Scand J Rehab Med 19: 77–84, 1987

EFFECTS OF ARM SUPPORT OR SUSPENSION ON NECK AND SHOULDER MUSCLE ACTIVITY DURING SEDENTARY WORK

Kristina Schüldt, Jan Ekholm, Karin Harms-Ringdahl, Gunnar Németh and Ulf P. Arborelius

From the Kinesiology Research Group, Departments of Physical Medicine and Rehabilitation and of Anatomy, Karolinska Institute, Stockholm

ABSTRACT. The aim of this study was to evaluate the effects on the levels on neck and shoulder muscular activity of ergonomic aids used to support or suspend the arm in different sitting postures, both with and without movement of the arm–hand. Ten skilled women workers performed a standardized simulated work cycle similar to assembling printed circuit boards, in different sitting postures with and without ergonomic aids. The elbow was supported by a loosely-mounted, padded plate. For suspension, a new device, the K-block, was used giving an adjustable, constant suspending force. Full-wave rectified, low-pass filtered, time-averaged and normalized EMG was used. Surface electrodes were applied over six neck and shoulder muscles. The results show that a reduction in the level of activity in neck and shoulder muscles can be obtained with either aid. The reduction, whether caused by suspension or support of the arm, was related to the sitting posture. Elbow support might be more efficient than arm suspension in a sitting posture with the whole spine flexed, while arm suspension might be more efficient when the trunk is inclined slightly backward. Elbow support and, particularly, arm suspension may thus be recommended as technical aids in sedentary assembly work for patients with easily elicited cervical spine and/or shoulder pain. It is also suggested that arm suspension may be used to improve ergonomic conditions at workplaces.

Key-words: rehabilitation, cervical spine, ergonomic aid, EMG, neck and shoulder muscles, prevention, muscle load

Many patients with neck and shoulder problems need rehabilitative help before going back to work. Some have work-related neck and shoulder muscle pain which might be relieved or reduced by some ergonomic aid reducing the level of activity in the painful muscles. Patients already under rehabilitation have e.g. cervical spondylosis with easily elicited pain, and these people too, should benefit from reduction of load on the cervical spine, for example through diminished load on the muscles connecting the cervical spine with the shoulder girdle.

Another factor underlying this investigation is the high prevalence of neck and shoulder muscle pain in sedentary work (3, 9, 12, 13, 16), and the fact that in most cases this pain is held to be caused by maintained static muscle contractions (6). It would then be logical to assume that measures leading to diminished static contractions in the neck and shoulder muscles would reduce the occurrence of such work-related myalgia.

During neck movements, the level of activity in neck and shoulder muscles is lower when the arms rest in the lap than when they are elevated (7). Arm positioning in manual tasks is important for the level of activity of shoulder muscles (8, 19). In an evaluation (2) of head and trunk posture with different desk slopes during reading and writing when most subjects supported their elbows on the table, it was found that with increasing desk slope the cervical and lumbar spine were extended and that the level of muscular activity in the trapezius muscle remained low. However, no change in EMG relating to varying desk slopes could be demonstrated.

Elsewhere, opinions differ as to the value of elbow support in reducing neck and shoulder muscle load during sitting work and some evaluations have been contradictory (15, 20).

The traditional suspension device is based on a metal spring, giving an upward-directed force acting on the arm. This force is greatest when the spring is lengthened, i.e. when the arm is low; and smallest when the arm is in a high position. This sometimes leads to difficulties in coordinating arm–hand movements, which in its turn might give a low acceptance of this ergonomic aid. A new suspension device, the "arm balancer", gives an adjustable but constant suspending force irrespective of the length of cord extracted from it. Thus, the arm is suspended by the same force no matter whether the arm is high or low, which is advantageous for coordination of movements. No study of the effect of suspension of the arm during work has been published, except for our preliminary results (5). Preliminary results from a field test showed less perceived pain when arm suspension was used in sitting work (1).

The aim of the present study was to evaluate the effects on the levels of neck and shoulder muscular activity of ergonomic aids used to support or suspend the arm–hand in different sitting work postures both in a static arm position and during movements of the arm–hand. The activity levels were compared with those obtained in the same postures but with no aid. The following specific questions were studied:

- Is neck and shoulder muscular activity affected by the use of arm suspension or of elbow support during a standardized simulated work cycle in various sitting postures?
- Do the various sitting postures influence the effects of the two ergonomic aids upon the level of activity in neck and shoulder muscles?
- Do the effects of the ergonomic aids differ when the movements of the arm–hand in the upper part of the work area are compared to those in the lower part?

