

ELECTROMYOGRAPHIC ACTIVITY AS AN INDICATOR OF BACK LOAD AT WORK

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1. INTRODUCTION

Back muscles act with a shorter lever arm to lumbar vertebrae, than external loads while e.g. handling loads. Thus the tension in back muscles is the most important factor contributing to the spinal load.

In static conditions the electromyographic (emg) activity and the force production of limb muscles have been found to correlate well with each other linearly (2) or nonlinearly (9). Assuming the same to be valid for back muscles, the load on the back has often been evaluated by the emg-activity of erector spinae muscles, as described by root mean squares (rms) or rectified averages of the raw emg-signal (e.g. 1, 3). However, in dynamic work some additional factors influence this relationship. The relationship between muscle force and emg-activity is strongly dependent on the length of the muscle (5); in elongated muscles most of the force is produced by passive stretching, not by an active contraction. In back muscles usually no electric activity appears in a stooped down posture (4). Muscles develop greater forces in eccentric than in concentric contractions with the same electric activity (5).

Our aim was to develop a portable multichannel system with which electromyography of back muscles can be recorded at work places during normal work. The relationship between emg and biomechanically computed muscle force in non-rotated postures was studied in laboratory. Moreover, we studied the differences in emg-activities of left and right erector spinae muscles in rotated postures in static and dynamic conditions to see if the differences could be used as indicators of trunk rotations at work.

2. MATERIALS AND METHODS

The recording system had to be light and small, so that it could be carried by a worker without disturbing the work. However, both artefacts induced by electrode and cable movements, and electric interference had to be rejected effectively. To fulfil these requirements a system was constructed (Figure 1) consisting of surface electrodes, preamplifiers attached close to the electrodes, a main unit and a small tape recorder (TEAC HR-30E). The system has four EMG-channels. Besides band-pass amplifiers, the main unit has a timer and remote control circuits for the recorder to allow recording of fixed length samples with fixed intervals during a whole work-day. Of the seven channels of the recorder one is used for noise compensation and one for a time reference signal for the sampling method. The whole recording system weighs less than 1 kg, and it can be carried in two pockets.

The laboratory experiments were done with 10 healthy subjects, 5 men (age 29-36 years, height 178-189 cm, weight 67-79 kg), and 5 women (age 33-42 years, height 160-171 cm, weight 45-64 kg).

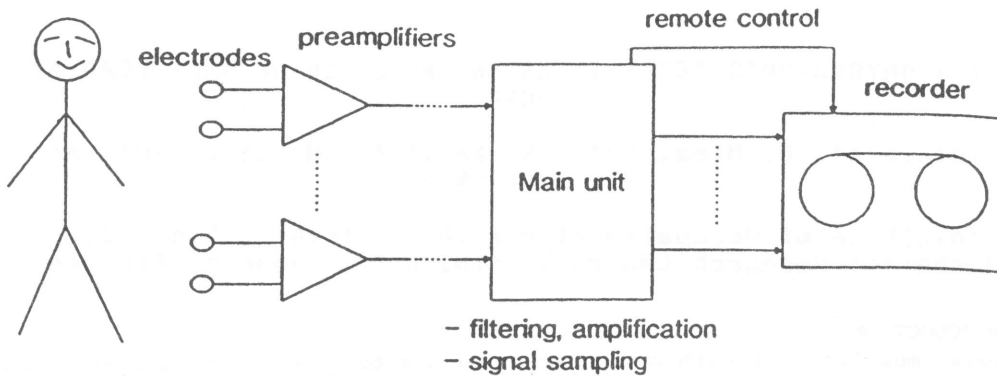


Figure 1. Block diagram of the recording system.

The emg-electrodes were placed at the L1 and L4 levels on both sides of the spine midline. The electrodes of one electrode pair were placed longitudinally and the displacement between the electrodes was 3 cm when the subjects sat with their spine flexed. The experiments began with a period of rest, followed by an isometric maximal voluntary contraction (IMVC) of back muscles with the subjects lying prone.

