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Muscle Learning Therapy—Efficacy of a Biofeedback Based Protocol in Treating Work-Related Upper Extremity Disorders

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Work-related upper extremity disorders (WRUEDs) continue to present significant treatment and financial challenges to providers, employers, and insurers. This retrospective study reviews outcomes for 309 subjects who, between 1995 and 1999, were referred through the workers' compensation system for treatment of computer keyboard- and mouse-related WRUED injuries. The mean length of time from the recorded date of injury to the date of intake was 12.9 months. Subjects were offered a 12-visit course in muscle learning therapy (MLT). MLT is an operant conditioning program which uses surface electromyography (sEMG) to train injured workers to control their muscles during work activities. Patient response to therapy was obtained by a therapist-administered questionnaire during Visit 8 of 12. A group of 309 subjects, who had failed to respond to a previous course of therapy (typically physical therapy), reported significant improvements of pain in the neck, thorax, and upper extremities. Ninety six percent reported that they felt "more in control," 86% reported feeling "better overall," and 81% reported either "working the same and feeling better" or "working and accomplishing more." This study provides preliminary support for this approach and provides justification for controlled clinical trials in the future.

KEY WORDS: work-related musculoskeletal disorders; computer keyboard related upper extremity pain; cumulative trauma; therapy of work-related musculoskeletal disorders; biofeedback.

INTRODUCTION

The earliest reference in the literature to work-related repetitive motion disorders (WRUEDs) is in 1713 by Bernardini Ramazzini (1). Although these problems have been recognized for centuries, the apparent increase in incidence, prevalence, severity, and cost of WRUEDs during the latter half of the twentieth century has created a powerful incentive to find treatments that are clinically and financially effective.

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Work that requires repetitive motions, awkward postures, or static muscle loading over prolonged periods of time is the primary, but not the sole, causative agent in WRUEDs (2,3). The absence of a dose–response relationship between work activity and injury suggests that other factors contribute to the injury process. Some workers develop symptoms at low activity levels while others are asymptomatic at very high levels of activity. Only a certain percentage of workers exposed to identical tasks will become symptomatic. Multiple interacting factors specific to each individual, to their environment, and their response to that environment contribute to injury (4–6).

Body habitus, gender, overall health, and fitness, all factors intrinsic to the individual, play a role in the development of WRUEDs (7–9). Awkward postures forced by the work environment are recognized causative factors. Computer operators may inadvertently use awkward postures and poor technique due to a lack of training, or they may develop a high risk “work style” as the behavioral component of a complex stress response (10). Computer operators whose personal style is to use more keystroke force report higher levels of symptom severity despite similar levels of upper extremity strength (11). The innate ability to rapidly reduce muscle tone between actions is associated with lower rates of pain complaints (12,13). The psychological work environment, and the employee’s response to, and perception of, that environment, are additional important factors (14). A stressful work environment, job dissatisfaction, conflicts with supervisors, low pay, and lack of discretion in work activities are recognized WRUED risk factors (15).

Provision of an optimal workstation and simple instruction in good work habits and body mechanics is often sufficient to allow resolution of WRUEDs (16). When injured workers are unable to benefit sufficiently from basic interventions and instruction then more extensive and aggressive training can be beneficial.

Biofeedback protocols utilizing surface electromyography (sEMG) have long been used to treat chronic muscular pain (17). Biofeedback treatment protocols for chronic pain can be more effective and produce more sustained improvement than either cognitive–behavioral therapy or conservative medical intervention (18).

An operant conditioning program for computer-related WRUEDs has been developed. The technique employed in this study, muscle learning therapy (MLT), is based on a biofeedback protocol utilizing sEMG. Symptomatic computer users are trained to assume and maintain appropriate postures, rapidly decrease muscle tone between activities, and decrease inappropriate muscle activity regardless of the underlying cause of the symptoms.

This paper describes a retrospective outcome study of 309 consecutive individuals who were unresponsive to various forms of hands-on-therapy (physical therapy, occupational therapy, chiropractic, or acupuncture). These individuals were then referred to Ettare Pain Treatment Clinics with the complaint of a computer keyboard- or mouse-related neck, thorax, or upper extremity disorder. All subjects included in the study were treated with the MLT protocol.

METHODS

Study Population

Between 1995 and 1999 442 individuals with computer-related complaints, who had already completed a course of hands on therapy elsewhere, were referred for MLT by physicians in the community. All of these individuals described computer usage as the primary cause of their complaints. All had computer keyboard- or mouse-related neck, thorax, or upper extremity pain, and all had an accepted workers' compensation injury claim. Payment for care was made through the California workers' compensation insurance system. All subjects were offered 12 sessions of MLT. Fifty of these subjects left the treatment program before the 8-week point and thus did not have complete data to analyze, 83 completed eight visits but did not have complete data because of therapist oversight. The remaining group of 309 patients constitutes the study group.

