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INTENSITY AND CHARACTER OF PAIN AND MUSCULAR ACTIVITY LEVELS ELICITED BY MAINTAINED EXTREME FLEXION POSITION OF THE LOWER–CERVICAL–UPPER-THORACIC SPINE

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ABSTRACT. The aim of this study was to find out whether maintained extreme flexion position of the lower-cervical–upper-thoracic spine in a sitting posture could induce pain, and thus possibly play a role in work related disorders with cervico-brachial pain. Ten healthy subjects assessed pain intensity of experimentally-induced pain on a Visual Analogue Scale (VAS). The quality and location of the pain was indicated on a drawing of the body. The load moment induced by the weight of the head-and-neck was calculated. The EMG activity levels were recorded from the splenius, thoracic erector spinae-rhomboid, and descending part of trapezius muscles. This posture, which resembles the posture in some common work, caused pain in all subjects. The pain was experienced within 15 min, increased with time, disappeared within 15 min after the end of provocation, but was again experienced by nine subjects the same evening or next morning and lasted up to four days. The primary location was in the dorsal part of the lower cervical and upper thoracic spine; three subjects also reported pain in the arms and one in the head. The recorded EMG levels were very low, but they increased somewhat during provocation. It is suggested that thorough recordings of work postures should be included in ergonomic analyses to provide a basis for the avoidance of such positions which might provoke pain.

Key words: Cervico-brachial pain, spine, pain assessment, ergonomics, electromyography, neck muscles

It has been shown that pain occurs when knee and elbow joints are loaded for some time in an extreme position (a position at the limit of the motion range), and the time course of the pain intensity has been described (12). In a previous study from our group (5, 11) we found that extreme joint positions in the cervical spine do occur in some sitting work postures. One of the most common of these positions in sitting work postures assembling printed circuit boards was maximally flexed lower-cervical-upper-thoracic spine. If extreme position-induced pain also occurs in the cervical spine it is important that ergonomic analyses take account of this.

The aim of the present study was to see if pain could be felt after maintained, experimentally controlled, extreme position in the lower neck, similar to common sitting work postures, and if so, whether the extreme position and/or pain induced changes in muscular activity.

The following questions were analyzed:

1. Do pain sensations occur when a subject in a sitting posture keeps the lower-cervical and upper-thoracic spine in an extreme flexion position?
2. If so, what is the time course of pain intensity?
3. Does the extreme position lead to post-provocation pain, and if so, what is its duration?
4. What is the location of the pain?
5. What pain qualities and other sensations are experienced?
6. Does the extreme position induce increased level of muscular activity; and if so, is this at a level which may be expected (2) to cause muscular pain due to maintained static contraction?

MATERIALS AND METHODS

Ten healthy female volunteers with informed consent took part in an experimental study. Their ages were 21–26 (mean 24) years, mean height 1.69 m (S D 0.06) and mean weight 63.8 kg (S D 6.3). None had any symptoms from the cervical spine, either previously or at the clinical examination preceding the experiment. To exclude the possibility of divergent personality traits of importance for the pain assessments (23), the subjects answered the Karolinska Scale of Personality questionnaire (1, 20) and a body focus questionnaire (3, 7). The result of the analysis of influence of different personality characteristics on experimental pain assessments is under preparation and will be described elsewhere.

Each subject sat as shown in Fig. 1, slightly inclined backward in a special chair with back support up to about the fifth thoracic vertebra. The subject's thorax was strapped to the back support at the level of manubrium sterni. The arms rested in the lap to minimize muscle

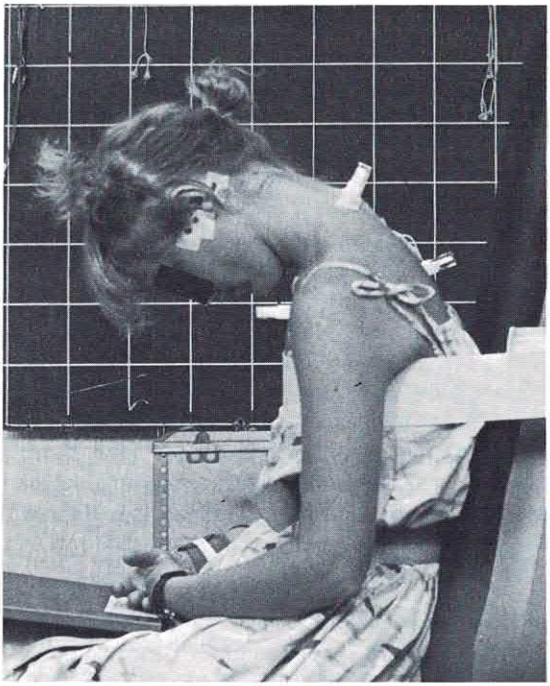

Fig. 1. Subject seated with lower-cervical–upper-thoracic spine in an extreme flexion position. Thoracic spine strapped to back support. Arms resting in lap.

activity and muscular force due to their weight. In this position the subjects were asked to keep the head-and-neck in a relaxed, forward-flexed position. This posture loads the lower cervical and upper thoracic spinal motion segments in an extreme flexion position.

