

## EVALUATION OF MUSCLE FORCE BY THE USE OF SURFACE ELECTROMYOGRAPHY

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### ABSTRACT

Bipolar electromyography with surface electrodes is used for the evaluation of muscle force. The individual maximum force ( $F_{max}$ ) is the reference value (100%), and this  $F_{max}$  is measured in the same position of the arm in which the occupational work is done. The native EMG is integrated as well as the EMG which is transmitted during the occupational work by means of a 4-channel telemeter.

In the workshop of a service station the highest values of expended muscle force of the flexors and extensors of the forearms were established in work on dismantling motors designed for a complet overhaul (48% of the maximum); in operating a lever device designed by the author, lift muscle forces were expended in a range of 5% to 48% and in the case of a rehabilitation worker in the range of 15% to 100%.

The increasing specialization in work operations gives rise to a onesided excessive and long-term load on certain muscle groups of the limbs and thus also on joints and connective tissues. The most frequent factors responsible for illnesses due to overload of the upper limbs<sup>1,4,5,6,7,8</sup> are the following:

- the high degree of muscle force expended at static or static-dynamic work,
- the position of, particularly, the upper limbs, whether it is a position required by the working process, or an unsuitable position due to habit,
- the frequency of working movements during a time unit,
- the pressure of tools and manipulated objects on hand muscles, distribution of these pressures, and possibly the simultaneous effects of vibration, cold, etc., and
- the quality of the protective gloves used, primarily from the aspects of worsened gripping, slipping of tools due to dirtied gloves, and pressure of the gloves in the area of the carpal tunnel.

Of the factors mentioned above which must be assessed as a complex whole, direct measurement of muscle force is of advantage: the evaluating apparatus of tensometric recorders is relatively simple, and the results in physical units are almost immediately known and well comparable. On the other hand, designing suitable transducers for a concrete control device of machines or various tools is

rather difficult. The difficulties are enhanced in variable operations consisting of a number of movements of very short duration and a frequent change of tools (assembly and dismantling in car repairs). In some types of activity the recording of muscle force is technically impossible (rehabilitation work). For this type of activity an indirect method is used; it is based on monitoring the EMG, recorded by surface electrodes from muscles during work.

#### SUBJECTS AND METHODS

Under field conditions, 6 motor-mechanics (AM) were examined at various operations connected with the dismantling of car engines and their general overhaul; 3 lift operators (TV) in a mine lift; and 3 rehabilitation (RP) workers (women) in the health service. All were skilled workers in the age group of 26–40 years.

A four-channel BIOTEL (Schwarzer) telemetric system was used for the transmission of the native EMG. The native EMG was possible to integrate in intervals of 0.5 to 60 sec, but the intervals of 5 sec and 1 sec were the most used; the choice of the length of the integrated segments depended on the length of the working operation. The integrated values were transmitted to an impulse counter and tape recorded. In the laboratory the data were converted in digital form by means of punch-tape (Cellatron) and statistically evaluated. If the EMG record was to be subjected also to frequency analysis, then the native EMG was first recorded on a tape-recorder (Analog-7-Phillips) and this record used either for evaluation on the integrator or on an apparatus suited for EMG frequency analysis.

Examinations were made according to the following principles: Biopotentials are determined from muscle groups participating in the given activity at the exertion of maximal muscle force ( $F_{\max}$ ); the integrated EMG values at these maximum forces correspond to 100%.  $F_{\max}$  should be determined immediately before the measurement of occupational work because the fatigued muscle could show different values in the integrated EMG record due to fatigue processes in the muscle.  $F_{\max}$  is measured in the same or a very approximate position of the limb in which work operations are performed. Electrodes are positioned in the same place during the measurement of maximum force as well as of muscle force during work operations. This means that both types of measurement are performed on the same day.

Technical equipment permitting it is useful to express  $F_{\max}$  also in physical units (Newton). By comparing the values obtained with tabular values, we can judge the physical fitness of the person examined from the aspect of muscle force, and perhaps prevent possible aggravations. If technical equipment does not permit to measure maximum force in physical units in industrial work, then we measure at least the maximum muscle force of hand grip on a manual dynamometer, and this is then compared with the standards of our population. In our laboratory we use a manual dynamometer constructed in the workshop of IHE. Signals from the tensometer are evaluated on a TDA-6 (Mikrotechna) commercial apparatus.

## RESULTS AND DISCUSSION

An investigation of occupational activity was carried out at workplaces where it was necessary to assess whether the occurrence of the illness, generally known as "tennis elbow", i.e. the syndrome of pain and local tenderness in the region of the lateral epicondyle of the humerus, might be largely an effect of the work done.

The electromyogram was recorded from the extensors and flexors of the right (P) forearm in all subjects; in operators, also from the left (L) forearm; and in rehabilitation workers, also from the muscles of the right-hand thenar. Figure 1 shows the mean values of muscle force expended during the working movements of most operations involved in the given occupation. Besides mean values, the maximum values obtained in measurements during the examination, are also given. In the case of motor-mechanics (AM) the maximum values might have been higher than shown in Figure 1 if the movements had been performed in very short intervals. However, during the examination of this group (AM) the technical equipment did not permit to integrate the native EMG in time intervals shorter than 5 sec. In the other two groups the maximum values were determined from one-second integrated records.

