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Charles R. Carlson
University of Kentucky, ccarl@email.uky.edu

Kennen T. Wynn
University of Kentucky


John Edwards
University of Kentucky

Jeffrey P. Okeson
University of Kentucky, okeson@uky.edu

Arthur J. Nitz
University of Kentucky, ajnitz1@uky.edu

See next page for additional authors

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Ambulatory Electromyogram Activity in the Upper Trapezius Region

Patients With Muscle Pain vs. Pain-free Control Subjects

Charles R. Carlson, PhD,*† Kennen T. Wynn, BA,* John Edwards, BA,*
Jeffrey P. Okeson, DMD,† Arthur J. Nitz, PhD,‡ Don E. Workman, PhD,§
and Jeffrey Cassisi, PhD§

Study Design. This study compared the ambulatory electromyogram activity of persons reporting pain in the shoulder and cervical regions with an equal group of persons not reporting such pain. Ambulatory electromyogram data were obtained over 3-day periods. In addition, all participants completed several standard psychological questionnaires.

Objectives. The results were analyzed with inferential statistics to determine whether subjects reporting significant pain in the shoulder and cervical regions had greater ambulatory electromyogram activity than an equal number of subjects not reporting pain.

Summary of Background Data. Considerable controversy exists regarding the role of muscle activity in the etiology and maintenance of muscle pain disorders. Given the availability of ambulatory recording devices that can provide a detailed record of muscle activity over an extended period of time, the present research was conducted to determine whether persons reporting shoulder and cervical pain could be differentiated from a group of normal subjects.

Methods. All subjects ($N = 20$) completed a battery of tests with standardized psychometric instruments and then were fitted with ambulatory electromyogram monitors to record electromyographic activity of the upper trapezius region of the dominant side; the time, duration, and amplitude of electromyogram activity greater than $2 \mu V$ was recorded. The monitors were worn during normal working hours (mean, 6.2 hours per day) over 3 consecutive days. In addition to wearing the monitors, all subjects completed hourly self-ratings of perceived muscle tension during the recording periods.

Results. As expected, subjects with muscle pain reported significantly more pain (mean, 4.9) than did the normal control subjects (mean, 0.9), $t(15) = 3.29$, $P <$

0.01. However, patients with muscle pain did not have greater average electromyogram activity (mean, $6.4 \mu V$) over the 3-day period as compared to the normal controls (mean, $7.1 \mu V$), $t(18) = -0.25$, $P < 0.80$. Self-monitoring of perceived muscle tension also did not reveal differences between pain subjects and the normal control subjects ($P < 0.75$).

Conclusions. Ambulatory measurements of electromyogram activity did not differentiate persons reporting upper trapezius or cervical pain from those that did not report such pain. Persons reporting pain are also not distinguishable from normal control subjects on a variety of self-report measures. These results raise questions regarding the role of ambulatory electromyogram recordings in the evaluation and treatment of muscle pain disorders. [Key words: EMG, cervical pain, muscle activity] *Spine* 1996;21:595-599

Introduction

There has been discussion recently regarding the role of muscle activity in the genesis and maintenance of muscle pain disorders.^{3,8,11} Historically, it has been assumed that muscle overuse is a primary factor in the development of muscle pain, especially acute muscle pain. Often personal experiences tend to confirm muscle overuse as a precipitator of muscle pain, as in the case where leg muscles are sore the morning after a lengthy run. While there are instances in which muscle overuse is directly linked with muscle pain, there are other situations (e.g., chronic tension-type headaches) in which it is not entirely clear what factors are responsible for the reported pain.¹⁵ Overall, the degree to which muscle activity is or is not influencing pain reports among persons presenting with muscle pain is a question that must be carefully evaluated.

In the facial pain literature, Lund and Widmer¹¹ have argued that data currently available do not support the general conclusion that muscle hyperactivity is a characteristic associated with chronic muscle pain disorders. For example, Dolan and Keefe⁷ found that in persons reporting right-sided masseter pain there was greater

*Department of Psychology, †Orofacial Pain Center, and ‡Department of Physical Therapy, University of Kentucky, Lexington, Kentucky, and §Department of Psychology, Illinois Institute of Technology, Chicago, Illinois.

