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EMG Levels in the Occipitofrontalis Muscles Under an Experimental Stress Condition[1]

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In view of the importance attached to the frontalis muscles by researchers into the etiology of head pain and its treatment by biofeedback techniques, it is surprising that no data have yet been reported on the functioning of the occipitalis muscles, which have a close physiological relationship to the frontales. This study explores the response of the frontalis and occipitalis muscles under a condition of experimental stress. Migraine and tension-headache sufferers were separately compared with a headache-free control group under four conditions: baseline, while listening to instructions, while carrying out an auditory vigilance task, and for a further resting period equivalent to baseline. Results showed that tension levels in the frontalis muscles were not elevated at rest in any of the experimental groups, nor were they significantly responsive to the experimental task. The occipitales however proved to have significantly higher levels in both the tension-headache and migraine groups during the task and recovery periods. The results for the tension group reached significance because of a drop in control group values. These results may have significance in determining the best site for electrode placement in biofeedback.

The current literature on the part played by the occipitofrontalis muscle system in both migraine and tension headache is marked by considerable confusion. Little agreement can be found as to whether the frontalis muscles provide the best site for training head muscles to relax (Shedivy & Kleinman, 1977; Harper & Steger, 1978; Burish & Horn, 1979) or whether

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EMG biofeedback is superior to other methods of treatment (Silver & Blanchard, 1978; Surwit & Keefe, 1978; Turk, Meichenbaum, & Berman, 1979). In a recent review of the literature on migraine headache, Adams, Feuerstein, and Fowler (1980) point out that most of the basic questions regarding the etiology and treatment of migraine headache still remain unanswered.

A question of fundamental importance to the treatment of headache by frontalis biofeedback is whether the pain experienced is the result of high levels of muscle tension during either the headache or the nonheadache phase. If it cannot be shown that headache sufferers have high resting levels, then the rationale for training in muscle relaxation is weakened.

The weight of available evidence does seem to indicate that frontalis muscle EMG levels are elevated when compared with normal controls or low-frequency sufferers (Van Boxtel & Roozeveld, 1978; Philips, 1977a; Tunis & Wolff, 1954; Hutchings & Reinking, 1976; Vaughn, Pall, & Haynes, 1977; Haynes, Griffin, Mooney, & Parise, 1975). These results are however not invariable. Some studies have shown little or no relationship between head pain and elevated EMG levels. Neither Cohen, Rickels, and McArthur (1978) nor Martin and Mathews (1978) found elevated frontalis levels in headache subjects while they were completing a series of experimental tasks. Bakal and Kaganov (1977) found no difference in resting EMG levels between tension headache subjects and controls, but found significant differences between these groups and a migraine sample both during a headache and while headache-free. Philips (1977a) also found frontalis in migraine sufferers to be higher than that of tension headache subjects.

Haynes, Griffin, Mooney, and Parise (1975) point out that while their study showed that some tension subjects demonstrated significantly higher frontal EMG levels during headache, several did not. The authors speculate that one of the possible explanations is that other head muscles, not measured, were in contraction.

Turk et al. (1979) have suggested that muscle tension headache may not be the result of high levels of frontalis activity but rather of muscle contraction in other parts of the head, neck, and shoulders, with little generalization across muscle groups.

In the search for other head muscles relevant to head pain, EMG investigations have been carried out on the functioning of the “neck” muscles (usually splenius/semispinalis capitus) by Philips (1977), Pozniak-Patewicz (1976), Martin and Mathews (1978), Shedivy and Kleinman (1977), and Van Boxtel and Roozeveld (1978). Only the results from the studies of Bakal and Kaganov and of Pozniak-Patewicz demonstrate higher neck levels in headache groups, once again leaving some doubt as to the role of these muscles in headache.

The possibility of the temporalis muscles also being involved is raised by the findings of Philips (1977a) and Tunis and Wolff (1954), who found some evidence of elevated temporalis EMG levels during and between headaches in patient groups.

An important variable in studying the involvement of muscle activity in pain is the dynamic performance of the muscles—that is, what they do while under stress.

A small number of experimental stressors have been reported in an attempt to clarify this aspect of head muscle functioning. They include, for example, mental arithmetic (Cohen, 1978), bursts of noise (Bakal & Kaganov, 1977), problem solving (Martin & Mathews, 1978; Van Boxtel & Roozeveld, 1978), pain stimuli (Martin & Mathews, 1978; Wolff, 1963), and imaginal events (Philips, 1977a). The results are difficult to interpret because of difference in experimental design, the nature and length of application of the stimulus, the involvement of other muscles, and patient selection.

