11(1): 1-9, 2001.

5- Marras, W.: Overview of Electromyography in Ergonomics, In: Selected Topics in Surface Electromyography for Use in the Occupational Setting: Expert Perspectives, edited by Soderberg, G.L., U.S., Department of Health and Human Services, Public Health Service, Centers for Disease Control; National Institute for Occupational Safety and Health., 2002.

6- Marras, W.S., Davis, K.G. and Maronitis, A.B.: A Non-MVC EMG Normalization Technique for the Trunk Musculature: Part 2. Validation and Use to Predict Spinal Loads, Journal of Electromyography and Kinesiology, 11(1), 11-18, 2001.

7- Soderberg, G.L., and Knutson, L.M.: A Guide for Use and Interpretation of Kinesiologic Electromyographic Data., Journal of Physical Therapy, 80(5), 485-498, 2000.

الملخص العربى

استخدام طريقتين من طرق معايرة النشاط العضلى الكهربى فى تحليل نشاط الدفع

الغرض من هذه الدراسة هو تقييم مدى كفاءة طريقتين مختلفتين من طرق معايرة النشاط العضلى الكهربى. الطريقة الاولى والشائعة الاستخدام هى المعايرة باستخدام أقصى انقباض عضلى ثابت والطريقة الثانية هى باستخدام وضع السكون قبل البدء فى أداء المهمة وقد تم تسميته بوضع الصفر. وقد تطوع عشرون شخص من الاشخاص الطبيعيين فى المشاركة فى هذه الدراسة. وقد قام كل شخص بدفع دولاب يحتوى على أحمال تساوى 30 % من وزنه وذلك عند زاوية ميل للجذع 40 درجة. واثناء هذه المهمة تم تسجيل النشاط العضلى الكهربى لعضلات الجذع اليمنى واليسرى ولعضلات البطن اليمنى واليسرى. ولعمل معايرة للنشاط العضلى تم تسجيل النشاط العضلى لنفس العضلات أثناء وقوف الشخص فى وضع الانتصاب وتم تسميته وضع الصفر والطريقة الثانية للمعايرة تمت عن طريق تسجيل النشاط الكهربى للعضلات أثناء أقصى انقباض عضلى ثابت. وقد تم عمل عملية تكامل لبيانات رسم العضلات الكهربــى وقد تم تحديد قيمة النشاط العضلى بعمل نسبة من كل طريقة من الطريقتين. وقد أوضحت الدراسة أنه لا توجد علاقة ذات دلالـة احصائية بين معايرة النشاط العضلى باستخدام طريقة "وضع الصفر" وباستخدام طريقة "أقصى انقباض عضلى ثابت". وتم استنتاج أن طريقة "وضع الصفر" غير مستحبة أثناء استخدام رسم العضلات الكهربى فى الدراسات الميكانيكية.