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activity in the left masseter region as compared to the right masseter region. If muscle hyperactivity were a major factor in the pain reports, one might expect that muscle activity in the painful side would be greater than the activity on the nonpainful side. In a well controlled study,⁹ it was found that muscle activity in the masseter regions was not greater in patients with pain as compared to normal control subjects during rest, but was during a stressful challenge task involving a personally relevant stressor (e.g., a stressful event in the past week that had an intensity of "7" on a "0-10" scale) in a laboratory setting. Carlson and colleagues³ did not find masseter muscle activity to be greater in persons reporting masticatory pain as compared to normal controls during rest or during a laboratory challenge involving math computations. Taken together, these data do not support a clear role for muscle hyperactivity in the onset and maintenance of facial pain disorders.

In the back pain literature, a similar conclusion can be made. While it was recently shown that muscle activity during flexion/extension may be altered in persons with back pain as compared to normal controls,¹⁷ there is little difference in the resting levels of activity between patients with pain and normal subjects.⁸ There is, however, evidence generally similar to that reported for facial pain, in that electromyogram (EMG) activity in painful muscles (lumbar paraspinals) is greater during stressors of a personally relevant nature.^{9,10} Cassisi and colleagues⁵ have shown that muscle activity in the lumbar paraspinal region of patients with back pain is actually less than the activity of normal subjects during a standard series of exercises. What emerges from the back pain literature is that EMG activity at rest does not differentiate patients with pain from normal subjects in a laboratory environment although EMG activity during a stressor may reflect differences. However, it is not necessarily the case that these differences will reveal subjects reporting pain having greater EMG activity than normal subjects.

Given the beliefs about muscle activity and pain, it is not unreasonable to make the same claims for muscle involvement in cervical pain as in other muscle pain disorders. Cervical pain is a common malady presenting in the clinical environment and in the general population. A recent epidemiologic study found that 34% of the respondents had experienced cervical pain in the past year with 14% reporting cervical pain lasting for greater than 6 months.¹ Dysfunctions in the cervical region can have effects at distant sites⁴ and it is often difficult to determine the exact cause of the physical complaints because of the endowed multiple interconnected communication networks in this region of the body. The research literature investigating the relationship between cervical muscle activity and pain in those muscles is limited. Rugh et al¹⁶ used ambulatory monitors to evaluate the relationship between cervical muscle activity and headache pain. Their findings indicated

there is no difference in ambulatory muscle activity between chronic headache patients and normal controls. These results are consistent with a growing body of data suggesting that muscle hyperactivity as monitored by EMG recording is not a useful way to differentiate patients with pain from normal subjects. The study, however, was done with persons primarily reporting headache pain, and therefore leaves open the possibility that those persons with cervical pain specifically may evince higher levels of muscle activity in that region.

The present study was undertaken to explore the relationship between reports of muscle pain and ambulatory EMG activity over a meaningful period of time involving routine activities. Given the currently available data exploring the linkage between EMG and pain report, it was expected that patients with pain would not have greater levels of muscle activity than normal control subjects. This study also included several psychological questionnaires to determine whether patients with pain may differ from normal subjects on variables such as response style, anxiety, or anger.

■ Method

Subjects. A group of persons reporting cervical muscle tension and pain ($N = 10$) were recruited for this study. The muscle pain subjects were identified through interview with a health professional affiliated with an orofacial pain clinic; the only requirement for participation was the self-report of persistent cervical muscle pain. No specific medical diagnoses linked to the cervical pain were available. This group of individuals was matched with an equal number of persons ($N = 10$) who described themselves as not experiencing such symptoms. All subjects included in this sample were female. The average age of the pain group was 37.6 years; the average age of the normal group was 36.7 years, $t(18) = 0.17$, $P < 0.87$. The weights of the subjects were also obtained because there is evidence to suggest that surface EMG recording may be influenced by the electrical insulation properties of subcutaneous tissues (e.g., muscle, fat) that are highly related to a subject's body weight. The average body weight for the pain subjects was 65.5 kg and the average weight for the control subjects was 62.5 kg, $t(18) = 0.77$, $P < 0.45$.

