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THE HAND IN NECK MANOEUVRE AS A TOOL TO ANALYZE PAIN-GENERATING MECHANISMS IN THE SUBACROMIAL IMPINGEMENT SYNDROME

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ABSTRACT. A scoring system for a standardized composite movement of the shoulder – the Hand in Neck (HIN) manoeuvre – is presented. The EMG activity of the supraspinatus muscle was studied in 5 healthy subjects at different performance levels of this test. It is shown that the supraspinatus muscle is about four times more active during normal performance than at the subnormal levels, which among themselves do not differ. EMG activity was also studied during normal performance of another standardized manoeuvre – the Pour out of a Pot (POP) test. Based on a comparison of the EMG data with clinical data from patients with the subacromial impingement syndrome it is suggested that an abnormal HIN test indicates the presence of a traction responsive pain generator in the supraspinatus tendon. In the same patient group, the combination of a normal HIN test and an abnormal POP test indicates pain generated by compression of subacromial structures.

Key words: electromyography, subacromial impingement syndrome, shoulder joint, pain assessment.

INTRODUCTION

In order to assess results of treatment for painful shoulder disorders, several standardized composite movements of the shoulder have been used (1, 3, 13, 14). In the *Hand in Neck (HIN)* manoeuvre, the subject is instructed to put his/her hand around the base of the neck and attempt to extend the upper arm so that the elbow reaches the coronal plane. A standardized rating system for abnormal performance has been presented in a preliminary report (14). In the present paper, the scoring system is described in detail.

When discussing a potentially pain provoking manoeuvre it is important to consider mechanisms that may interrupt an active movement when it causes pain. Via a spinal loop a reciprocal inhibition of the contracting muscles and an activation of their antagonists can occur, but it is more likely that the movement will be interrupted at an earlier stage by supraspinal mechanisms, reflecting the effect of "anticipation of worsening pain". Changing to psychological terminology this is equivalent to saying that the interruption of the intended movement is determined by the pain tolerance limit of the individual patient.

During the HIN manoeuvre certain structures, including the joint capsule, the coracohumeral ligament (4, 9) and the rotator cuff, will be exerted to a traction force. Our hypothesis is that loss of function in the HIN manoeuvre in patients with painful shoulder disorders reflects the presence of a pain generator located in one or more of these structures.

In another study (11), when we recorded HIN manoeuvre scores in patients before and after treatment for the subacromial impingement syndrome, we found that the outcome of treatment was related to HIN performance. In order to understand the pain mechanisms involved, it is necessary to know whether the supraspinatus tendon is subjected to more tension during any particular type of HIN performance than in others, and we therefore decided to record EMG activity of the supraspinatus muscle in normal subjects at different HIN positions. For reasons of comparison, normal performance of another standardized composite movement – the *Pour out of a Pot (POP)* manoeuvre (14) – was also studied. Based on the present findings, examples are given of how conclusions regarding pain generators can be drawn from the outcome of the HIN and POP manoeuvres.

MATERIAL AND METHODS

Subjects

Five healthy subjects, 2 women and 3 men, with a mean age of 41 (range 27–55) years, were studied with EMG recordings