MATERIAL AND METHODS

Ten skilled woman workers from an electronics plant (Ericsson, Stockholm) participated in the study (Table I). In a laboratory they performed a standardized simulated work cycle in different sitting postures with and without ergonomic aids.

EMG recordings were made using surface electrodes (Ag–AgCl, Medicotest, Denmark) attached to the skin in the direction of the muscle fibres. The level of muscular activity was recorded as full-wave rectified lowpass filtered and time-averaged EMG, using a time constant of 0.1 s (Devices AC 8 and Neurolog NL 104,703). The time-averaged electromyograms were recorded using heat-sensitive paper (Devices). Unfiltered, direct EMG signals were recorded in parallel on a UV-recorder (Honeywell Visicorder 1508), in order to exclude artefacts during the recordings. All signals were also simultaneously visualized on an oscilloscope (Tektronix RM 565) connected in parallel. This was used particularly for testing electrode function.

To make comparisons possible between the levels of activity in different muscles, a normalization was performed (4, 5, 14, 17, 18). A reference level was recorded for all subjects before and after the experiments. This level represented the highest activity obtained during a series of standardized maximum voluntary isometric test contractions against resistance and with the trunk stabilized in a sitting position. The level of activity recorded for each work posture during the actual work cycle was then divided by this level. The values thus obtained are presented as a percentage of the time-averaged myoelectrical potential (TAMP%) during the maximum isometric test contraction. The standardized maximum voluntary isometric test contractions were as follows: 1) Attempted elevation of arm and shoulder with resistance at distal forearm. 2) Same with resistance proximal to elbow. 3) Attempted abduction of arm at 45 degrees in plane of scapula, with resistance proximal to elbow. 4) Vertical elevation of shoulder against resistance (with stabilization of cervical spine against lateral flexion). 5) Attempted scapula movement in medial-cranial direction against resistance and with cervical spine stabilized. 6) Attempted forward movement of head and cervical spine with resistance against forehead. 7) Extension of neck with resistance at occiput. 8) Neck extension with resistance at upper part of cervical spine and chest stabilized.

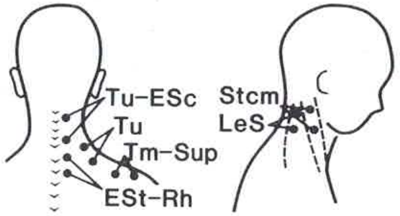


Fig. 1. Location of recording electrodes. Tu-ESc: upper part of trapezius covering erector spinae cervicalis. Tu: upper part of trapezius at anterolateral margin. Tm-Sup: middle part of trapezius covering supraspinatus. ESt-Rh: erector spinae thoracalis covered by rhomboids. LeS: levator scapulae. Stcm: sternocleidomastoideus.

Location of electrodes

For recording activity from the neck and shoulder muscles analysed in this study, pairs of surface electrodes were placed as follows (Fig. 1):

Tu-ESc: Over the upper part of the descending portion of the trapezius muscle covering the cervical erector spinae, with one electrode at the level of vertebra C2 (C3) and the other 0.03 m more caudally. The recording obtained was probably a combination of the muscular activity of the uppermost part of the trapezius (which here is thin and narrow) and the erector spinae cervicalis muscle (the extensor of the middle and upper cervical spine including the atlanto-occipital joint).

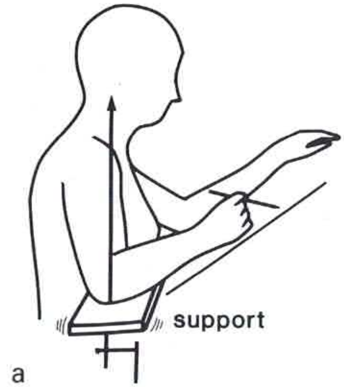
Tu: At the antero-lateral margin of the descending portion of the trapezius at the midpoint between muscular origin and insertion.

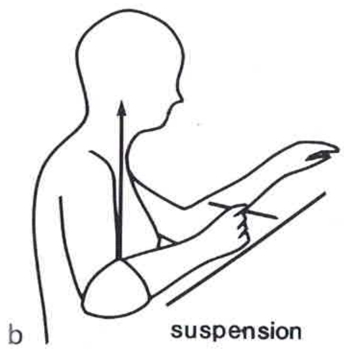
Tm-Sup: At the lateral part of the shoulder, where the transverse (middle) portion of the trapezius covers supraspinatus.