In considering the role of other head muscles in headache, it is somewhat surprising that the role of the occipitales has received no attention. These muscles are the frontales' counterparts and lie on the occipital and temporal bones of the skull. They are joined to the frontales by way of a broad fibrous layer covering the top of the skull.

This study sought to reexamine the role of the frontalis muscle in headache both during rest and while under experimental stress, and at the same time to evaluate the role of the occipitalis muscles under the same conditions.

In choosing the experimental task for this study, the important considerations were that it could be undertaken while resting with closed eyes to minimize other muscle artifact, and that it should actively engage the subject with little chance of adaptation. The task chosen (and described below) was an auditory vigilance task.

METHOD

Subjects

Subjects were recruited from university staff and students, and from responses to a newspaper advertisement.

For the migraine group ($N = 10$) the median age was 38.5 years, with a range from 25 to 52. The median age for the tension group ($N = 10$) was

30 years, with a range from 18 to 39. For the control group ($N = 10$) the median age was 25.5 years, with a range from 21 to 40.

All of the migraine and tension headache subjects had been diagnosed medically before the beginning of the experiment and fulfilled the brief criteria set out by Philips (1977)—that is, they had two or more of the following symptoms: unilateral onset, nausea and vomiting, and sensory prodromata. The tension group complained of a troublesome headache that may have involved nausea but not vomiting, and otherwise demonstrated no symptoms indicating a vascular involvement. The control group had never suffered from a headache, or so rarely as to make recall difficult. All subjects were interviewed in detail using a headache questionnaire that included items relating to onset, duration, nature, frequency, and laterality of pain; possible precipitants; drugs taken; as well as other demographic and familial details. The difference between the headache groups was essentially one of the degree of severity, with those suffering from migraine having an obvious vascular involvement, and with greater and more disabling pain than the tension headache group. The subjects in both groups had at some time taken medication for head pain, but at the time of testing none was on drugs of any sort.

All recordings were taken in a sound-deadened, temperature-stable room. Activity from electrode sites was monitored with a pair of Devices No. 3542 differential amplifiers in a Devices M 19 polygraph. Top roll-off was set at 500 Hz, while the low frequency was set at a time constant of .03 seconds (approximately 35 Hz). Pen sensitivity was 100 μv/cm. Integration of the raw traces was by Devices No. 3520 integrators, which, on a medium time constant, had a storage and discharge time of 500 milliseconds.

For sampling frontalis muscle activity, sensors were placed 2.5 cm above the eyebrow and directly above the pupil (Davis, Brickett, Stern, & Kimball, 1978). Occipitalis muscles were found by identifying the superior nuchal line of the occipital bone and then by measuring approximately 5 cm from the helix of the ear; the muscle could often be palpated. Electrodes were placed bilaterally over each muscle.

All electrode sites were cleaned with alcohol and lightly abraded. Electrode cream was then rubbed into the site and the electrodes attached. For occipitalis this procedure was followed after the area had been shaved. All electrode resistances were below 10 k ohms and average 3 k ohms.

The electrodes were made from silver and measured 12 mm across, with a depth of 3 mm.

Procedure

Subjects were given a detailed explanation of the experimental procedure. They were then seated in a semireclining position in a light-dimmed environment and were requested to relax as well as they could with closed eyes. Subjects were asked to relax and were given details of Wolpe's subjective units of disturbance scale, related to the degree of relaxation experienced (Wolpe, 1969). At the end of a 6-minute baseline period, subjects were asked to assess their degree of relaxation on the subjective scale. Recording proceeded when the subjects indicated that they had achieved a level of 45 or lower—that is, they were a little more relaxed than usual. The period allowed for stabilization was effective as all but two of the subjects reported a score of under 50 within the time period. Both of these subjects were from the tension group and were given a further 5-minute period of relaxation. Subsequently, a 2-minute baseline recording was taken. Subjects were then instructed in the task by way of a prerecorded tape taking 1 minute 40 seconds. A 10-second pause was allowed between the conclusion of the instructions and the beginning of the task, to allow for clarification if requested. The task period of 6 minutes' duration was then begun. On its completion, subjects were instructed to remain seated quietly for a further 3 minutes. Recording was continuous until completion.

The task was a simple auditory vigilance task in which a series of single randomized digits were read out at a rate of one per second. Subjects were given a hand counter and were requested to press it each time they heard an even number preceded and followed by an odd number. The total possible number of errors was 48. No attempt was made to assess the final score accuracy.