Procedure. The study was conducted through the Behavioral Psychophysiology Laboratory in the Orofacial Pain Center at the University of Kentucky. Each subject began the study during the early morning of a normal work day. After introduction regarding the purposes of the study, all subjects gave informed consent and completed several screening questionnaires (McGill Pain Questionnaire, Short Form¹²; State-Trait Personality Inventory¹⁸; and the Miller Behavioral Style Scale¹³). The electrode leads for an ambulatory EMG monitor (Bio-Prompt 3000, Physical Health Devices) were then attached to the upper trapezius muscle on the dominant side; the EMG monitor was placed into a holster attached around the waist. Muscle activity from the dominant side was recorded because the authors believed that the most likely site for observing differences in muscle activity would be that muscle that is more often used. Each subject was given an introduction to the operation of the unit and its care. In addition, subjects

were given self-monitoring forms to record their own perception of muscle tension on an hourly basis. After activation of the unit, subjects were released and encouraged to resume their normal routines.

The Bio-Prompt was programmed to record the duration and intensity of muscle activity exceeding $2 \mu\text{V}$ over an 8-hour period. When the subjects were ready to retire in the evening, they removed the sensors and turned the unit off. On the following morning, subjects returned to the clinic for reattachment of the sensors. Each subject wore the unit for 3 consecutive working days. Along with the EMG monitoring, subjects recorded on an hourly basis their perceptions of muscle activity using a 100mm visual analogue scale anchored at one end with "no muscle tension" and at the other end with "highest possible muscle tension."²

Physiological Recording. As indicated previously, the EMG recordings were made with a BioPrompt EMG monitor. The skin at the recording site was prepared by vigorous rubbing with an alcohol swab. Then, bipolar silver-silver chloride miniature surface electrodes (0.5 cm in diameter) were prepared by applying a small dab of electrode cream on the electrodes and attaching them with adhesive collars. The sensors were placed at the midpoint of the muscle belly of the upper trapezius muscle on the dominant side of the subject. This placement was determined by anatomical landmarks and palpation while the subject activated the upper trapezius muscle. The ground electrode was placed 1 cm apart from each of the active electrode leads. Continuity of the electrodes with the skin surface was continuously monitored by the BioPrompt, which was programmed to alert the subject with a beep if the resistance between the active electrodes rose above a threshold value of 100 ohms.

The EMG signal was passed through a band pass filter in front of the root mean square conversion. The band pass width was 100–540 Hz with a 60 Hz notch filter. The time constant for the root mean square to DC conversion was 40 milliseconds; the integrated signal was then sampled and stored at 128 Hz. The BioPrompt was programmed to record any activity exceeding $2 \mu\text{V}$. Average integrated EMG activity and the duration of the activity, in seconds, was computed and stored in the unit for the entire recording period. At the beginning of the next recording period, the recorded data first were downloaded with BioScope Software (Physical Health Devices, Boca Raton, FL) onto a microcomputer (PC-DOS) and printed for an archival record; then the unit was reprogrammed for the coming day's recording. All data analyses were performed by using the SYSTAT data analysis program for microcomputers.

■ Results

Pain Report

Each subject completed the McGill Pain Questionnaire, Short-Form at the initial session to standardize their reports of pain in the cervical region. The Miller Pain Questionnaire yields sensory, affective, and overall pain rating scores. There were significant differences between the pain subject's reports and reports from normal subjects on all three pain subscales. Pain subjects' sensory scores (mean, 10.3; standard deviation [SD], 8.2) were significantly higher than the normal subjects' sensory

scores (mean, 2.5; SD, 4.1), $t(16) = 2.64, P < 0.02$. The Miller Pain Questionnaire affective scores were similarly different, with pain subject's ratings (mean = 3.38; SD, 2.3) significantly greater than the normal subjects' ratings (mean, 0.70; SD, 1.3), $t(16) = 3.19, P < 0.01$. Overall pain ratings on a 100mm visual analogue scale also showed that pain subjects (mean, 48.6; SD, 7.3) assigned higher scores to their pain than did normal subjects (mean, 8.9; SD, 8.0), $t(15) = 3.29, P < 0.01$. The varying degrees of freedom associated with these results and subsequent analyses reflect incomplete subject data sets due to clerical error in administering questionnaires to all subjects.