ESt-Rh: Over the triangular aponeurosis of trapezius located at the level of C7–T1, with the underlying rhomboids covering the thoracic erector spinae: one electrode at the level of vertebrae C7–T1 and the other about 0.03 m caudally.

LeS: Over the (upper part of) levator scapulae with both electrodes placed between the posterior margin of the sternocleidomastoid and the anterior margin of the trapezius muscle.

Stcm: At the midpoint of the sternocleidomastoid muscle.





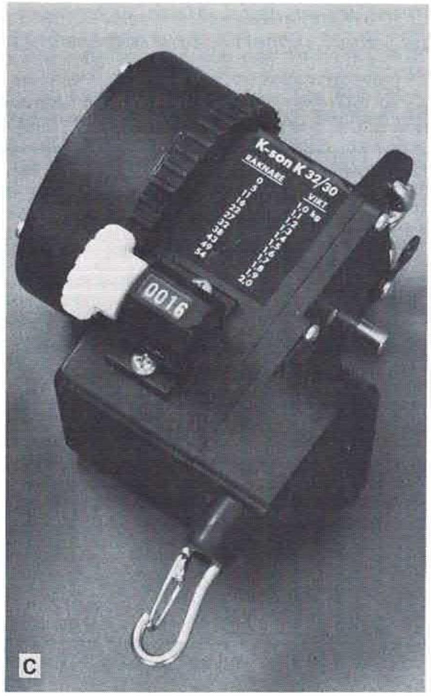


Fig. 2. Ergonomic aids: (*a*) elbow support, (*b*) suspension of arm, (*c*) arm balancer.

Ergonomic aids

The following ergonomic aids were used: 1. The elbow was supported by a horizontal slightly padded plate mounted to allow small horizontal plate movements (Fig. 2*a*). 2. The arm was suspended by means of a sling around the elbow region (Fig. 2*b*) and a cord connected to an arm balancer ("K-block", Mabs Int AB, Norrköping, Sweden) (Fig. 2*c*), adjusted to give a constant elevating force of 20 N.

Work postures investigated

The effects of the ergonomic aids were studied in three selected sitting work postures with and without aids:

- flexed cervico-thoraco-lumbar spine (whole spine flexed) and attachment frame horizontal (A in Table II);
- whole spine vertical and straight and attachment frame angled 35 deg. to the horizontal (B in Tables II and III);
- thoraco-lumbar spine inclined slightly backward, cervical spine vertical and straight and frame angled 75 deg. (C in Tables II and III).

The simulated, highly-standardized task consisted of initially keeping a soldering pen (weight 0.07 kg) aimed precisely at a central dot (filled circle in Fig. 3) on a card in the attachment frame for 5 s, followed by a slow 9 s, clockwise movement aiming the pen successively at the nine positions from top left on the card ("a" in Fig. 3) and back to the same dot ("i" in Fig. 3) on the card when a rough square had been described. The attachment frame stood on a table. Both the inclination of the frame and the height of the table (AVEBE Industries, Stockholm) were adjustable. Eye-to-object distance was kept constant at 0.3 m for all postures.

Statistics

Data plots of the material indicated that the EMG level values could be considered approximately normally distributed. The differences between activity levels in the

Table I. *Subjects' age, work experience, body weight and height*

No.	Age (yrs)	Work experience (yrs)	Weight (kg)	Height (m)
1	37	8	47	1.62
2	34	6	57	1.60
3	54	8	50	1.60
4	34	3	50	1.64
5	21	3	45	1.50
6	32	13	60	1.68
7	55	10	53	1.67
8	43	1.5	73	1.70
9	38	1.5	55	1.56
10	41	7	55	1.62
$\bar{X}$	38.9	6.1	54.5	1.62
SD	10.2	3.8	7.9	0.06

Table II. *Statistical analysis. Mean differences between activity levels (TAMP%) without and with ergonomic aid (elbow support or arm suspension) in static situation and during standardized movement of arm–hand*

For description of postures see Methods and for abbreviations of recording locations (Tu-ESc etc) see Methods and Fig. 1