The intensity of discomfort/pain was assessed by the subjects who, when asked "Does it hurt? Please, mark how much", made pencil markings on a Visual Analogue Scale (VAS) (16, 19, 21). The scale used was a 100-mm long, horizontal line anchored by *No discomfort or pain, does not hurt at all* at one end and *Worst pain imaginable* at the other. This type of anchoring has also been suggested by Gaston-Johansson et al. (9) and by Seymour et al. (22) respectively. From previous experiments (12) it was considered important for the subjects to be familiar with the kind of discomfort/pain sensation that might be experienced in the pain-provoking position. The subjects were therefore exposed to four different loads on passive elbow joint structures (12) before the cervical spine pain provocation. This procedure also allowed the subjects to practise assessing this sensation and to use the VAS. In addition to the VAS pain intensity scale, the subjects were given drawings of the front and back of a human body as well as side views of the head-and-neck, on which they were asked to mark the location of their pain and its qualities. The following sensory-cognitive categories were adopted: pulling/pressing, throbbing, burning, stabbing, pricking, shooting, grinding, and other. Notes were taken of subject's other supplementary remarks and sensations.

In the pain-provoking spinal extreme position, pain intensity assessments were given on fresh VAS forms once a minute. A pain drawing was completed every fifth minute. Thus the subjects had no access to previously completed scales and drawings. The subjects were told to interrupt the pain-provoking spinal extreme position whenever the discomfort became too great. During the post-provocation period, pain intensity was followed until it passed off. The subjects were also asked to assess any experience of discomfort, hurt or pain on the VAS and to make pain drawings every evening and morning after the experiment until two days had elapsed with no sensations of this kind.

Electromyograms (EMG) were recorded by using surface electrodes (Ag–AgCl) placed in a standardized way with 0.03 m centre distance on the right side of the subjects (Fig. 2) over:

1. Splen.: The splenius muscle at the level of C2 between the uppermost parts of trapezius and sternocleidomastoid,

2. ESt-Rh.: The aponeurosis of the trapezius covering the rhomboid and cervico-thoracic erector spinae muscles,

3. Tu.: The descending part of the trapezius at the anterolateral border.

The EMG signals were full-wave rectified, low-pass filtered and averaged over time using a time constant of 0.1 s (NeuroLog 104 amplifier). Raw EMG was recorded in parallel for checking possible disturbances (Devices amplifiers, AC 8). An electronic timer marked the EMG curves and thus allowed comparison between muscular activity levels and pain ratings at any given time.

To be able to compare activity levels across muscles and between subjects, the EMG was normalized. Test contractions of relevant muscles were performed at the beginning and also, after the subjects had recovered, at the end of the experiment. Firm resistance was given against neck extension (head in a neutral position) and/or shoulder elevation or arm flexion at 90 degrees. The maximum activity level for each subject and each muscle was recorded and used as reference level (100%). The level recorded when the subject was in the pain-provoking

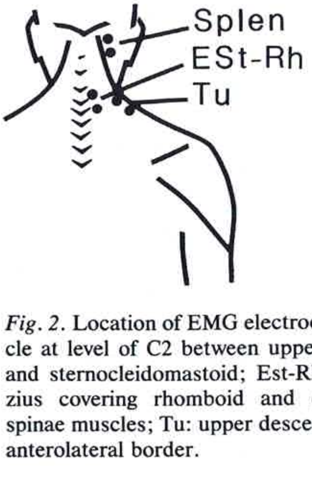

Fig. 2. Location of EMG electrodes. Splen: splenius muscle at level of C2 between uppermost parts of trapezius and sternocleidomastoid; Est-Rh: aponeurosis of trapezius covering rhomboid and cervico-thoracic erector spinae muscles; Tu: upper descending part of trapezius at anterolateral border.