Electromyogram Activity

The Bio-Prompt records the time of day, duration (seconds) and average intensity (μV) of all EMG activity greater than $2 \mu\text{V}$ during the recording periods. To create comparable summaries of EMG activity for all subjects, each subject's EMG data were first summarized into an average overall activity score. These scores were obtained by summing the total units of activity (μV) during the day and dividing that value by the total number of seconds of activity during the recording period, since not all subjects wore the monitors for the same period of time. This strategy thus enabled computation of the subject's overall average muscle activity for each of the 3 days of recording and an overall average level of muscle activity could be determined. The average length of time for recording was 6.2 hours per day for the sample; there was no significant difference between the amount of time the monitors were recording in the pain group as compared to the control group. There was also no significant difference in muscle pain subjects' average EMG activity (mean, $6.4 \mu\text{V}/\text{second}$; SD, 6.1) over the 3-day period as compared to the normal control subjects (mean, $7.1 \mu\text{V}/\text{second}$; SD, 5.4), $t(18) = -0.25, P < 0.80$.

Self-Monitoring of Muscle Tension

For each day, the subject's hourly self-monitoring ratings expressed as "subjective units of tension" ("0" represents no muscle tension and "10" highest possible muscle tension) were averaged and an overall average for the 3-day recording period was determined. No differences were found between the ratings for pain subjects (mean, 2.79 subjective units of tension; SD, 1.1) and the controls (mean, 2.95 subjective units of tension; SD, 1.0), $t(16) = -0.31, P < 0.76$. The relationship between overall self-monitoring scores and the actual EMG activity that was recorded was also explored through correlational analyses. For neither group was there a significant relationship between self-ratings of muscle tension and EMG activity (for subjects with pain, $r = 0.05, P < 0.90$; for normal subjects, $r = -0.34, P < 0.42$).

Personality Inventories

There were no differences between subjects with pain and normal control subjects on state or trait measures of anxiety (pain subjects' Trait anxiety mean, 19.8; SD, 2.1 vs. control subjects' trait anxiety mean, 18.8; SD, 5.2; pain subjects' state anxiety mean, 20.4; SD, 4.5 vs. control subjects' state anxiety mean, 17.0; SD, 4.9) or anger (pain subjects' trait anger mean, 20.0; SD, 4.7 vs. control subjects' trait anger mean, 19.3; SD, 5.2; pain subjects' state anger mean, 16.0; SD, 4.8 vs. controls' state anger mean, 13.4; SD, 5.5), all t values < 1.60 . Similarly, there was no difference on the Blunting subscale of the Miller Behavioral Style Scale between the pain subjects (mean, 5.0; SD, 2.9) and the normal control subjects (mean, 5.9; SD, 3.3), $t(17) = -0.62$, $P < 0.54$. There was a nonsignificant trend for pain subjects (mean, 11.33; SD, 2.3) to be more interested in monitoring themselves and their environments than normal subjects (mean, 9.2; SD, 2.4), $t(17) = 1.94$, $P < 0.07$, from their data on the monitoring subscale of the Miller Behavioral Style Scale.

Discussion

The present data are consistent with a growing volume of experimental findings that fail to support the commonly held belief that muscle pain is accompanied by elevated levels of EMG activity.^{3,11} These findings point to the possibility that other factors may be playing a role in the development of some muscle pain reports. Whether muscle overactivity may have preceded the onset of the muscle pain in this group of patients cannot be ruled out in the present data set since this study was not a prospective design. Therefore, there still is the possibility that overactivity may precede muscle pain. Nevertheless, the data from this study suggest that persons reporting muscle pain do not display greater levels of muscle activity during their waking routines than do persons not reporting muscle pain.

Another theory for the development of muscle pain is the muscle deficiency model.¹⁴ This model suggests that muscle pain arises from an inability of the muscles to perform normal routines without the production of pain. The pain likely arises from muscle fatigue, ischemia, or increased pressure on free nerve endings. This theory then predicts that the muscle activity of persons with muscle pain should be less than that of persons not reporting pain in an effort to minimize the production of pain. Several recent findings have presented data supporting this hypothesis.⁵ However, the current data set does not support the muscle deficiency hypothesis because there were no significant differences in muscle activity between the muscle pain group and the normal controls.