	Static			Movement		
Postures	A	B	C	A	B	C
EMG-recording						
Elbow support						
Tu-ESc	2.5 NS	1.0 NS	−3.6 NS	4.8 ***	1.9 NS	−0.8 NS
Tu	10.5 ***	6.1 **	0.4 NS	9.9 ***	5.8 *	1.4 NS
Tm-Sup	12.7 **	7.5 *	−0.7 NS	11.9 **	7.4 *	1.3 NS
ESt-Rh	9.8 *	4.9 **	−0.5 NS	10.8 ***	5.3 *	1.3 NS
LeS	−0.4 NS	0.0 NS	0.1 NS	0.1 NS	−0.1 NS	−0.1 NS
Stcm	1.0 NS	0.4 NS	−0.4 NS	0.1 NS	−0.2 NS	0.0 NS
Arm suspension						
Tu-ESc	5.6 *	3.4 *	−0.5 NS	6.0 *	4.6 NS	1.3 NS
Tu	9.0 **	7.6 **	1.5 NS	7.9 *	9.1 **	3.0 **
Tm-Sup	10.3 *	9.3 *	−0.6 NS	10.2 *	9.3 *	3.0 *
ESt-Rh	8.7 *	5.7 *	1.2 NS	8.0 ***	6.9 *	1.7 NS
LeS	−0.6 NS	0.7 NS	0.0 NS	−0.1 NS	0.0 NS	−0.7 NS
Stcm	0.5 NS	0.5 NS	−1.2 NS	1.0 NS	0.2 NS	−1.6 NS

*** $p<0.001$; ** $0.001<p<0.01$; * $0.01<p<0.05$; NS = not significant.

sitting postures were also plotted against the values for each posture. In most cases there were no tendencies to correlation between differences and values in the postures. These results allowed us to use: Student's *t*-test for paired observations. Significance level $0.01<p<0.05$ is regarded as a tendency. Statistical levels of significance $0.001<p<0.01$ are regarded as significant and $p<0.001$ as highly significant.

RESULTS

The effect of elbow support in the static situation is shown in Fig. 4. In the whole-spine-flexed sitting posture (left column) the elbow support gave a highly significant reduction of the muscle activity in the descending part of the trapezius muscle (Tu), a significant reduction in the horizontal part of the trapezius muscle (covering the supraspinatus) (Tm-Sup) and a tendency to reduction in the thoracic erector spinae (covered by the rhomboids) (ESt-Rh). No differences were found in the level of activity in the cervical erector spinae covered by the trapezius, the levator scapulae or the sternocleidomastoid muscles with the elbow support.

In the posture with the whole spine vertical and

Table III. *Statistical analysis. Mean differences between activity levels during arm–hand movement at higher (=between points b–c) and lower (=between points f–g) areas of the work object with ergonomic aid (higher minus lower)*

Otherwise as in Table II

	Arm suspension		Elbow support	
Postures	B	C	B	C
EMG-recording				
Tu-ESc	0.6 NS	0.5 NS	0.2 NS	1.1 NS
Tu	1.7 *	0.8 NS	0.9 NS	0.8 NS
Tm-Sup	3.0 NS	0.8 NS	1.4 *	0.7 NS
ESt-Rh	2.0 *	0.3 NS	0.7 NS	0.6 NS
LeS	0.6 NS	0.2 NS	0.2 NS	0.4 NS
Stcm	−0.3 NS	−0.2 NS	−0.4 NS	0.0 NS

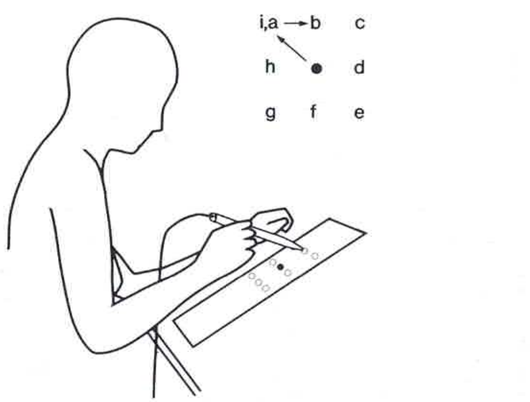


Fig. 3. Standardized task with soldering pen in static situation kept at the filled circle and during slow clockwise movement from dot "a" to dot "i".