Data Reduction and Analysis

As the Devices polygraph produces a time stripe on the trace every 6 seconds, this interval was used to sample the EMG record. The samples for each of the experimental periods—baseline, instruction, task, and recovery—were averaged giving a single number for each subject on each experimental period. From an examination of the means and standard deviations of these data it was apparent that the variance tended to increase with the means. In order to reduce this effect, these scores were then log-transformed, having the effect of standardizing the variance. These log-transformed data were then averaged across each of the experimental groups, giving a single score on each experimental period. The results are presented in Figure 1.

RESULTS

The data were initially analyzed as a univariate, three-factor experiment with measures made on three experimental groups with repeated measures made on two muscles over four time periods.

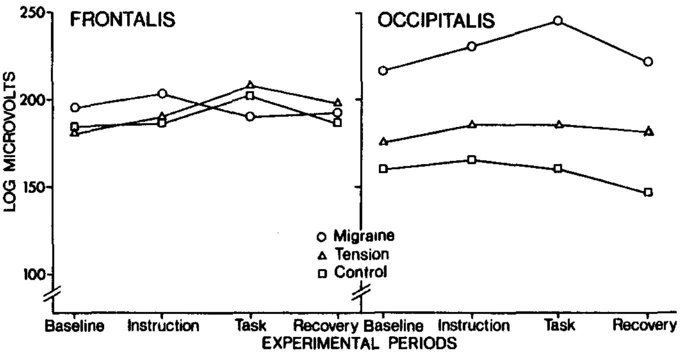

Fig. 1. Log-transformed group means for both muscles plotted over the experimental periods.

These results show a significant main effect for groups, $F(2, 27) = 11.091$, $p < .001$. The main effect for time periods was also significant, $F(3, 81) = 12.669$, $p < .000$. A significant interaction was also found between the experimental groups and the muscles, $F(2, 27) = 9.114$, $p < .001$. All other tests produced negative results.

The univariate ANOVA assumes strong symmetry conditions in the underlying error variances and covariances. A MANOVA analysis makes no such assumptions and was carried out, as well as a precaution against losing information, on each muscle separately (S.P.S.S. Update, 7.9.1981).

In this case the results were about identical in terms of the significance of outcome.

As the three-way analysis showed significant differences among the treatment means, post hoc comparisons were carried out on the groups over time periods using the Newman-Keuls formula.

No significant results were found for frontalis on any of the time periods. The occipitalis results showed no group differences at baseline; the migraine group differed from the tension and control groups at the instruction period. All groups differed from each other on task and recovery periods. This was so for the tension and control groups because of a decrease in control group scores.

DISCUSSION

Evidence as to the functional role of the frontalis muscles in head pain and its treatment had been shown to be rather inconclusive. However, the results from biofeedback studies using frontalis as the treatment muscle have been sufficiently encouraging to warrant further investigation. The choice of the most appropriate muscle for feedback is critical, and very little success has been reported in the search for alternative target muscles. As Neuchterlein and Holroyd (1980) point out, "At the present time it is unclear whether the preferred choice is the frontalis, the head or neck (or other?) most tense at rest, the muscle most reactive to stress or several of these."

It should be pointed out that, using surface electrodes of the type described in this study, the output will reflect muscle activity from a number of other facial muscles including the corrugator (a muscle continuous with the frontales), the periorbital muscles, and others. Increased activity can often be shown in frontalis when any of these muscles are flexed. The influence of periorbital muscles in elevating EMG output is particularly evident when subjects close their eyes—a relevant point when considering data from studies that require visual tasks.

However, the majority of studies on the frontalis muscle have used surface electrodes of approximately the same size as those used in this study, making results in this regard comparable.

It may reasonably be asked whether or not radiation from large adjacent muscles was affecting the output from occipitalis. The most likely group to have any influence are those in the neck. A further series of studies has been undertaken in which the activity of neck muscles (splenius capitus, semispinalus capitus) was assessed in relation to the activity of occipitalis during headache and headache-free periods. No evidence was found implicating these muscles in the output from occipitalis.

In the same series of studies the stressful nature of the vigilance task has been investigated, as it may be argued that the task is not very arousing. These later studies, which will be reported in greater detail, indicate that the task was "somewhat" or "very" stressful for approximately 85% of 60 subjects assessed.

The results from this study give evidence that the "frontalis muscles" are not significantly elevated at rest and are not reactive to the type of stress elicited by the experimental task. The occipitalis muscle in the migraine subjects was more reactive to stress and had higher resting levels than in either the tension group or the controls. The tension group tended to differ from the controls toward the end of the experimental period only because the controls dropped tension levels. The characteristic differences in the migraine subjects then was the reactivity of the occipitalis muscles. As muscle reactivity is an important variable, treatment trials may be more efficient if they are aimed at reducing muscle-tension awareness thresholds, a point considered by Philips (1977a) and Sime and DeGood (1977). In this regard, it is interesting to note that, in some migraine patients, the occipital muscles had every appearance of being in spasm, as they were sore to touch and demonstrated very high and variable EMG levels. None of the patients, however, was aware of pain or discomfort in that area, unless attention was drawn to them.