Static non-rotated postures studied included standing straight, and forward inclinations of the body of 15, 30, and 45 degrees. Deeper flexions were excluded because the emg-activity was expected to be negligible after 45 degrees (8). The subjects stood either without any external load or with a box weighing 10 or 20 kg. The angle of the hip-shoulder line was measured visually with an angle measuring device.

In rotated postures the trunk was rotated to the left or to the right so that the line between the hands was 45 degrees rotated from the frontal plane. The tests were only done with the box weighing 10 kg, and the height of the box was adjusted on the same levels as in the non-rotated tests.

In the dynamic tests the subjects lifted the box (or extended without a load) from the 45 degrees forward inclined posture to erect standing and then lowered again back to the initial posture. The same weights were used as in the static tests. The lifts had to be done smoothly without jerks, but no instructions were given regarding the speed of lifts.

The emg-signals were sampled by the computer with an A/D converter at 1000 samples/s. The signal describing the emg-activity was obtained from the raw emg-signals by full-wave rectification and sliding averaging with a selectable averaging window. The peak emg-activity during the IMVC test obtained with the window of 500 ms was used as the scaling value for the emg-activities recorded during the other experiments. In static experiments the mean emg-activities of muscles during a 3 s recording period were computed. For dynamic experiments the window length used was 200 ms and the peak activities were detected.

The emg-activity in non-rotated postures was compared to biomechanical muscle force estimates (BMF) based on optoelectronic kinematic recordings. The method was slightly modified from the method used by Leskinen et al (6), to produce the force of back muscles and not the compressive force on the spine. For static postures the parameters of linear regression between BMF and emg-activity were defined. For dynamic experiments the cross-correlation function between BMF and emg-activity was computed.

3. RESULTS

Figure 2 shows the means of the 10 subjects' BMF and emg-activity on the right erector spinae muscles at the L1 and L4 levels in static postures. The BMF increased homogeneously with the increasing flexion angle, but the emg-activity stopped increasing after 30 degrees of inclination at the L4-level, and even before at the L1-level.

The median coefficient of correlation in linear regression was 0.831 (range 0.08 - 0.986) when all postures were included in the regression, and 0.962 (range 0.548 - 0.986) when the inclination of 45 degrees was excluded from the regression.

Figure 3 shows the means of the peak BMF and the peak emg-activities on the right side in lifts. The peak BMF increased quite linearly with the increasing external load. There was no difference between lifting and

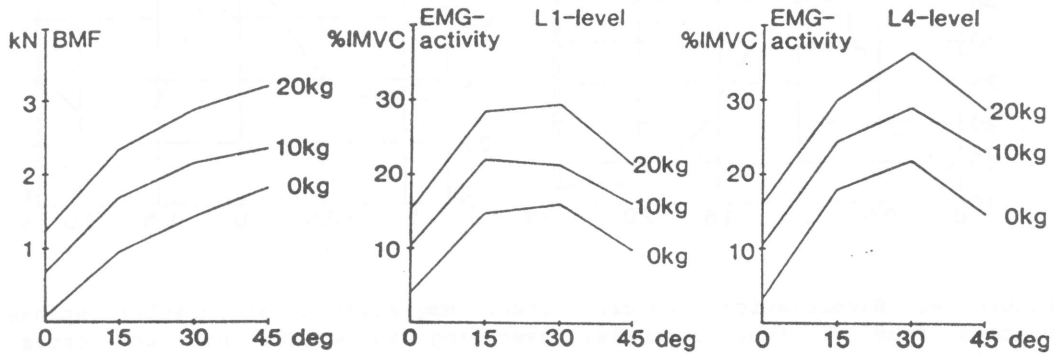


Figure 2. Mean biomechanical muscle force (BMF) and emg-activity of right erector spinae muscles at L1 and L4 levels in static holding of 0, 10 and 20 kg weights with different trunk inclinations.