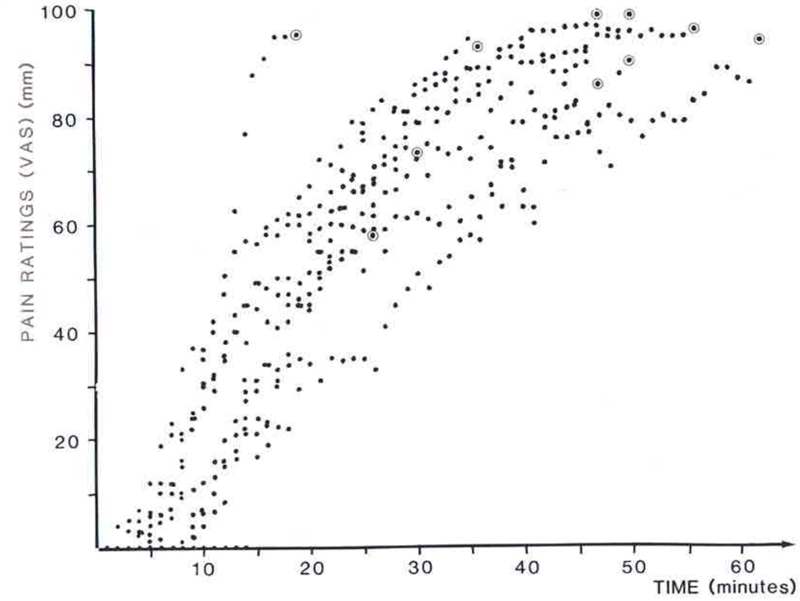

Fig. 3. Intensity of pain ratings on VAS (y-axis) during provocation by extreme flexion position for all subjects (time: x-axis). Last assessment before discontinuing provocation: dot marked with outer circle. (n=10).

position was presented as a percentage of this maximum. For satisfactory recordings of the low activity levels found in the pain-provoking postures (compared to the levels during the test contractions), the amplification was increased by two to four times during pain provocation.

In the analysis of a potential influence of increasing pain intensity on muscular activity levels, the mean of three values of activity level during the first and last three minutes respectively, of the pain-provoking period (arms resting) was used. Similarly, the recorded EMG activity levels for the very short periods of writing activities, e.g. when subjects made pain assessments, were also analysed.

For calculations of the load moment about the bilateral axis of the spinal C7-T1 motion segment induced by the weight of the head-and-neck, photographs were taken with a camera perpendicular to the sagittal plane of the subject with a reference bar in the focal plane of the photograph. The methods for photographing and for calculations of load moment in the cervical spine have been described in detail elsewhere (11). The photographs were also used for time-related measurements of the subject's cervical spine extreme flexion position.

For the statistical analysis Spearman's Rank Correlation Coefficient was used. The significance levels chosen were $p \leq 0.05$ ($r \geq 0.65$) and $p \leq 0.01$ ($r \geq 0.79$). For the analysis of EMG levels, median activity levels were used and the Wilcoxon matched pairs signed-rank test was applied.

RESULTS

Time course of pain intensity during provocation by extreme position

Sitting with the lower cervical and upper thoracic spine in a relaxed, maximally forward-flexed position was associated with experience of discomfort or pain by all ten subjects within 15 min. Although the assessments of intensity developed somewhat differently for the different subjects, as seen in Fig. 3, the pattern of intensity assessments on the VAS was very uniform.

The individual curves are shown in Fig. 4. When the pain started there was mainly a continuous increase over time, (although shorter periods of "plateaus" in the pain intensity curves could be seen). None of the assessments decreased more than 6 mm from the previous. Time and intensity for pain when first occurring and on discontinuation of provocation are also shown in Fig. 4.

Pain intensity course immediately after end of provocation

When the subjects started to move the cervical spine again (after the provocation had been discontinued), the pain decreased very fast (Fig. 5) and had disappeared for all subjects within 15 min (median 6 min).

Delayed post provocation pain

Although all the subjects reported complete recovery when leaving the laboratory after the provocation, three experienced discomfort/pain from the neck the same evening, and another six the next morning, as shown in Fig. 6. Only one person did not experience any discomfort after the experi-