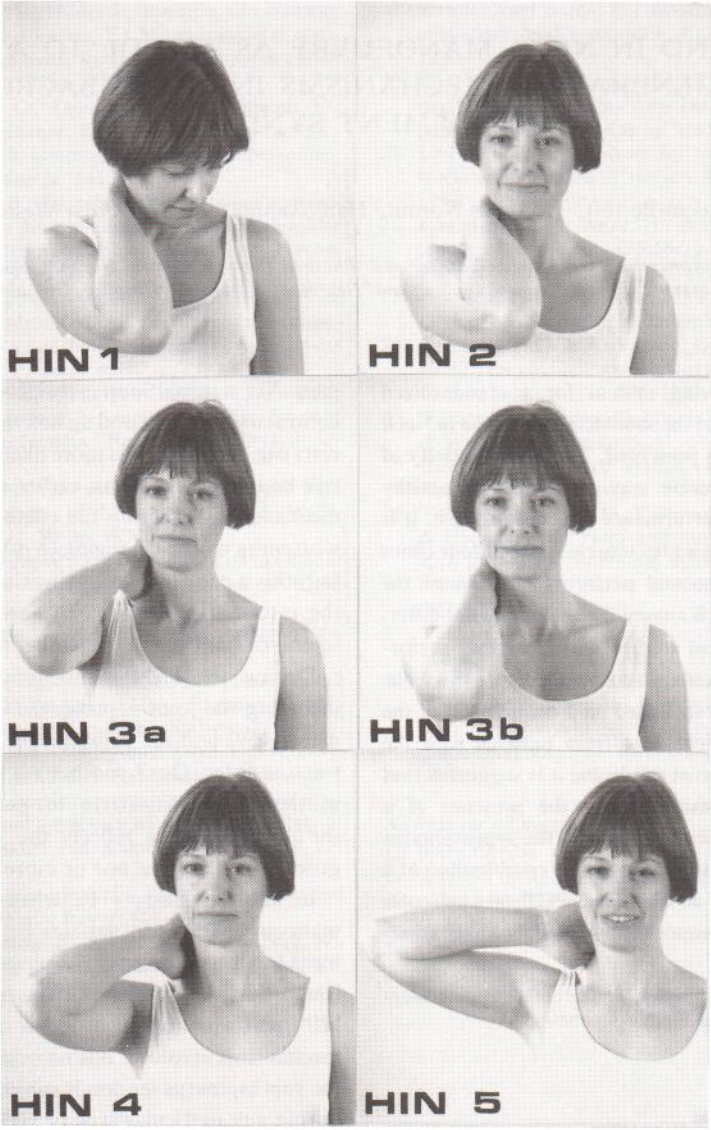

Fig. 1. Scoring system for the Hand in Neck manoeuvre. *HIN 0:* Cannot reach the back of the neck with the hand. *HIN 1:* Can hold the hand around the back of the neck, but compensates by holding the neck in ventroflexion and rotation to the opposite side. The shoulder is elevated, the arm adducted. *HIN 2:* Can hold the hand around the back of the neck, but compensates by elevating the shoulder and adducting the arm. *HIN 3a:* Can hold the hand around the back of the neck, but compensates by elevating the shoulder. *HIN 3b:* Can hold the arm around the back of the neck, but compensates by adducting the arm. *HIN 4:* Can hold the hand around the back of the neck, but cannot extend the upper arm to the coronal plane. *HIN 5:* Can perform the test normally, i.e. the elbow reaches the coronal plane.

from the supraspinatus muscle on each side. The results from the right side of one male subject were excluded, since it turned out that he had had shoulder luxation. All subjects were right-handed.

Recording technique

EMG was recorded with two hook electrodes of stainless steel wire (diameter 0.11 mm), lacquer-insulated except for the most distal 7 mm. By use of a cannula, the electrodes were inserted deep into the supraspinatus muscle about 1 cm apart, 4-5 cm from the medial border of the scapula. Once the cannula had been retracted, the wires caused no pain or discomfort and allowed free movements of the shoulder. The EMG signal was band-pass filtered (30–10 000 Hz), amplified (×200), and stored on tape (FM tape-recorder, Sangamo Sabre VI, USA) for subsequent analysis.

Table I. *Comparisons between the EMG activity of the supraspinatus muscle in different shoulder positions*

The column "approximate mean ratio" actually gives the antilog of [(mean log (x_j+1) minus mean log (x_k+1)] but serves as an approximation to the mean ratio between the compared groups. For instance the first row should be read: "The EMG activity in position HIN 5 is on the average about 5.1 times higher than in position HIN 1". Apart from those shown in the table there are no pairwise comparisons that give ratios that differ significantly from 1.0.

