

ELECTROMYOGRAPHIC ACTIVITY OF BACK MUSCLES, STATURE CHANGES AND PERCEIVED EXERTION IN CONTINUOUS MANUAL HANDLING WORK

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Mechanical load on the back at work has an effect on the generation of low back pain (Andersson 1981). To prevent back problems changes in work environment and work methods may be useful. To evaluate the results of such changes methods are needed to estimate the back load at work. In this study three such methods were used: electromyographic activity, stature changes and rating of perceived exertion.

EMG activity has been used as a descriptor of back muscle load at work (Andersson and Örtengren 1984, Burton 1986). The relationship of EMG activity to muscle force depends on muscle length and changes of muscle length (Leskinen, Nieminen, Kalli, Gautreau and Kuorinka, 1987), but in amplitude distributions of long recordings the overall effects of such factors will be cancelled, if the muscles have to work both concentrically and excentrically.

The intervertebral discs lose thickness during work because of fluid outflow. Changes of stature during a work day range from a few millimetres up to two centimetres (Tyrrell, Reilly and Troup 1985). To measure such small changes reliably a special measurement device is needed with which the posture in successive measurements is controlled to be unchanged (Eklund and Corlett 1984).

Rating of perceived exertion (RPE, Borg 1982) measures subjective overall reactions to physical work. In manual handling the load on the back is expected to be one of the major factors contributing to the exertion perception.

Methods

Nine subjects (five men and four women) worked handling boxes. Lifts from the floor to a roller table, pushing the table about 5 m, lifts from the table to a conveyor belt, and these three tasks reversed made up a cycle which was continued for 30 min with free pacing. Each subject selected the weight of the boxes with the 'rating of acceptable load' (RAL) procedure (Griffin, Troup and Lloyd, 1984) to be acceptable for lifting from table to floor and back up three times a minute for 30 min.

EMG of back muscles was recorded bilaterally at the L1 and L4 levels with a portable system consisting of surface electrodes, preamplifiers, main amplifiers and a small tape recorder (Teac HR 30-E) (Nieminen, Kalli, Leskinen and Kuorinka, 1986). For scaling the EMG activity we compared different test contractions to each other: isometric maximal voluntary contractions of trunk extensors while prone (IMP) and standing (IMS), maximal isometric lifting force at the knee level (IML), and a submaximal 'RAL-holding test' (RH), in which the subject held in 30° trunk flexion a box, the weight of which was the RAL for one lift in five minutes for an eight hours work day (Griffin et al., 1984).

Amplitude distributions of full-wave rectified and averaged EMG signals were used to describe the muscle load at work. The distributions of differences between the activities of right and left back muscles were used to indicate trunk rotations. All distributions were calculated for the whole 30 min period and for the four minute periods starting after the first and 26th minutes.

The stature was measured before the work and after working for 5, 15, 25, and 30 minutes with a device which had five contact switches behind the body to control the posture and a force plate to control the weight distribution between heels and soles. Before each stature measurement the subjects gave their RPE in Borg's (1982) category scale (0-10) with ratio properties. To assess possible differences the paired t-test was applied ($p \leq .05$).

Results

The mean RAL for three lifts and lowerings a minute for 30 min was 9.0 kg (s.d. 5.9 kg), and for one lift and lowering in five minutes for 8 h 13.3 kg (s.d. 10.4 kg). The subjects lifted in the average 160 times (s.d. 31) during the half an hour. The mean lifting frequency decreased ($p < 0.001$) from 32 (s.d. 3) during the first five minutes to 22 (s.d. 8) during the last five minutes.

The EMG activities on all four channels in different isometric tests are given in table 1 as proportions of the activities during isometric maximal extension while prone, which generally gave the highest activities.