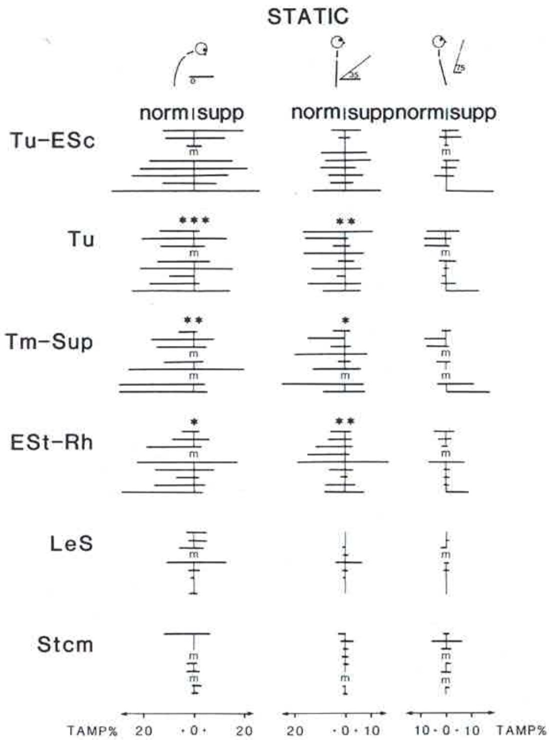


Fig. 4. Left column: effect of elbow support during static standardized simulated work in sitting posture with whole spine flexed (work object horizontal); left of mid-line (each column) posture without aid (=norm) and right of mid-line same posture with elbow support (=supp). Levels of muscular activity expressed as TAMP% for each subject (all columns) indicated with horizontal lines. Nine subjects. Absence of line=zero value. m=missing value. Recording electrode locations: Tu-ESc, Tu, Tm-Sup, Est-Rh, LeS and Stcm; for explanation of abbreviations see Methods and Fig 1. *** $p<0.001$; ** $0.001<p<0.01$; * $0.01<p<0.05$. Significance in decrease in level of muscle activity. *Middle column:* posture with whole spine straight and vertical (work object angled 35 deg.). *Right column:* posture with slight backward inclination of thoraco-lumbar spine, cervical spine vertical and straight (work object angled 75 deg.).

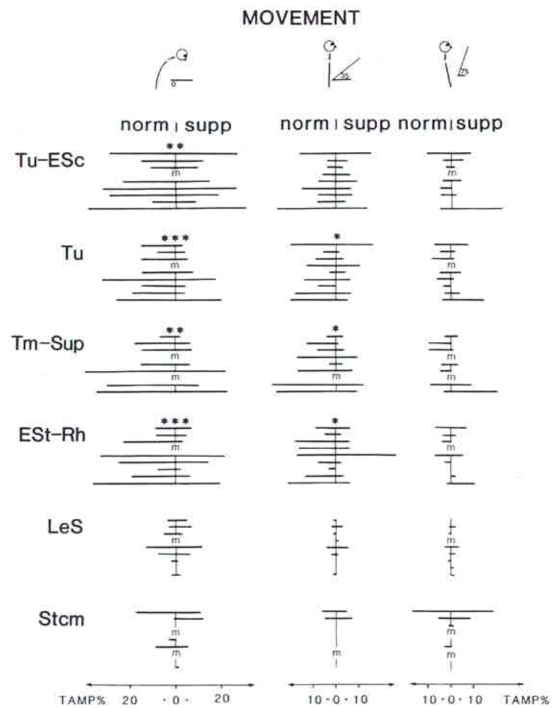


Fig. 5. Effect of elbow support during movement of arm–hand. Otherwise as Fig. 4.

straight (middle column), elbow support gave significantly reduced levels of activity in the Tu and ESt-Rh and a tendency to reduction in Tm-Sup. The elbow support did not reduce the level of activity in the cervical erector spinae covered by the trapezius, the levator scapulae or the sternocleidomastoid muscles.

A similar pattern for reduction of activity by elbow support was found during the movement of the arm–hand in the whole-spine-flexed posture (Fig. 5, left column), but the levels of significance were somewhat different. The same holds true for the sitting posture with the whole spine vertical and straight (middle column).

The sitting posture with the thoraco-lumbar spine inclined slightly backward and the cervical spine vertical and straight (right columns; figure 4 and 5) gave in itself low levels of muscular activity, and the elbow support did not contribute to any further activity reduction in any recording, neither in the static situation (Fig. 4), nor during movement (Fig. 5).