Comparison	Approximate mean ratio	95% confidence interval
HIN 5 vs. HIN 1	5.1	13.6–1.9
HIN 5 vs. HIN 2	4.5	12.0–1.7
HIN 5 vs. HIN 3a	2.9	7.8–1.1
HIN 5 vs. HIN 3b	7.6	20.5–2.9
HIN 5 vs. HIN 4	3.3	8.8–1.2
HIN 5 vs. all HIN < 5	4.4	9.6–2.0
HIN 5 vs. POP	1.2 N.S.	2.8–0.5
POP vs. HIN 1	4.2	11.7–1.5
POP vs. HIN 2	3.7	8.3–1.6
POP vs. HIN 3a	2.4	5.4–1.1
POP vs. HIN 3b	6.3	12.7–3.1
POP vs. HIN 4	2.7	4.9–1.5
Normal (HIN 5, POP) vs. abnormal (all HIN < 5)	4.0	7.2–2.2

Experimental procedure

With the subject sitting on a chair, EMG of the supraspinatus muscle was recorded with the arm in positions 1 to 5 of the HIN manoeuvre as depicted in Fig. 1. Each position was maintained for 15 s. No pain was experienced in any of the positions.

The POP manoeuvre involves emptying a one liter pot filled with water with the arm held in front of the body. The movement requires an isometric postural fixation of the humerus in forward flexion in the glenohumeral joint and an excentrically performed internal rotation. EMG was recorded for 15 s during a manoeuvre of this type.

At the end of the experiment, a 15 s maximal isometric contraction was performed with the arm parallel to the trunk and resistance applied to abduction force. No feedback from the EMG signal was allowed except during the maximal contraction.

EMG analysis

A mean voltage recording was obtained by full-wave rectifying the signal and passing it through an "integrator" with an exponential decay (time constant 0.1 s). The area under this curve (relative to the baseline during relaxation) was measured using a computer with commercially available software (Perisoft, Perimed AB, Sweden). For each position of the arm, the area was calculated during a 10 s period. To compensate for inter-shoulder variations caused by differences in electrode positions, all obtained values are expressed as percent of the EMG activity recorded during the first 10 s of a maximal voluntary contraction (MVC%) of the involved muscle.

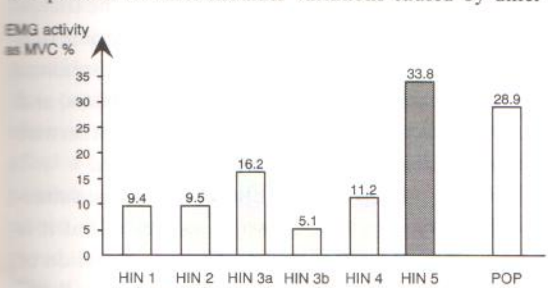

Fig. 2. Average EMG activity (arithmetic means) at different performance levels expressed as per cent of the EMG activity during maximal voluntary contraction (MVC %).

Statistical methods

The chosen overall significance level is 0.05. As the pairwise comparisons between the different HIN levels as well as the linear contrast HIN 5 versus all HIN < 5 levels should be regarded as a posteriori comparisons, interval estimates in these cases are derived from a two-way ANOVA, using the Scheffé method for multiple comparisons. The comparisons POP versus all different HIN levels, however, were decided upon beforehand. Therefore their interval estimates are derived from 6 separate paired *t*-tests, using the Bonferroni multiple comparison technique. In the last comparison in Table I the interval estimate is based on a two-way ANOVA which simultaneously takes all HIN levels, *as well as POP*, into consideration. A two-way ANOVA, comparing the different HIN levels, performed in the scale of Fig. 2, i.e. MVC%, will produce residuals that exhibit both a significant inequality of variance and a significant and strong positive correlation between the absolute values of the residuals and the predicted values, facts that severely violate the assumptions of the mathematical model underlying the analysis. To remedy these aberrations from the model, we used a transformation of the form $y = \log(x \pm 1)$. This will give the the results as conservatively biased estimates of ratios of the EMG activity at the different performance levels. Another consequence is that it will lessen the relative influence of the smallest observations, i.e. those that are likely to be associated with the largest relative errors of measurement. In the legend of Fig. 4, the two sets (HIN 5 and HIN < 5) of ordinal data are tested against a null hypothesis of independence, using Kendall's nonparametric correlation technique (2). All comparisons of proportions are tested for statistical significance by means of the continuity corrected Fisher's exact test (10). All *p*-values are two-sided.