Treatment: Muscle Learning Therapy (MLT)

Surface Electromyography

Reusable silver/silver chloride cup electrodes were used. The MLT protocol required three different electrode placements. The first pair (upper trapezii) was placed over the sternocleidomastoid muscles, just inferior to the mastoid process and over the lateral trapezius, slightly posterior and medial to the acromioclavicular joint. The second pair (thoracic paraspinals) was placed 2–3 cm laterally to T1 and T8 over the midbodies of the thoracic paraspinal muscles. The third pair (forearms) was placed equidistant from the anatomic snuff box with the first electrode being placed just proximal to and between the second and third MCP joints, and then placing the second electrode on the middorsal forearm. A Biolink Digital Telemetry Unit (Model 3370 D/4), UFI, Morro Bay, California, and UFI graphing software were used to display real time sEMG voltage, color coded for right and left, on a computer screen. The telemetry unit allowed the patient to move easily about the room.

Training

MLT uses an operant conditioning model to teach injured workers to control their muscles under conditions found in the workplace (19,20). Subjects are taught to reduce inappropriate, or excessive, muscular activity and thus reduce the load on the muscles, along with the sympathetic responses assumed to relate to it (21,22).

Subjects were typically seen for twelve 1-h visits of decreasing frequency over a period of 18 weeks. The initial eight visits were dedicated to training, and the final four focused on maintenance of the conditioning.

Subjects were instructed and encouraged until they were able to bring their muscle tracings down to 2 μV or lower, regularly and easily (as defined later), while at rest and later while walking, standing up, or sitting down. Each learned activity was repeated until it was internalized and automatic, occurring continually and spontaneously both at home and at work. During MLT training it was assumed and taught that the acquisition of new behaviors would eventually lead to a reduction of symptoms. Interestingly, during the first phase of training, when subjects were just starting to relax chronically tight muscles, there was often a period of increased pain.

Increasingly difficult tasks were provided. Subjects were required to carry a ball on an open tray at waist level with trapezii continuously at $<2\,\mu$V. Subjects were then required to be able to maintain upper trapezius and paraspinal tone at $<2\,\mu$V 90% of the time while typing.

The second stage of training was to learn to rapidly relax muscles between tasks. Subjects learned to drop muscle voltage at each of the three sites to less than 2 μV within 2 s of ending a task. Typical tasks included reaching, writing, threading a needle, and keying. Subjects were required to make at least one business and one personal phone call while maintaining the $<2\,\mu$V state.

When these tasks had been mastered, subjects were placed at an ergonomic computer workstation and the sEMG tracings were used to demonstrate proper adjustment of the chair and proper placement of the keyboard and mouse. Subjects were taught to adjust a workstation so that muscle activity levels remained in the $<2\,\mu$V state while sitting at that workstation. The subjects were then asked to type the names of the ordinal numbers in ascending order (i.e. one, two, . . .). This task becomes increasingly difficult with numbers in the hundreds and thousands. Additional difficulty was added by increasing speed, counting backwards, or typing in the numbers for a reverse serial seven calculation. While typing, the peak voltage, measured in the forearm, must not exceed 30 μV, and troughs must be 10 μV or less. Each subject was given the same tasks, even if their job did not involve that activity. Later, specific tasks associated with the subject's profession were added or emphasized.

Success in MLT training is based on the behavior of muscles meeting the following premises: 1) The trapezii rarely need to be active (maintain $<2\,\mu$V). 2) The low points of graphs (troughs) must drop to resting levels ($<2\,\mu$V) after each task is completed. 3) The reduction of loading after a task must be rapid (<2 s). 4) Muscle unloading (microrests) must occur at every potential rest point during each task. 5) The reduction of muscle loading must become automatic and continuous.

Data Collection

Data were collected directly by the treating therapists. A series of standard questions were administered verbally on the first and eighth visits and recorded by the therapist. Routine, but nonstandardized, chart notes concerning the subjects' progress were also made at each visit. Information obtained at the beginning of treatment included standard demographic data as well as "work status" and "prior treatments." In addition, the nature of the subjects' complaints, including which anatomic sites were affected and the severity of the associated complaints, was obtained.

On the eighth visit (typically 8 weeks after beginning the therapy), subjects were asked to state, for each individual anatomic site, whether their local pain had increased, decreased, or remained the same over time. If there had been a decrease in pain, they were asked to assign a percentage to the decrease in pain. These data were recorded on a form, the Symptom Status Grid. Additionally, the responses to a standard series of questions ("yes," "no," or "not applicable") concerning work efficiency and behavioral and subjective changes were recorded.