Table 1—EMG activities (mean and s.d.) in isometric maximal extension standing (IMS), isometric maximal lifting (IML) and 'RAL-holding test' (RH) in % of the activities during isometric maximal extension while prone (n=9).

test	L1 dx		L1 sin		L4 dx		L4 sin	
	mean	sd	mean	sd	mean	sd	mean	sd
IMS	81	18	78	16	78	14	81	13
IML	62	24	54	16	72	35	75	35
RH	24	9	21	7	29	10	29	8

Table 2 shows the main statistics of EMG activity distributions. The division of activities into classes in steps of 50 % of RH-level revealed that the activity on the right and left back muscles was above 200 % of RH-level on L1 4.8 % and 7.0 % of time and on L4 2.3 and 3.3 %, respectively. The amount of the highest activities did not change significantly during the experiment, but there was a shift ($p < 0.05$) from the second lowest class (50-100 %) to the lowest activity class (0-50 %).

Table 2—Means, medians, 25 and 75 percentile points of EMG activities (expressed as % of RH) of the whole 30 min period, and of four minutes periods in the beginning and end of work. The statistically significant changes from 1-5 min to 26-30 min are shown by asterisks: * $p < 0.05$ and ** $p < 0.01$.

period (min)	channel	mean	median	25 %	75 %
0-30	L1 dx	64	46	11	99
	L1 sin	69	49	15	105
	L4 dx	53	38	10	81
	L4 sin	93	43	10	89
1-5	L1 dx	74	59	21	108
	L1 sin	82	66	28	120
	L4 dx	61	48	19	87
	L4 sin	68	59	24	98
26-30	L1 dx	58 *	40 *	9 *	91
	L1 sin	64 *	45 **	12 *	98 *
	L4 dx	48 *	34 *	8 *	71
	L4 sin	51 **	35 **	8 *	79

Table 3 shows the statistics of activity difference distributions. The activity on the left was slightly dominating, but on the L4 level the distribution shifted towards zero and was narrower in the end of the experiment.

Table 3—Means, medians, 25 and 75 percentile points of EMG activity differences between right and left back muscles (% of RH) of the whole 30 min period, and of four minutes periods in the beginning and end of work. Positive numbers indicate higher activity to the right, negative to the left. The statistically significant changes from 1-5 min to 26-30 min are shown by asterisks:

* $p < 0.05$ and ** $p < 0.01$.

period (min)	channels	mean	median	25 %	75 %
0-30	L1	-6	-10	-38	+24
	L4	-4	-4	-26	+16
1-5	L1	-8	-12	-50	+29
	L4	-8	-9	-38	+16
26-30	L1	-6	-10	-38	+24
	L4	-4 **	-4 *	-26 **	+16

The mean loss of stature during the work was 3.4 mm, but from the end of a 15 min rest, which preceded the isometric tests and some other experiments, the total loss was 8.9 mm. The mean RPE changed from 2.1 at 5 min to 2.9 at 30 min. The changes from 5 min to 30 min were significant ($p < 0.05$) for both stature and RPE.

The statistical analysis of changes in EMG activity during the experiment showed that changes in means and 75 percentile points of EMG activity distributions correlated positively with the change in lifting frequency ($p < 0.05$) and the means negatively with RPE at the end ($p < 0.05$). No significant correlations were found between stature changes and EMG activity or between stature changes and RPE.

Discussion

The frequency of lifts (160/30 min) was smaller than the instruction of the RAL procedure, which is partly explained by the pushing phases of work. The drop of lifting frequency during the experiment gave us a chance to compare, how different methods describe the change in work load.

Electromyographic activity responds to momentary changes in work load quickly. Therefore it describes the real load distribution during a long work period reliably, but is also applicable for comparing different work methods with fairly short recording times.

RPE reacts more slowly than EMG activity to changes in work load so that it reflects both the momentary load and the load perceived before. Obviously the perception of exertion in it was a reason for the reduction in lifting frequency in our experiments.

Stature changes reflect the cumulative work load, because there is no

possibility for stature regain even if the work pace is reduced if there are no rest pauses. Stature can be used for all day load measurements. Also the effect of rest pauses during work could be studied with this method.

Combination of these methods proved feasible, and because they describe different aspects of the work load, they complement each other in describing the musculoskeletal load at work.

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