RESULTS

An overview of the results is given in Fig. 2, and more

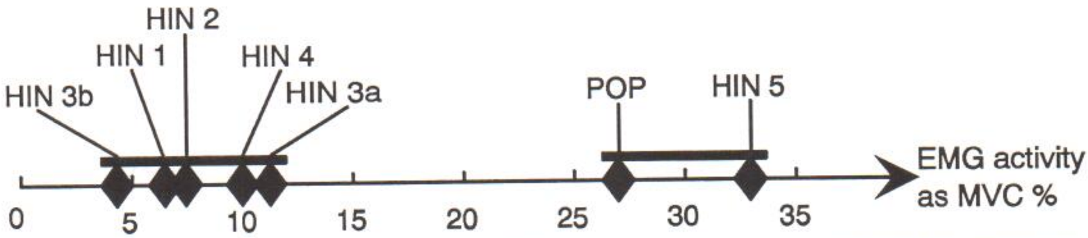

Fig. 3. Summary of statistical conclusions with average EMG activity (genometric means) at different performance levels. Overlying bars connect values that do not differ significantly. It should be explicitly pointed out that the difference between HIN 5 and POP is negligible from a statistical point of view – the probability that the mean POP value is actually equal to or larger than the HIN 5 value being as large as 43% (Wilcoxon's signed rank test).

precise comparisons are presented in Table I. The statistical conclusions based on the data in Table I are summarized in Fig. 3. Taking random variation into consideration there were no differences in the activity of the supraspinatus muscle between the different types of abnormal HIN positions (HIN <5), nor between normal HIN performance (HIN 5) and POP. In the latter two situations, however, the muscle was about four times more active than in the average of the HIN <5 positions, and the EMG activity was about 30% of that observed during a maximal voluntary contraction.

DISCUSSION

We consider the present recordings to be representative for the EMG activity of the whole supraspinatus muscle, since two separate electrodes with relatively large uptake areas were used, and since a priori there is little reason to assume that selective activation of different parts of the muscle can occur (because of the anatomical conditions selective activation would have little or no effect on the mechanical output). As the recordings were obtained under isometric conditions, and as the results are expressed as ratios, our EMG findings can therefore be translated with at least fair approximation to differences in tendon tension. Consequently, the data indicate that normal execution of the HIN manoeuvre requires a tension of the supraspinatus tendon that is about four times higher than during the different types of abnormal performance. This opens the theoretical possibility of using the HIN test to identify patients with traction responsive pain generators in the supraspinatus tendon.

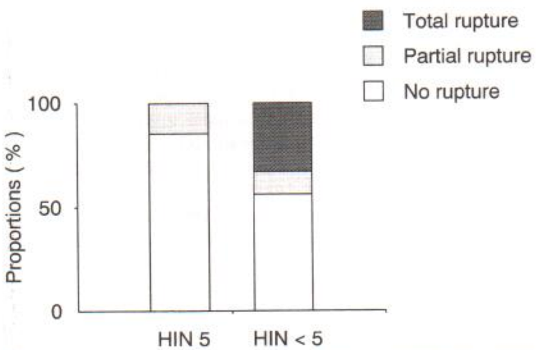

Fig. 4. Peroperative appearance of the rotator cuff versus HIN performance 1 year postoperatively in the 23 patients described in the text. Note that the patients with subnormal HIN performance ($n=9$) exhibit a clear tendency to have more severe degenerative changes in the rotator cuff compared with those with normal performance ($n=14$). This tendency is statistically significant ($p<0.02$). "Total rupture" stands for a transverse full thickness rupture.

In patients with the subacromial impingement syndrome, pathological changes in the rotator cuff are often present, and the critical area for wear on the humeral side is centered on the supraspinatus tendon (8). Sensitization of muscle nociceptors resulting in a considerable lowering of their threshold to pressure and traction has been demonstrated in the cat (7), and there is also evidence of central sensitization following activation of nociceptive muscle afferents (5). It has furthermore been shown that the slowly conducting afferent units innervating the calcaneal tendon in the cat are of similar types to those innervating the triceps surae muscle (6). It therefore seems safe to assume that a local pathological process in the supraspinatus tendon may result in sensitization of nociceptors, and that these nociceptors may be activated at otherwise non-painful levels of compression or traction.