Statistical Analysis

Statistical calculations were performed using SAS version 6.12, SAS Institute, Cary, NC. All reported p-values are two-tailed and in comparison, they make no allowance for the number of significance tests performed.

Changes in pain levels were estimated in terms of percent decrease (1% through 100%) on the Symptom Status Grid. A patient experiencing no pain change at an anatomic site received 0% for that site, while increases in pain were arbitrarily assigned scores of negative 100%.

The nonparametric Wilcoxon Signed Rank Test was used to evaluate whether the distribution of pain change scores differed significantly from 40%. While the results are presented in partitioned ordinal categories, the analyses were performed on the continuously scaled scores. In an attempt to set the criteria for improvement at a level with some clinical significance only subjects who reported an improvement of greater than 40% in pain were counted as having responded to therapy. Levels of improvement in WRUED patients in “control” groups has been reported to be in the range of 40% (23,24).

RESULTS

All subjects evaluated in this study completed the intake questions. Each subject had chart notes that allowed assessment of their progress and response to treatment. The study population was composed of 309 consecutive individuals who had completed at least eight MLT visits, had completed the Symptom Status Grid, and had completed a full course of some sort of hands-on-therapy prior to their referral for MLT. Subjects in this group completed a mean of 11.5 visits (standard deviation 1.44, range 8–20) out of the typical 12-visit course. A total of 83% of these subjects had received physical therapy, and 4% had received occupational therapy. Treatments typically included common modalities (heat, cold, ultrasound, massage, iontophoresis, etc.), stretching, and strengthening exercises. Of the remaining 13% of the subjects, 1% had been treated either with acupuncture or chiropractic protocols, and 12% had completed two different types of therapy prior to referral for MLT.

The demographic characteristics of the study group are shown in Table I. A total of 244 (79%) subjects were female, and 65 (21%) were male. Most had multiple anatomic sites of discomfort, typical of computer keyboard- and mouse-related upper extremity complaints. The “duration of symptoms” was determined as the time between the date of injury as recorded in the California workers’ compensation system and the patient’s first MLT treatment session.

Table II shows the distribution of symptom improvements. For the two most commonly reported painful areas (upper trapezius and forearm), 75% of the subjects reported 40% or greater improvement in symptoms after MLT. These improvements were statistically significant. The other commonly reported injuries (wrist, cervical, hand, finger, elbow,

Table I. Demographic and Baseline Characteristics of Study Group[a]

	Age (yrs)	Number of symptomatic sites	Time from injury to first MLT appointment (months)
Mean	38.0	6.7	12.9
Std. error	0.53	0.11	0.91
Median	36	7	7.3
Min, max	20, 65	1, 10	0.5, 137.1

[a] $N = 309$.

Table II. Distribution of Symptom Improvement

Anatomic site	n	Percentage reported improvement in symptoms									p value[b]
		0–40%[a]	% of n	40–59%	% of n	60–79%	% of n	80–100%	% of n	% ≥ 40	
Trapezius	257	64	24.9	61	23.7	63	24.5	69	26.8	75.1	<.001
Forearm	237	59	24.9	59	24.9	59	24.9	60	25.3	75.1	<.001
Wrist	201	67	33.3	51	25.4	47	23.4	36	17.9	66.7	<.001
Cervical	176	51	28.9	35	19.9	48	27.3	42	23.9	71.0	<.001
Hand	159	60	37.7	32	20.1	22	13.8	45	28.3	62.3	.003
Finger	140	47	33.6	27	19.3	25	17.9	41	29.3	66.4	<.001
Elbow	140	37	26.4	39	27.9	28	20.0	36	25.7	73.6	<.001
Thoracic (mid)	133	33	24.8	32	24.1	29	21.8	39	29.3	75.2	<.001
Headache	131	51	38.9	31	23.7	18	13.7	31	23.7	61.1	.031
Low back	59	38	64.4	14	23.7	5	8.5	2	3.4	35.6	<.001[c]

[a]0–40% includes an increase in pain.
[b]Wilcoxon Signed Rank testing the null hypothesis that the pain decreases are distributed around 40%.
[c]Confirms the null hypothesis that pain decreases are distributed around 40%.

midthoracic, and headache) also showed statistically significant improvements, with 40% or greater improvement reported by at least 61% of the subjects.

Fifty nine subjects reported low back pain as a complaint at intake. Only 21 (35.6%) reported improvement greater than 40%. In this case, The Wilcoxon Signed Rank Test confirmed that the true amount of improvement reported by the low back group is not different from 40%. The MLT protocol used did not produce a reported improvement in back pain.