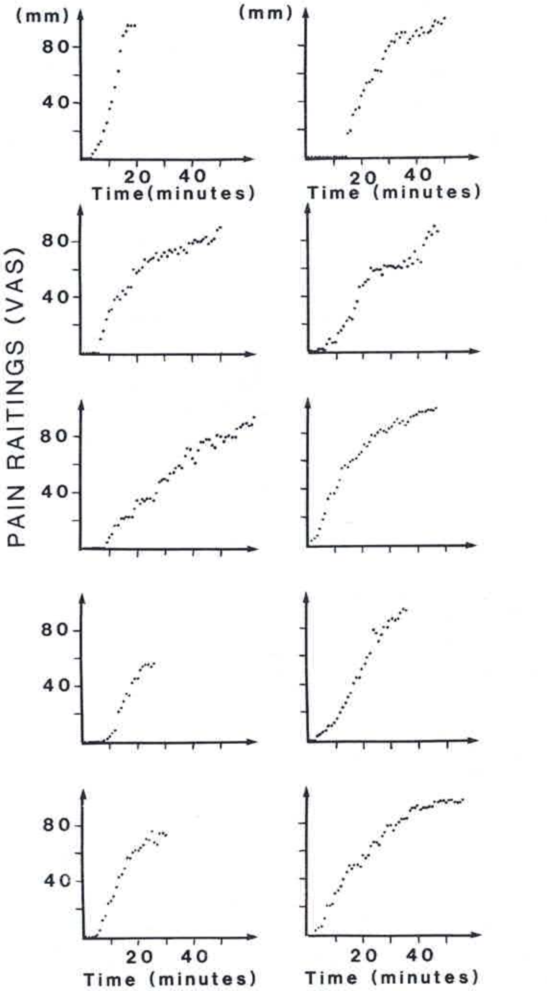

Fig. 4. Individual curves for pain intensity ratings during pain provocation. VAS on *y*-axis; time on *x*-axis.

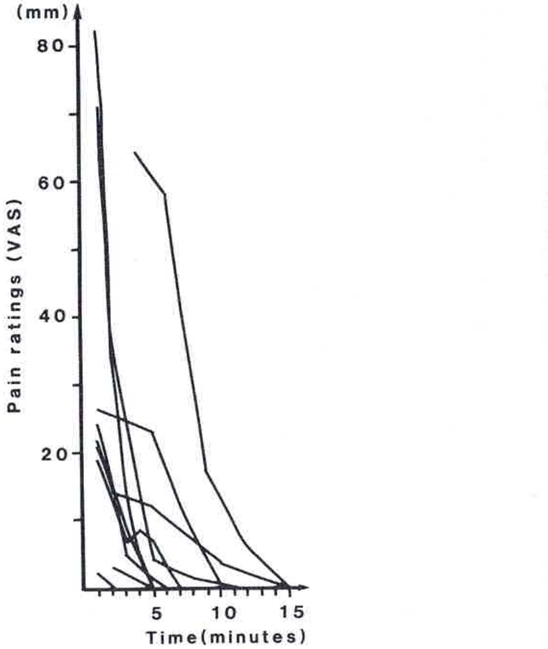

Fig. 5. Individual curves for pain intensity ratings (*y*-axis) immediately after discontinuation of pain provocation (time: *x*-axis).

ment. The late post-provocation discomfort/pain was at its maximum 12–24 hours after the experiment and had in all cases disappeared after 96 h (4 days), with a median of 48 h (2 days).

Analysis of covariation gave no significant correlation when different parameters of the provoked pain, such as duration, accumulated intensity levels per second and intensity at discontinuation, were related to intensity experienced immediately or some time after the provocation. However, the average assessments of pain intensity during provocation (e.g. mean assessment per subject for the provocation period) correlated with the intensity experienced within the first minute after the end of provocation (r=0.66). Where the initial pain-free period was shorter, there was a tendency (r=−0.70) to higher pain intensity levels five minutes after the end of the provocation period, and the time taken for pain to disappear was also longer (r=−0.70). With a short pain-free period, there was also a tendency for the pain intensity levels accumulated per twelfth hour after provocation to be higher (r=−0.73).

Influence of load moment on pain intensity

The mean load moment about the bilateral axis of the C7-T1 spinal motion segment increased from 3.1 Nm (S D=0.8) which was the load moment when subjects were sitting with the head-and-neck in an erect relaxed (neutral) posture, to 6.6 Nm (SD =0.9) when this region was kept in the extreme flexion position. There was a positive correlation between magnitude of induced load moment and duration of pain during provocation (r=0.70), average assessed pain intensity (r=0.67) during pain provocation, and pain intensity levels accumulated during provocation (r=0.72). There was low correlation between load moment and post-provocation pain intensity and duration.