The exact pain-generating mechanism in the subacromial impingement syndrome is unknown, but it is our hypothesis that both compression and traction of pain-sensitive structures are of importance. As a background for the following discussion, it should be kept in mind that a failure to perform normally in the

HIN test is not readily explained by a compression of subacromial structures, since a reduction of the pressure in the subacromial space, even to negative values, is known to occur in a position resembling HIN 5 (12). It should also be pointed out that the short duration of the muscular contraction during performance of the HIN test makes an ischaemic muscular origin of the pain improbable. Furthermore, it should be noted that restriction of the passive range of movement is not a characteristic of the impingement syndrome. Sigholm *et al.* (12) performed a passive movement in such patients, bringing the arm into a position very similar to HIN 5, but with more extreme external rotation; none of them experienced pain.

In an attempt to differentiate between compression and traction mechanisms in the subacromial impingement syndrome, we have analyzed clinical data from a subgroup of 23 patients with this diagnosis who participated in a larger study (11). The reason for selecting this particular subgroup for comparisons with our experimental data are homogeneity of treatment and fulfillment of a predetermined ex juvantibus criterion of a "correct" diagnosis. These 23 patients were all subjected to anterior acromioplasty – an operation that widens the anterolateral opening of the subacromial space. They all had a more than 50% reduction of total pain score, when comparing initial scoring data and the scores at one year after the operation. (Total pain score is the sum of pain scores at rest and during the POP manoeuvre, both determined by the VAS technique.) Fifteen of these patients became completely free from pain. The remaining 8 had partial but substantial pain relief. At the end of the study, 13 of the 15 painfree patients (87%) performed the HIN manoeuvre normally versus only 1/8 (13%) among those with only partial pain relief. The difference is highly significant ($p < 0.0007$).

When all facts are taken into consideration it seems probable that the abnormal HIN performance in the latter group was caused by a traction responsive pain generator in the supraspinatus tendon. This would also explain why acromioplasty was only partially effective – a mere decompression is not supposed to affect a traction mechanism. Not unexpectedly the 9 patients with subnormal HIN performance had more severe degenerative changes in the rotator cuff compared to the 14 patients with normal performance (Fig. 4). Three of the patients in the first group had a transverse full thickness cuff rupture. In these cases it is conceivable that mechanical factors unrelated to pain-induced inhibition of the supraspinatus muscle contributed to subnormal motor performance. However, after their exclusion from the analysis the relation between HIN performance and pain is still obvious – 13/14 (93%) pain-free in the HIN 5 group vs 2/6 (33%) in the HIN < 5 group ($p < 0.009$).

Admittedly, other structures such as the anterior joint capsule and the coracohumeral ligament are also exerted to traction during the HIN manoeuvre, but they are not thought to be damaged in the impingement syndrome, and lesions in the supraspinatus tendon – not necessarily observable peroperatively – are therefore strongly suspected of acting as pain generators. The patients who obtained full pain relief by the operation apparently lacked traction evoked pain, as evidenced by their normal HIN test.

The EMG activity of the supraspinatus muscle during normal performance of the POP and HIN manoeuvres differed very little and from a probability point of view not at all. If exactly the same mechanism were responsible for loss of function in both tests, one would expect all patients with normal performance in the HIN test to perform normally also in the POP test. Before surgical treatment, 11 of the 23 patients mentioned above had a normal HIN test. In contrast, only 2 of these 11 patients performed normally in the POP test. If it is accepted that loss of function in the HIN test in these patients is determined by a traction activated pain generator in the supraspinatus tendon, it is obvious that some other mechanism, for instance compression, must have been the main cause of loss of function in the POP test. A compressive mechanism is strongly supported by the fact that the POP manoeuvre necessarily is performed with the shoulder in protraction, a position that is known to result in a narrowing of the anterior inlet to the subacromial space (15), and by the considerable rise in pressure in the subacromial space demonstrated at an upper arm position similar to that in the POP test (12).

By this study we hope to have demonstrated that the HIN manoeuvre can be used not only to follow the course of painful shoulder disorders but also as a tool for the analysis of pain mechanisms. In conclusion, we suggest that an abnormal HIN test in patients with the subacromial impingement syndrome indicates the presence of a traction responsive pain generator in the supraspinatus tendon. In the same patient group, the combination of a normal HIN test and an abnormal POP test indicates pain generated by compression of subacromial structures.

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