The effect of suspension of the arm by means of the "K-block" in the static situation (Fig. 6) differed from the effect of elbow support in that suspension gave, in addition, a tendency to reduction of the activity in the uppermost cervical erector spinae covered by the trapezius (Tu-ESc) in the whole-spine-flexed posture (left column) and in the whole-spine-vertical-and-straight posture (middle column). For the recordings from Tu, Tm-Sup and ESt-Rh with arm suspension in these two sitting postures, the pattern was similar to that found with

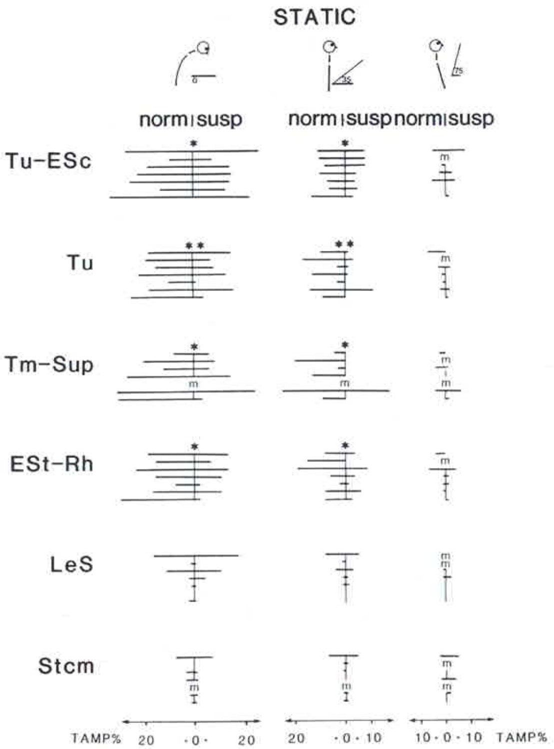


Fig. 6. Effect of suspension of arm during static work. Seven subjects. Susp=suspension of arm. Otherwise as Fig. 4.

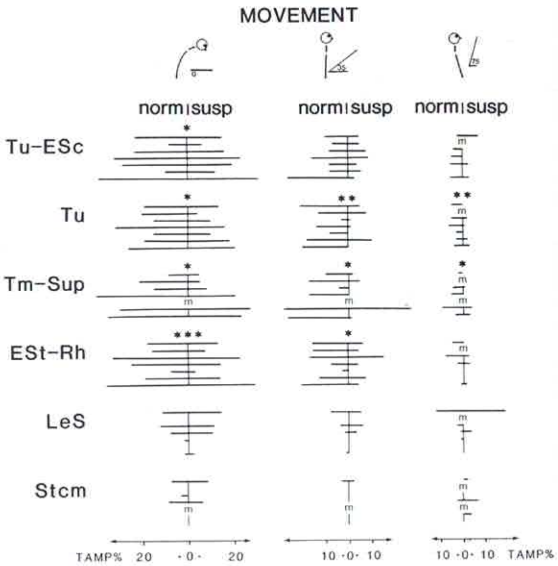


Fig. 7. Effect of suspension of arm during movement of arm–hand. Otherwise as Fig. 6.

arm support, i.e. with reduced or tendency to reduced activity level.

In the static situation, no reduction was shown in any recording in the sitting posture with the thoraco-lumbar spine inclined slightly backward and the cervical spine vertical (Fig. 6, right column). During arm movement, however, in the thoraco-lumbar-spine-inclined-slightly-backward posture (Fig. 7, right column), significant reduction in muscle activity was found in the descending part of the trapezius muscle (Tu) and a tendency to reduction in the horizontal part of the trapezius muscle (Tm-Sup). In the other postures (Fig. 7, left and middle columns) a pattern similar to the static situation with suspension shown in Fig. 6 was found.

A comparison was made between the differences in activity level with ergonomic aid during arm movement along the upper (points *b–c*) and the lower part (points *f–g*) of the work object respectively (Fig. 3). The results are shown in Table III. No significant differences could be demonstrated, only tendencies to higher levels of activity during the movement along the higher part of the work object.

DISCUSSION

The EMG normalization procedure followed in this study has been discussed earlier (4, 5, 14, 17, 18, 21). Some of its advantages are the possibilities of comparing muscle activity levels between different muscle recordings and in different subjects. One methodological problem is, however, to establish the maximum activation level. An attempt to reduce this error is the standardization of the test contractions and the retest procedure after the experiment. In this study we are not concerned with absolute values expressed at TAMP%, but the intra-individual values and differences, and thus this error does not significantly affect the conclusions. There is no assumption in this study regarding level of muscular activity and muscular force.