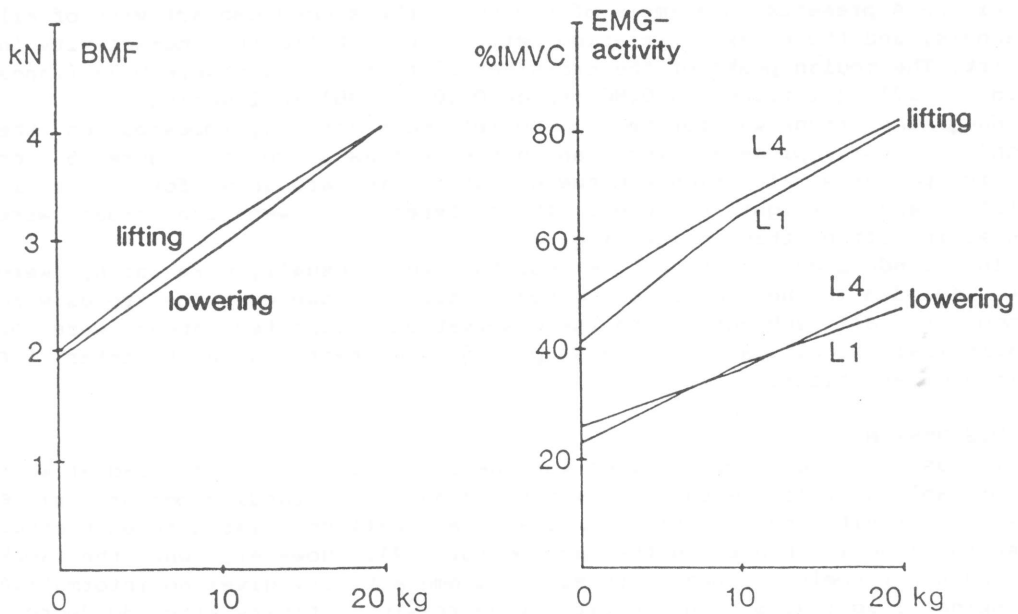


Figure 3. Average BMF and emg-activity peaks when lifting and lowering different weights from and to 45 degrees inclination.