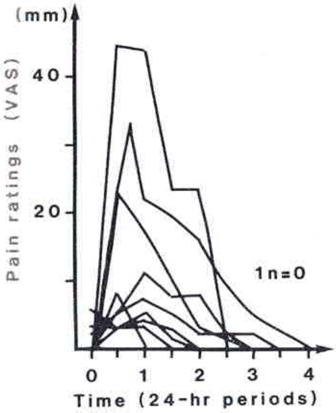

Fig. 6. Individual curves for pain intensity ratings (*y*-axis) per 24-h periods (*x*-axis) following the day of pain provocation.

Location of pain

The location of the pain just before the discontinuation of provocation can be seen in figs. 7 and 8. The pain always started in the dorsal lower cervical and upper thoracic region and spread towards the head and the shoulders. Three of the subjects specified pain in one or both arms (two on the back, as shown in Fig. 8, and one on the front). Another two reported sensations of numbness in one or both arms, i.e. 5 subjects experienced sensations in the arm.

Pain qualities

As shown in Fig. 9 all the subjects specified the quality of pain during provocation as 'pulling'. The words 'grinding' and/or 'burning' were also frequently used, as well as words for pain-like sensations other than those suggested. These were sensations of numbness, weakness, dull pain and heaviness and tingling. The qualities stabbing, pricking and shooting were only expressed for intensity levels higher than 50 mm on the VAS. The qualities grinding, pulling and burning were expressed for both low and high intensity levels. However, the higher the intensity levels were, the more different words for the qualities were chosen by each subject. In the 78-hour period after provocation, qualities such as pulling were expressed by three subjects, and other/dull pain by four. The quality grinding was expressed by two subjects, one of them also using the words 'burning' and 'shooting'. The subjects expressed altogether between three and six qualities each (median: four qualities).

Other sensations

During pain provocation, seven of the subjects also said they experienced one or more of the vegetative sensations such as sweating, nausea, tiredness, dizziness, general coldness or warmth.

Level of muscular activity in extreme position with and without pain

As shown in Fig. 10, the median muscular activity levels of the ten subjects during the pain provocation were very low, 0–6% of maximum, although the ranges sometimes reached 14% of maximum. As expected, the activity levels were higher during writing compared to when the arms were at complete rest, both at the beginning and at the end of the provocation period. When the pain-free first

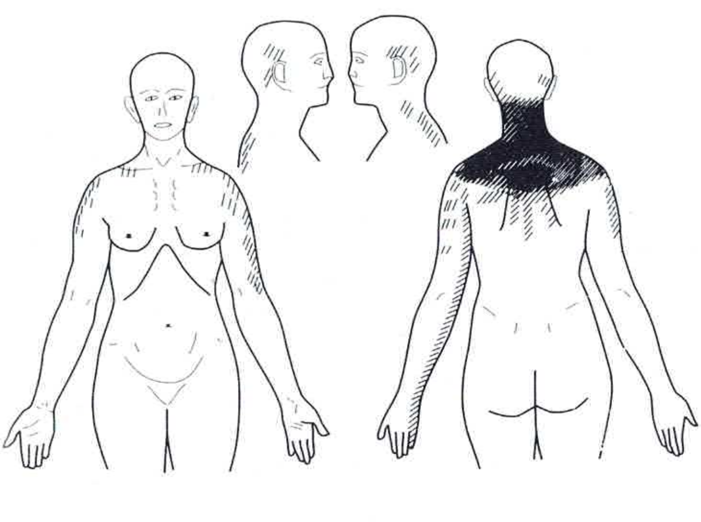

Fig. 7. Localization of pain just before discontinuation of maintained extreme flexion position of lower cervical upper thoracic spine. Areas of pain of ten subjects are superimposed.