Why were these results at variance with other studies that did detect high frontalis resting activity? One likely explanation is that the patients selected were not comparable with those in other studies. None of the patients in this study, for example, was taking drugs of any sort regularly. In the study by Budzynski, Stoyva, and Adler (1973) "patients" in both experimental groups were taking quite large doses of drugs, many of which were minor tranquilizers.

A number of studies have indicated that anxiety may increase muscle potentials. Malmo and Shagass (1949) found significantly higher muscle potentials in anxious patients, compared with controls, while both were undergoing an experimental stress task. Sainsbury and Gibson (1954) found a relationship between forehead EMG and anxiety measured on scales derived for the purpose. Balshan (1962) found large increases in skeletal muscle tension in anxious women only while listening to an auditory stimulus. Similar increases were not found in controls. More recently, Smith (1973) found that frontalis muscle levels correlated positively with trait and state anxiety, measured on Cattell's IPAT, in a nonheadache sample. It does seem, then, that future studies should control for this variable.

The finding that resting frontalis EMG levels are not significantly different in headache groups is not an isolated one. A number of studies have also reported a lack of concordance between frontalis muscle levels and the experience of head pain (Haynes et al., 1975; Cox, Freundlich, & Meyer, 1975; Coursey, 1975; Epstein & Abel, 1977; Holroyd, Andrasik, & Westbrook, 1977; Martin & Mathews, 1978; Anderson & Franks, 1980). More recently, Gannon, Haynes, Safranek, and Hamilton (1981), using an arithmetic stressor, found no differences in frontalis output between muscle contraction subjects and controls. The reasons for the discrepancies between studies must surely lie in the myriad combinations that are possible involving patient selection, electrode size and placement, integration and analysis of the output signal, the stage in the headache sequence at which the output was sampled, and so on. The resolution of the matter will have to await better detailed and controlled studies than many of those reported.

The selection of patients is of fundamental importance. Philips (1977) used a combination of a number of symptoms to diagnose migraine, and a lesser number of identify tension headache. Martin and Mathews (1978) took a novel approach, accepting physicians' referrals together with a rating of the likelihood that this diagnosis was correct. This reliance on medical diagnosis has been shared by a number of researchers (Budzynski et al., 1973; Tasto & Hinkle, 1973; Van Boxtel & Van Der Ven, 1978; Diamond, Medina, Diamond-Falk, & DeVeno, 1979) or has not been addressed at all (Kondo & Canter, 1977). In some papers the criteria were alluded to but not stated (Budzynski, Stoyva, & Adler, 1970; Haynes et al., 1975; Chesney & Shelton, 1976). Epstein and Abel (1977) added a new dimension to the diagnosis of tension headache by requiring all of their subjects to have high average integrated frontalis EMG levels before they were selected for study. They refer to other criteria as well, but they do not specify these. In their later paper (Epstein, Abel, Collins, Parker, & Cinciripini, 1978) it appears that this was the major diagnostic feature.

It seems to be not widely recognized that the differential diagnosis of headache may be inherently unreliable and that clear specification of subject parameters is necessary for replication.

An attempt was made in this study to select subjects about whom there would ideally be little disagreement in placing them within their designated categories. That is, they were typical of the standard medical descriptions of vascular and tension headaches. The statement that they were medically diagnosed does not mean that this was the major criterion; it means that, usually, other medical causes for head pain had been excluded, increasing the likelihood that the final assignment to groups was valid. In making the statement that the migraineurs were the more severe, the cogent arguments put by Bakal and Kaganov (1977) were kept in mind—that is, that tension and migraine headache might be not distinct diagnostic entities but identifiable points along a continuum of severity.

The frontalis appears to be purely a muscle of facial expression that serves to lift the eyebrow and pull the scalp forward. The occipitalis pulls the scalp backward and, as very few subjects were able to move the muscle voluntarily, seems to have no extant function. It may be speculated that the muscles were once used to raise the hair in a crest to communicate with others. Darwin (1896) made reference to this ability when he wrote, "Messrs Savage & Wyman state that the scalp [in apes] can be freely moved backwards and forwards and when the animal is excited it is strongly contracted." Whatever the case, these results give good reasons to consider the occipitales in the search for stress-responsive and trainable muscles.

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