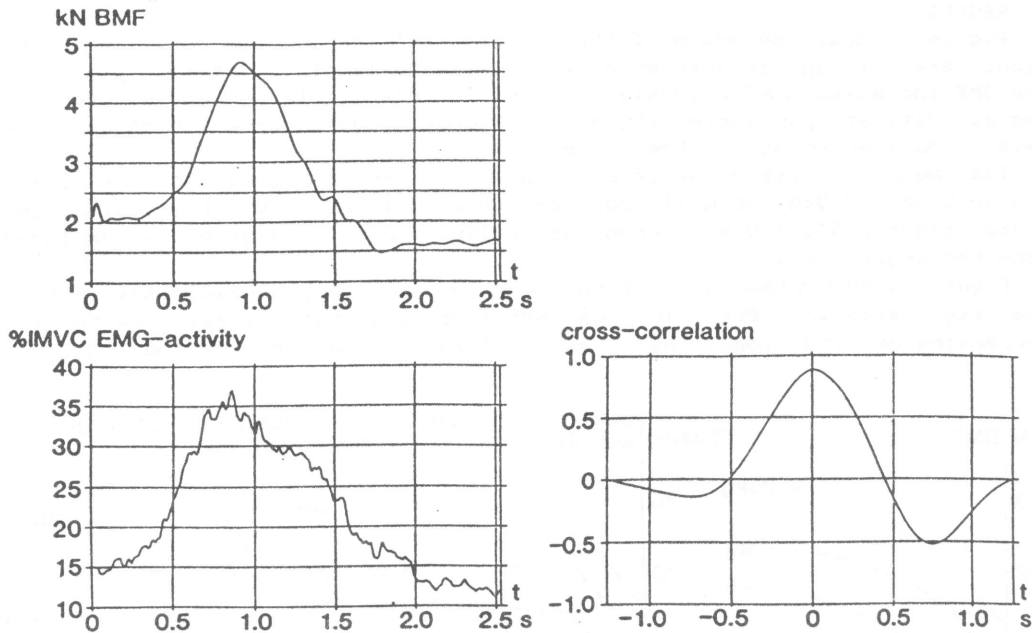


Figure 4. Biomechanical muscle force, emg-activity of erector spinae muscles (sum of four channels, averaging window 200 ms) and cross-correlation of BMF and emg-activity in a lift of 20 kg.

lowering in the BMF. Also the peak activity increased homogenously with the load. However, there was a big difference between lifting and lowering; the peaks in lifting were almost twice as high as in lowering.

Figure 4 presents an example of the BMF, the summed emg-activity of all channels, and the cross-correlation between the BMF and the emg-activity in a lift. The median peaks of the cross-correlation function were 0.72 (range 0.18 - 0.97) in lifting and 0.80 (range 0.10 - 0.96) in lowering.

When the trunk was rotated to the left more activity appeared on the right erector spinae muscles than on the left as shown in Figure 5 for static postures. In Figure 6 the emg-activities are shown for lifts in rotated and straight postures. The differences between the sides were bigger in lifting than in lowering.

The standard deviations of the results, which usually were high, were not included in the figures to improve clarity. However, the trends were common to all subjects, and the observations reported above were of statistical significance (at least $p < 0.05$) when tested with the t-test for paired observations.

4. DISCUSSION

The use of long emg recordings for the evaluation of spinal load at work is probably justified when work is done in an erect standing posture, since the emg-activity and the spinal load are very well correlated to each other when the load is changed in the same posture (2). However, when the work includes extremely stooped postures, the emg-activity gives no information on spinal load (4, 8). Our results of decreasing activity after 30 degrees of inclination support the earlier findings that when the muscle length is

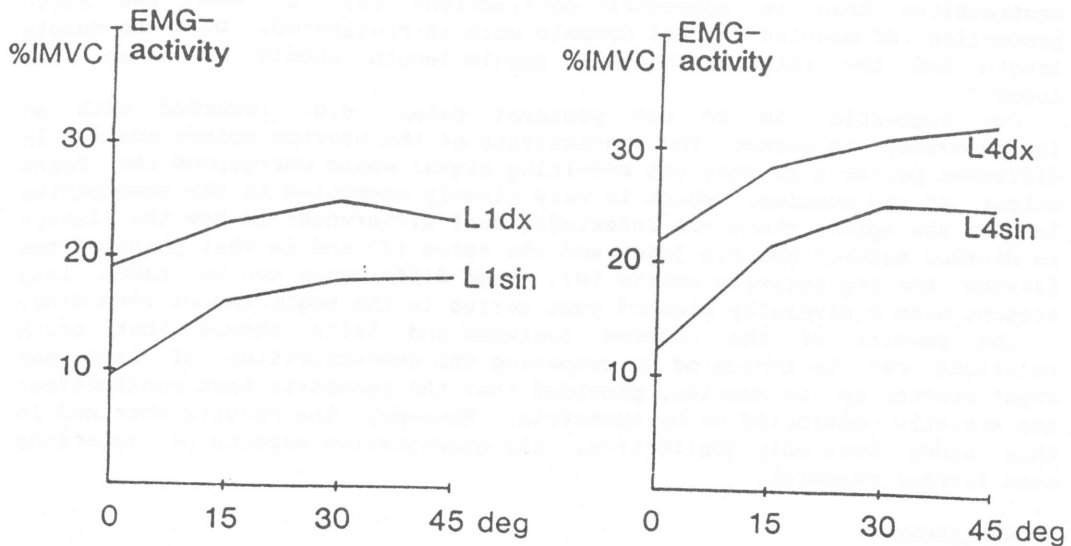


Figure 5. Mean emg-activity of erector spinae muscles in static holding of 10 kg with the trunk rotated to the left.