This is not an unexpected finding. While biofeedback protocols can improve low back pain, the MLT upper extremity protocol employed in this study does not address the low back. Any improvement in low back pain reported by subjects is more likely related to proper adjustment of chairs and postures while at their workstations.

There were an additional 133 patients who had received a prior course of therapy but did not have a completed Symptom Status Grid, and thus could not be included in the data analysis of the study group's outcomes. The lack of data was either due to being lost to follow up prior to 8 weeks (50 subjects), or due to therapist oversight (83 subjects). The demographics of this group in terms of sex, age, and number of symptomatic sites were statistically equivalent to those of the study group. However, these patients did have chart notes that allowed a determination of their status as of their last office visit. Ninety seven (73%) reported that their symptoms were improved, 35 (26.2%) reported that their symptoms were unchanged, and 1 (.7%) reported worsening symptoms.

The improvement in symptoms described in Table II is matched by improvements in well-being and coping skills as shown in Table III, which highlights self-reported behavioral and subjective changes. Subjects were allowed to answer yes to more than one question. A high percentage of subjects, 96%, reported that they felt more in control, 89% reported that they had increased coping skills, and 86% reported that they felt better overall.

Table IV shows self-reported changes in work capability. The questions were mutually exclusive; subjects could only answer "yes" to one of them. Overall, 81% felt that they were either feeling better or were accomplishing more at work. At the time of intake, 266 (86.1%) were working, 38 (12.3%) were not working because of their injury, and 5 (1.6%) were not working for other reasons. Of the 38 who were not working at the time that they

Table III. Behavioral and Subjective Changes

Behavioral and subjective changes	Yes	No	Not asked[a]	N/A[b]	% Yes
More in control	298	3	8	0	96.4
Coping skills increased	213	7	19	70	89.1
Feels better overall	261	15	27	6	86.1
Reduced recovery time	206	21	42	40	76.6
Feels less intense	158	43	25	83	69.9
Less medication used	139	46	13	111	70.2
Less exhausted by the end of the day	136	61	27	85	60.7
Improved sleep	80	50	16	163	54.8

[a]Therapist neglected to ask question.
[b]Not an original issue.

began MLT therapy, 16 returned to work, 5 returned to vocational rehabilitation, and 17 remained off work.

DISCUSSION

This is a preliminary study of the effects of MLT therapy on computer-related WRUEDs. The self-reported response of subjects to this treatment is positive but a controlled clinical trial will be needed to prove its efficacy.

During the first week of training, subjects typically developed increased muscular pain, especially in the trapezii and upper back. This pain would decrease over the next week of therapy. Subjects were warned to expect this increase in pain. Rather than encouraging dropouts, the ability of the therapist to predict a counterintuitive event gave the subjects more confidence in the therapist and the protocol. This pain is felt to be related to the stretching of tissues that have been shortened by chronic muscular contraction.

Using the Wilcoxon Signed Rank Test, the subjects reported statistically significant improvement of greater than 40% in all reported painful areas except low back. The MLT therapy employed was specifically directed at the muscles of the forearm and thorax and therefore it was not expected to have an effect on the low back. This finding provides some indication of the specificity of the approach and the reliability of the data collection techniques.

Subjects did function as their own sequential controls. Each patient had already completed a course of hands-on-therapy but either the patient, or their treating physicians, felt that their response was insufficient and some additional therapy was necessary. This unresponsive group had a positive response to MLT.

Table IV. Reported Changes in Work Capability

Work capability	n	%
Working same but feeling better	167	54.0
Working and accomplishing more	83	26.9
No change in work capability	25	8.1
Not asked because this was not an original issue	27	8.7
Unknown	7	2.3
Total	309	100

The 309 subjects in the study group had been symptomatic for up to 1 year on average. All subjects had an accepted workers' compensation claim placing them into a group which typically does not report improvement simply to please the therapist. Workers with WRUEDs treated in community based programs frequently report little or no improvement in their overall status even after multiple interventions (23).

That MLT might be effective in subjects who had not responded to physical therapy is biologically plausible. The most likely final common pathway causing WRUEDs is excessive muscle and/or tendon loading (2,3,25,26). The concept of "work style," (10) wherein each worker's cognitive, behavioral, and physiological responses to work and work environment dictate how, and with how much force, a particular task is accomplished, explains how the totality of the person and the work environment combine to produce injurious muscle and tendon loading. MLT training is thought to allow the conscious mind to interrupt the flow of inappropriate requests for increased muscular activity in response to an unconscious work-style construct. MLT should enable symptomatic computer operators to do the same amount of work with less muscle tone and effort.

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