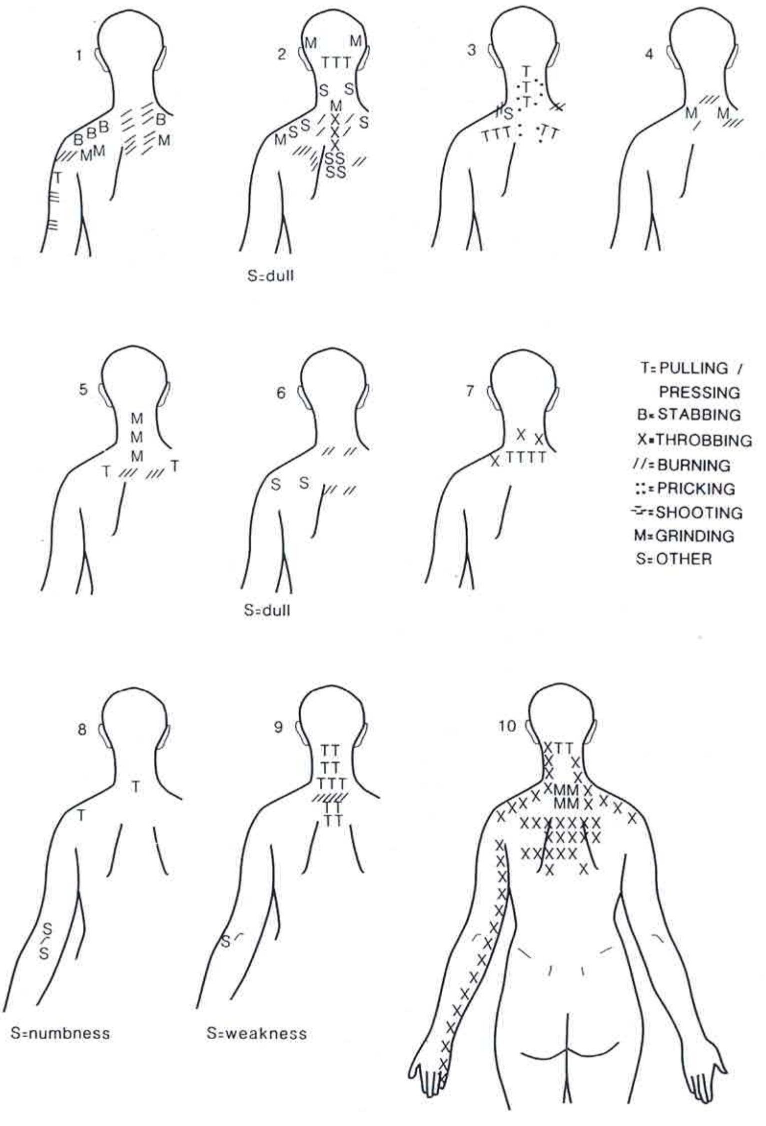

Fig. 8. Pain qualities and localization noted on drawings of dorsal aspect of body by ten subjects just before end of pain provocation. Localizations were approximately symmetrical on both sides except for subject no. 10 who marked burning pain in only one arm (and ventral side of same shoulder), and subject no. 5 who marked grinding, stabbing pain in one arm on anterior side only. Subject no. 1 marked pulling, shooting pain in both arms on both anterior and posterior sides.

three minutes of provocation were compared to the painful last three minutes, the latter showed increased activity levels in the descending part of the trapezius and the splenius muscles, and tendency to increased level in the thoracic erector spinae/rhomboids (ESt–Rh). Re-measuring the lower cervical spine flexion angle on the photographs showed that increased activity levels did not correspond to attempts to decrease the neck flexion angle.

The muscular activity levels did not correlate with pain intensity measures during provocation. However, some muscular activity levels, as described below, correlated with some pain assessments made after provocation. The activity levels in the descending part of the trapezius at the beginning and at the end of pain provocation, 2% of the maximal activity at most, were positively correlated with the pain intensity level five minutes after the end of provocation ($r=0.71$ and $r=0.92$ respectively) and also with the time taken for pain to disappear ($r=0.49$ and $r=0.87$). There was also a tendency to correlation between higher experienced pain intensity during the first minute after the end of provocation and increased activity levels in the splenius muscle ($r=0.67$ for the first and $r=0.55$ during the last three minutes of provocation).

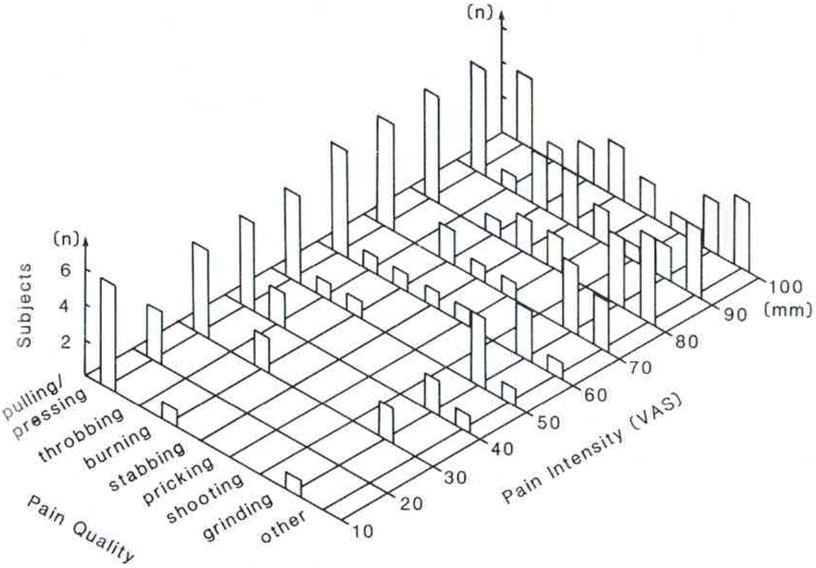

Fig. 9. Three-dimensional diagram illustrating number of subjects (*y*-axis), qualities of pain (*x*-axis), and intervals of pain intensity ratings (VAS) (*z*-axis) during maintained low cervical spine extreme flexion position. Intervals 1–10 mm, 11–20 mm and so on. ($n=10$.)