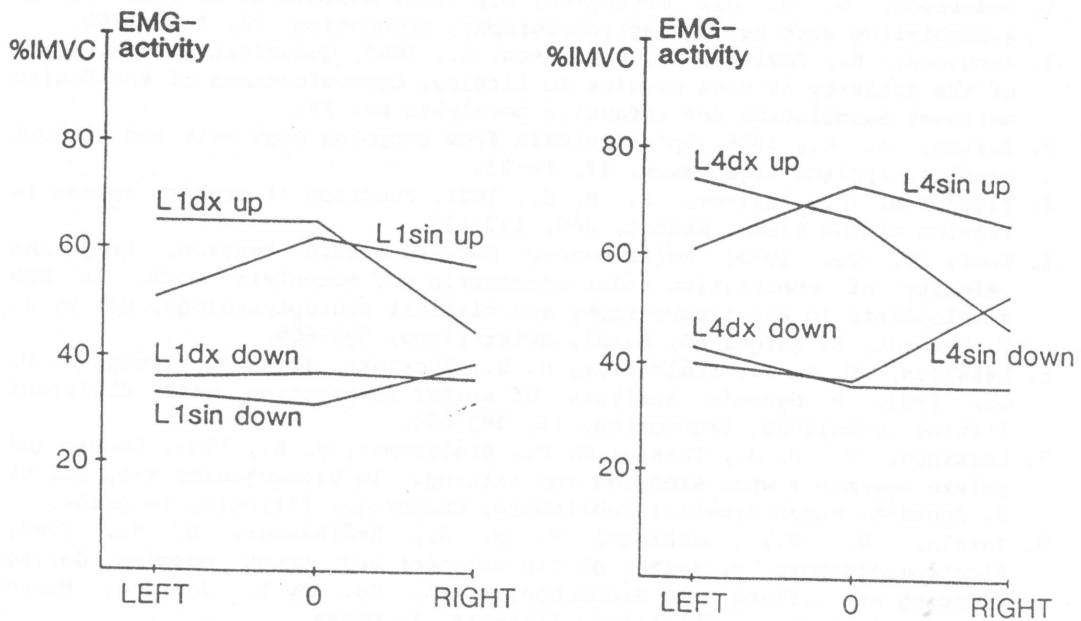


Figure 6. Average peak emg-activities of erector spinae muscles in lifting (up) and lowering (down) in 45 degrees left and right rotated and straight (0) postures.

increased, an increasing portion of the force output comes from passive straining of the muscle itself and of the posterior ligaments (e.g. 4).

The difference that we found in peak emg-activities of lifting and lowering despite the equal peak BMF's is supported by the finding that muscles create greater forces with equal activities in eccentric

contractions than in concentric contractions (5). So when the force production of muscles in real dynamic work is considered, both the muscle length and the rate of change in muscle length should be taken into account.

Our suggestion is to use postural data, e.g. recorded with an inclinometer, to correct the emg-activity of the erector spinae muscles in different postures so that the resulting signal would correspond the force output of the muscles, which is very closely connected to the compressive load on the spine. There are interindividual differences in how the flexion is divided between the hip joint and the spine (7) and in what phase of the flexion the emg-activity ceases (8). Such differences can be taken into account with a carefully planned test series in the beginning of recording.

The results of the rotated postures and lifts showed that trunk rotations can be indicated by comparing the emg-activities of left and right erector spinae muscles, provided that the isometric test contractions are strictly controlled to be symmetric. However, the results obtained in this study were only qualitative, the quantitative aspects of rotations need further research.

ACKNOWLEDGMENT

This study was supported by the Finnish Work Environment Fund

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