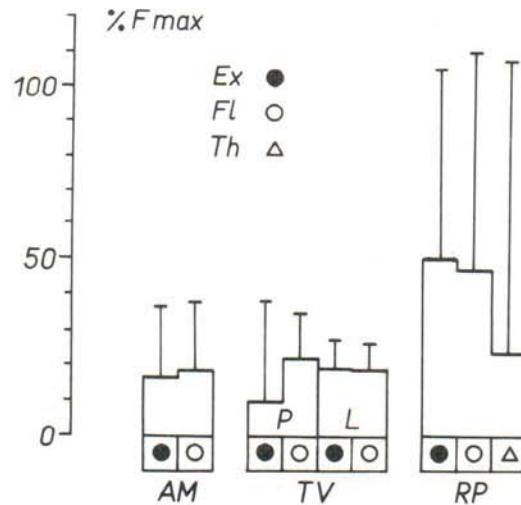


FIG. 1 - Mean values and maximum values of the integrated EMG obtained during the occupational work. AM motor-mechanic, TV-lift operator, RP-rehabilitation worker.

From our laboratory experiments, monitoring long-term tolerance at the performance of dynamic muscle work, as well as from the reports of some authors<sup>2,3</sup> it may be assumed that dynamic work done at 30%  $F_{max}$  is well tolerable long-term, and that this value should not give rise to an overload of the muscular and connective apparatus.

If we take into account the other criterion, i.e. the highest values of muscle force measured during industrial work then in the groups AM and TV (Fig. 1)

the emergence of epicondylitis could be hardly attributed to excessive short-term load.

In the case (Fig. 2) of rehabilitation workers (RP) the highest values were identical with  $F_{\max}$  values, and even during the actual work the measured values were higher than the values obtained during the examination of  $F_{\max}$ .

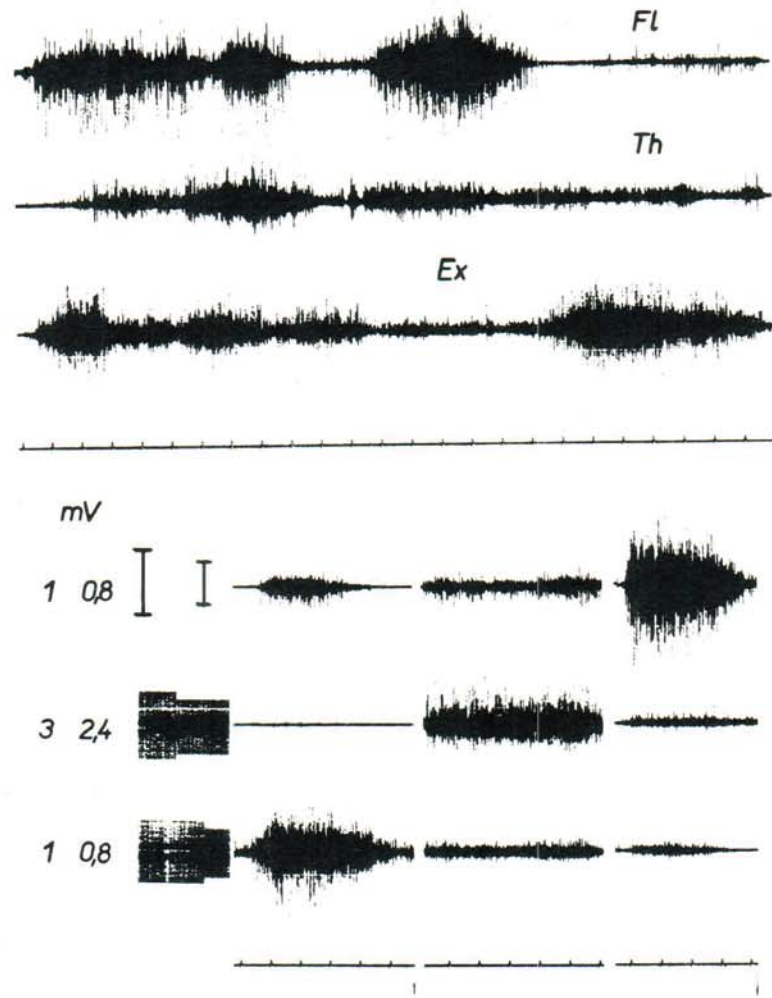


FIG. 2—EMG record from examinations of a rehabilitation worker. The upper part of the figure shows the record from an examination during rehabilitation work. The lower part shows the EMG at determination of maximum muscle force; on the extreme left are values in micro-volts.



From the results it may be concluded that in the case of motor-mechanics (AM) and operators of mine lifts (TV) the disease (epicondylitis) could not be unambiguously described as an occupational one, while in the case of rehabilitation workers it was undoubtedly due to the occupation.

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