In some further statistical analyses (where the coefficients were not ranked), the influence of load moment on pain intensity assessments was eliminated. It was then found that there was a tendency for increase in muscular activity levels to correlate negatively with pain intensity during provocation.

DISCUSSION

The situation in which pain occurs (experimental or clinical), the causal connection of the pain and the level of control of the situation (e.g. summarized by Chapman et al. (4)) are considered to play a role in the development and the experience of pain. With these as background factors, it should be noted that posture-induced pain was reported by all the subjects within 15 min of provocation in an extreme flexion position of the lower cervical spine (similar to several work postures), and that the pain intensity curves showed a striking individual resemblance. Thus, these phenomena seem to be less variable than expected.

The sensation of pain is always personal and thus the experience of pain intensity levels could be expected to vary considerably in the same experimental situation. Although the subjects made each assessment of pain intensity on a fresh form, no assessment decreased more than 6 mm from the previous one. It may be claimed that the increase in pain intensity with time reflects the subjects' ability to remember the previous location of their pencil marks and their desire not to diverge too much from that. However, the increase of induced pain with time agrees with previous studies on elbow and knee joints (12).

The intensity level on discontinuation of the provocation was high. This might reflect the complete control the subjects had over the experimental situation, including their ability to stop the provocation. Thus the affective dimension of pain might have been relatively low, making the subjects more inclined to withstand high intensity levels (15, 19). The high intensity levels found might reflect the choice of sensation that the subjects was asked to assess (namely discomfort/pain) and also the phrase chosen to anchor the scale at the right-hand end (Worst pain imaginable). Different studies, showing among other things that VAS can be used to measure experimentally-induced pain reliably (19), have reported these variables to influence the intensity level of the assessments (9, 19) and the sensitivity of the scale (22).

The rate of pain level increase declined in most cases near the end of the provocation period. No other study has suggested whether this is due to psychological or physiological mechanisms or both.

In several subjects, the extreme flexion position in the lower cervical spine caused pain or a sensation of numbness localized in the arms. Comparing our results with the literature, it was not possible

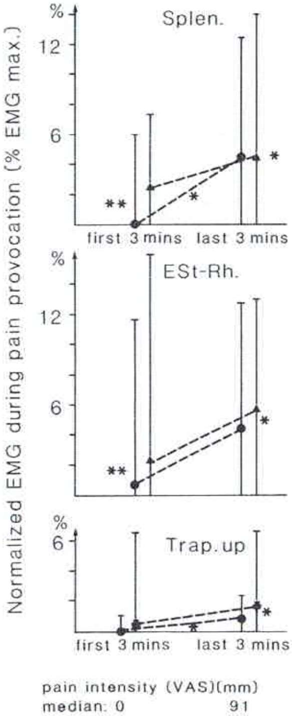

Fig. 10. Muscular activity levels expressed as normalized EMG (*y*-axis) with comparison between first and last three-minute periods of provocation (medians and ranges of each individual average activity level during a three-minute period) (*x*-axis) by cervical spine extreme flexion position ($n=10$). Resting arms: filled circles. During writing: filled triangles. *$0.01<p\leq0.05$; **$0.001<p\leq0.01$.

from the location of pain found in our study to draw any conclusions about what kind of structures were provoked. However, the primary local pain as well as the pain reported from the arms (Fig. 7) mainly agreed with localizations from the experiments on pain provoked by injections of irritants in deep soft tissues (e.g. deep paravertebral muscles or ligaments) at the C7-and T1-levels (6, 17, 18). The induced pain, in their studies as well as in ours, was not only locally distributed very near the provoked region but also referred to a distant area. This is probably an example of the mechanism responsible for the phenomenon of referred pain. Since, however, the location reported by subject no. eight correlated well with a dermatome, it cannot be completely excluded that nerve roots or their vessels might have been interfered with in some way, although flexion is not held to be the most transectional-area-reducing position for the intervertebral foramina (14, 24). The quality of distal pain and arm sensations experienced by some of the subjects was of the same kind as that caused by nerve root compression (such as weakness of numbness), or by mechanical stimulation of dorsal root ganglia (e.g. 'shooting') (13).