Another methodological problem is how to record from one single anatomically defined muscle in the neck and shoulder region. The denomination of some of the recordings appears somewhat too distinct. The recordings over ESt-Rh, Tu-ESc and Tm-Sup probably include activity from more than one muscle (18). For the ESt-Rh recording the electrodes were placed over the triangular aponeurosis of the trapezius at the level of vertebra T1 to avoid trapezius activity, and the proportion of EMG activity contributed by e.g. the adjacent rhomboids and erector spinae is uncertain. In general, the most superficial of the muscles should contribute most to the recorded EMG activity, but here the rhomboids have a tendinous part from the mid-line laterally. In the recording of Tu-ESc, the uppermost part of trapezius is rather thin and narrow, probably adding splenius/semispinalis activity. An indirect indication of different muscles being recorded from Tu-ESc and Tu is that they showed different patterns, which contradicts the assertion that the trapezius was the dominant muscle in both recordings, as the electrodes cover the same trapezius fibres, proximally and more distally respectively. Thus Tu probably represents pars descendens of trapezius and Tu-ESc probably a combination also including cervical erector spinae to a substantial degree. In the Tm-Sup recording, the proportion of activity from trapezius and supraspinatus is uncertain. The fibres of trapezius covering supraspinatus originate more caudally from the spine and represent the transverse portion, which is here rather thick.

Earlier studies (5,18) have shown the effect of changes in sitting posture upon static activity in neck and shoulder muscles; the posture with the whole spine flexed gives higher muscular activity levels than the vertical trunk posture, which in turn gives higher levels than the posture with the trunk slightly inclined backward. The reduction in muscular activity level by suspending or supporting the arm seems to depend somewhat on the sitting posture. Elbow support might be more efficient than arm suspension in the whole-spine-flexed sitting posture, one which, however, is not to be recommended (18) since it gives higher activity levels than other postures. Arm suspension might be more efficient than elbow support in the sitting posture with the trunk inclined slightly backward.

There are some other differences to note for the two devices. When using the elbow support, the elbow must of course be able to rest on the support plate during the whole work cycle. As soon as the elbow is lifted from the plate, for instance to reach the upper part of the work area, the reducing effect is eliminated. The device based on constant-force suspension (K-block) here works differently, since the reducing effect on the muscle activity is continuous. If the hand must cover a large work area, K-block suspension is probably advantageous since it can diminish muscular activity regardless of elbow position. Checks that our subjects did not lift the elbow from the support plate are reflected in the findings that activity levels did not differ between movements over the lower and the upper parts of the work area respectively.

The results show that a reduction in the level of activity in neck and shoulder muscles can be obtained with either aid. Thus arm suspension or elbow support seem both to be appropriate preventive measures for reducing neck and shoulder muscular load in sitting assembly work. By using these aids it might be possible to reduce the load level below the suggested limit levels (10, 11) for acceptable static load. Recommendation of arm suspension as an ergonomic aid in primary prevention has recently been debated. As our results show that the level of activity is reduced when this aid is used, its introduction appears logical, if the purpose is to reduce the level of static muscular activity. On the other hand, it has been suggested that this kind of ergonomic aid might delay the development of better ergonomic design of machines, equipment and workplaces. Of course we support the view that primary prevention should be a self-evident constituent of machine design. It will, however, take time before results are transformed into new workplaces, and in the meantime we believe it is better to work with what is to hand, where the measures have some documented effects.

Another opinion is that changes in the ways work is organized (e.g. job rotation) would be preferable to physical changes such as arm suspension. Yet even if the work is organized optimally, this does not exclude the benefit from arm suspension in tasks involving most neck and shoulder muscle loading. Thus both steps can be taken simultaneously and independently.

The conditions in rehabilitative work differ from those in primary prevention, though many of the underlying principles for load reduction are the same. In general, the rehabilitation patient is already disabled by neck and/or shoulder pain, however caused, and one of the problems is to be able to cope with an earlier, or a new, working situation. Here arm suspension can be recommended, and its pain-reducing effect can easily be tested in each individual case, both during the training phase and also under real working conditions. Our preliminary experience of this clinical application is encouraging.

ACKNOWLEDGEMENTS

This study was supported by the Karolinska Institute, the Swedish Medical Research Council (projekt no. 5720) and the Swedish Work Environment Fund (ASF:83–0520).