It is sometimes suggested that persons reporting persistent muscle pain represent a personality style characterized by some unique constellation of psychological factors that enhances their proclivity to overreport

symptoms. This study examined that hypothesis by including several standardized measures of personality style thought likely to reflect such dimensions. While there was a tendency for the pain group to be greater self-monitors, this was not supported statistically at the 0.05 level. The small sample size of the study may have legitimately effected the outcomes because it is likely that the effect size observed in this study for the self-monitoring scale would result in a statistically significant outcome with an increase in sample size. Nonetheless, there were no other psychological differences noted between the pain group and the normal comparison group.

The current data suggest that causal mechanisms for the onset and development of chronic muscle pain, at least, have yet to be elucidated. Data from our own laboratory have suggested that dysregulated autonomic activity may be playing a role.³ We have not found EMG activity to distinguish subjects with facial pain from matched controls in two major studies, by Carlson et al³ and Curran et al.⁶ However, we have noted that heart rate, systolic blood pressure, and respiration rates appear to be elevated in muscle pain patients as compared to normal control subjects when they are subjected to stressors. Clearly, these findings potentially represent correlational relationships because of the design limitations of clinical studies. These data, however, are also consistent with a recent pilot study completed in our laboratory (unpublished data) that experimentally examined the relationship between sympathetic function and muscle activity. In this study, normal subjects were exposed to either a sympathomimetic drug (Terbutaline) or normal saline in a placebo-controlled, double-blind study of pressure pain thresholds. Persons who were administered the Terbutaline displayed elevated heart rate and respiration rate as compared to the saline condition, but EMG activity was not significantly different between the two groups. We found in this study that muscle activity is not necessarily related to the activity of the autonomic nervous system; such a result is also consistent with our clinical observations of patients with masticatory muscle pain.

Except for cases of acute muscle injury, the muscle overactivation hypotheses is not likely to be a satisfactory explanation for persistent muscle pain. Future research needs to be directed toward other potential mechanisms. Given the ubiquitous nature of muscle pain disorders and their potential economic consequences, this is an area for continued investigation; we recommend looking more closely at the role of the autonomic nervous system and psychological factors associated with an approach to life reflecting careful monitoring of the self and the environment. This latter approach is often termed "excessive vigilance," and may provide an integrative framework for understanding how current psychological and physiological findings can be brought together.

The sample size of the present study was relatively small. While this severely limits the generalizability of the results, they do provide an important interpretive framework for the direction and design of future studies. Our data do not suggest that even with a larger sample size there would likely be a difference between normal subjects and cervical pain subjects. In fact, if the present means were used, one might expect that muscle pain subjects would actually be found to have less activity. Another major limitation of the study is that we were not able to control for the general activity level of the subjects (i.e., the type and intensity of work). However, the subject's own self-report data would suggest that this may not be a major concern since both groups reported equivalent levels of muscle tension during the recording sessions. Since EMG activity and self-reports were not correlated, this interpretation needs to be cautiously embraced. An interesting future study might control for the subjects' work activities by presenting them with a standard series of tasks over a specified period of time. Another shortcoming of the present data set involves our inability to obtain information regarding medical diagnosis and medication usage for patients and controls; future investigations should include such information. While the present data set has limitations, we believe the findings are valuable as they strongly suggest that ongoing cervical muscle activity does not differentiate persons reporting cervical pain from those who do not report such pain.

Cervical pain most likely results from either pressure, temperature, chemical, or psychological sources like any other pain syndrome. While the current data set do not support muscle activity as playing a central role in the sample evaluated, this does not help in determining what the fundamental source or sources of the the pain might be. With the commonness of cervical pain, we believe continued research of etiologic mechanisms is important because effective treatment is ultimately based on an accurate understanding of the factors initiating and perpetuating dysfunction.

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Address reprint requests to

Charles R. Carlson, PhD
 Department of Psychology and Orofacial Pain Center
 112 Kastle Hall
 University of Kentucky
 Lexington, KY 40506-0044