Although pain had completely disappeared some time after provocation, a delayed sensation of pain lasting one to four days was reported from nine of the young subjects, whose cervical spines were completely healthy. This might be a possible mechanism for prolonged pain if provocation is repeated daily and the effect thus in some way becomes accumulated.

The muscle activity levels during the provocation period were very low for most of the subjects, probably not reaching levels normally expected to cause pain (2, 10). It appeared that those who had lower muscle activity increase had more pain during the provocation. The delayed post-provocation pain, however, was greater in subjects for whom the onset of pain occurred earlier during the provocation and/or who showed higher (although at low magnitude) activity levels in the descending trapezius. It is obvious that a maintained extreme position does not lead to a reflexive gross increase of muscular activity. However, the very low activity levels did increase somewhat, possibly due to the pain, indicating that tonic (sustained) reflex mechanisms might have been elicited.

Several qualities were expressed by each subject to define the pain, indicating that the denominations are poor for specifying what different tissues are involved in the pain mechanism. The qualities chosen were neither bound to a particular location, nor to a certain pain intensity level. However, although some qualities such as stabbing, pricking and shooting were added at higher intensity levels, our subjects used, for example, the words 'grinding' and/or 'pulling' on the same occasion as 'stabbing' and 'burning' and within almost the same localization over the shoulders and on the lower cervical and upper thoracic region of the spine. Gaston-Johansson has studied pain assessment with particular reference to pain terms, instrument development and pain description (8, 9). She asked different subjects to assess the pain intensity level of different defined pain quality terms (8). She found that different qualities, e.g. grinding, gnawing and cutting (stabbing) could be ranked in increasing order with reference to increasing intensity levels. Our study did not have the same purpose and is thus different in most respects. We asked the subjects to assess the overall intensity level, while Gaston-Johansson asked the subjects to assess the intensity level they associated with different defined qualities. However, it is interesting to note the similarity regarding the qualities such as cutting (stabbing) and shooting which in both studies were associated with higher intensity levels of pain.

Feinstein et al. (6) also reported vegetative reactions such as sweating and nausea after injections of irritant into the deep soft tissue structures of the back. These reactions were more common after injections in the thoracic and rare in the cervical or sacral regions. In the present study vegetative reactions were elicited by the extreme position. We have not found in the literature whether these reactions are connected with this particular region of the spine; nor do we know whether these reactions are secondary to pain or mediated directly from the loaded spine structures. However, Feinstein (6) reported that vegetative reactions were not proportional to severity of pain. Neither were they found in a previous study of pain provoked by maintained extreme positions of the elbow joint (12) in spite of rather high intensity levels.

Summary of main findings and conclusions

1. Pain sensations do occur when healthy persons, in a sitting posture similar to common work postures, keep the lower cervical and upper thoracic spine in a maintained extreme flexion position. Some of our subjects experienced vegetative reactions.

2. The time course of such pain, under the conditions of this experimental study, was that the subjects experienced the first pain two to 15 min after adopting the extreme position, and chose to discontinue because of too much discomfort 16 to 57 min after onset of pain, at which moment the pain intensity ratings were rather high (58 to 99 mm VAS).

3. The pain passed off completely within 15 min after provocation was discontinued, but was again experienced by all but one subject the same evening or the next morning and lasted up to four days. Thus, post-provocation pain can occur after extreme positions.

4. The primary locus of the pain was in the dorsal part of the lower cervical and upper thoracic spine, but pain referred to the arm or to the head occurred as well.

5. The pain qualities pulling and grinding were most often experienced; burning, shooting, pricking and throbbing were also often experienced. The qualities stabbing, pricking and shooting were only expressed at higher pain intensity ratings.

6. The level of muscular activity in the trapezius, splenius and thoracic erector spinae/rhomboids was generally very low when the extreme position was maintained (with the arms resting). Thus the pain sensations related to the extreme position do not seem to be generated by sustained static contractions above the critical level held to cause pain. However, the EMG levels in the trapezius and splenius increased somewhat during the maintainance of extreme position, indicating that in a work situation this increase due to extreme position would add to a static contraction caused by arm work.

7. Since sustained extreme joint or spinal positions can cause pain—locally and referred—it is suggested that ergonomic analyses should to an increased extent inlcude studies of joint or spinal positions, not only to further primary prevention but also as rehabilitative measures for patients returning to work.

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