REFERENCES

1. Arborelius, U. P. & Harms-Ringdahl, K.: The results from a full scale field test of an arm suspension balancer. Proceedings of Int Scientific Conf on Work with Display Units, Stockholm, Sweden, p. 333–335, 1986.
2. Bendix, T. & Hagberg, M.: Trunk posture and load on the trapezius muscle whilst sitting at sloping desks. Ergonomics *27:* 873, 1984.
3. Bjelle, A., Hagberg, M. & Michaelsson, G.: Clinical and ergonomic factors in prolonged shoulder pain among industrial workers. Scand J Work Environ Health *5:* 205, 1979.
4. Ekholm, J., Arborelius, U. P., Fahlcrantz, A., Larsson, A.-M. & Mattsson, G.: Activation of abdominal muscles during some physiotherapeutic exercises. Scand J Rehab Med *11:* 75, 1979.
5. Ekholm, J., Arborelius, U. P., Németh, G., Schüldt, K., Harms-Ringdahl, K., Nisell, R. & Svensson, O.: Effects of load reduction measures upon the locomotor system during standing and sitting work. Research Report to Swedish Work Environment Fund, Karolinska Institute, Stockholm, 1983 (in Swedish).
6. Hagberg, M.: Occupational musculoskeletal stress and disorders of the neck and shoulder: a review of possible pathophysiology. Int Arch Occup Environ Health *53:* 269, 1984.
7. Harms-Ringdahl, K. & Ekholm, J.: Influence of arm position on neck muscular activity levels during flexion-extension movements of the cervical spine. *In* Biomechanics X (ed. B. Jonsson & M. Hagberg), 1985 (in press).
8. Herberts, P., Kadefors, R. & Broman, H.: Arm positioning in manual tasks. An electromyographic study of localized muscle fatigue. Ergonomics *23:* 655, 1980.
9. Hünting, W., Grandjean, E. & Maeda, K.: Constrained postures in accounting machine operators. Appl Ergonomics *11:* 145, 1980.
10. Jonsson, B.: Kinesiology, with special reference to electromyographic kinesiology. *In* Contemporary Clinical Neurophysiology (ed. W. Cobb and H. Van Duijin), EEG suppl. no 34: 417–428. Elsevier, Amsterdam 1978.
11. Jonsson, B.: Measurement and evaluation of local muscular strain in the shoulder during constrained work. J Human Ergol *11:* 73, 1982.
12. Kvarnström, S.: Occurrence of musculoskeletal disorders in a manufacturing industry, with special attention to occupational shoulder disorders. Scand J Rehab Med, Suppl. 8, 1983.
13. Maeda, K.: Occupational cervicobrachial disorder and its causative factors. J Human Ergol *6:* 193, 1977.
14. Németh, G.: On hip and lumbar biomechanics. Scand J Rehab Med, Suppl. 10, 1984.
15. Norin, K. & Seimer-Andersson, B.: Can elbow support relieve neck and shoulder load during sedentary assembly work—a biofeedback study. Report from the Occupational Health Service, Ericsson Information Systems, 1982 (in Swedish).
16. Onishi, N., Nomura, H., Sakai, K., Yamamoto, T., Hirayama, K. & Itani, T.: Shoulder muscle tenderness and physical features of female industrial workers. J Human Ergol *5:* 87, 1976.
17. Perry, J. & Bekey, G. A.: EMG–force relationships in skeletal muscle. CRC Critical Reviews in Biomedical Engineering *7:* 1, 1981.
18. Schüldt, K., Ekholm, J., Harms-Ringdahl, K., Németh, G. & Arborelius, U. P.: Effects of changes in sitting work posture upon level of static neck and shoulder muscle activity. Ergonomics, in press 1986.
19. Sigholm, G., Herberts, P., Almström, C. & Kadefors, R.: Electromyographic analysis of shoulder muscle load. J Orthop Research *1:* 379, 1984.
20. Svedenkrans, M.: Work with and without elbow support—a study of the load on the neck and shoulders. Report from IBM Sweden Inc, Stockholm, 1980 (in Swedish).
21. Zuniga, E. N., Truong, X. T. & Simons, D. G.: Effects of skin electrode position on averaged electromyographic potentials. Arch Phys Med Rehab *51:* 264, 1970.

Address for correspondence:

Kristina Schüldt, MD
Department of Medical Rehabilitation and
Physical Medicine
Karolinska Hospital
P. O. Box 60 500
S-104 01 Stockholm
Sweden