Ipsilateral Electromyographic Activity of Shoulder Muscles During Unilateral Maximal Resistance of Grasp in the Prone-on-Elbows Position

Bryan John Wodaski
Western Michigan University

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IPSILATERAL ELECTROMYOGRAPHIC ACTIVITY OF SHOULDER MUSCLES DURING UNILATERAL MAXIMAL RESISTANCE OF GRASP IN THE PRONE-ON-ELBOWS POSITION

by

Bryan John Wodaski

A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the requirements for the Degree of Master of Science
Department of Occupational Therapy

Western Michigan University
Kalamazoo, Michigan
April 1986
IPSILATERAL ELECTROMYOGRAPHIC ACTIVITY OF SHOULDER MUSCLES
DURING UNILATERAL MAXIMAL RESISTANCE OF GRASP
IN THE PRONE-ON-ELBOWS POSITION

Bryan John Wodaski, M.S.
Western Michigan University, 1986

This study reports the relationship between electrical output of the deltoid muscle and the pectoralis major muscle (clavicular portion) ipsilaterally, following maximal resistance to grasp of the non-dominant hand while in the prone-on-elbows position. Forty-two normal college students were recruited from Western Michigan University, Kalamazoo, and were randomly assigned to experimental and control groups. The experimental subjects' shoulder muscles' electrical activity was measured for changes from baseline to maximal contraction during two trials. The control group was measured in the same manner but they were not asked to contract their hand against resistance. For both groups electrical activity was monitored by electromyographs. The results showed a statistically significant increase of the electrical activity from baseline for the deltoid muscle and pectoralis major muscle ipsilaterally during maximal resistance to grasp of the non-dominant hand while lying in the prone-on-elbows position, rejecting the null hypothesis.
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CHAPTER I
THE PROBLEM

Introduction

Many different activities have been proposed to produce resistance to grasp in order to encourage cocontraction of muscles surrounding the glenohumeral joint (Ayres, 1974; Pedretti, 1985; Sattely & Kandel, 1962; Stockmeyer, 1967; Trombly, 1983). Occupational therapists have used such activities as squeezing an object in the hand (Ayres, 1974; Pedretti, 1985; Sattely & Kandel, 1962), board games, crafts (Trombly, 1983), and shooting water pistols at targets to secure the muscles around the glenohumeral joint (Stockmeyer, 1967; Trombly, 1983). The literature suggests that when such activities are done in the prone-on-elbows position, the muscles of the glenohumeral joint are facilitated through the increased demand placed on them to cocontract in order to stabilize the joint (Stockmeyer, 1967; Trombly, 1983).

Rood noted cocontraction was a condition in which muscles contracted around a joint simultaneously to provide stability to the joint (Trombly, 1983). However, a review of the literature revealed no experimental evidence that maximal resistance to grasp while in the prone-on-elbows position encouraged cocontraction of muscles surrounding the glenohumeral joint.

In support of the concept of cocontraction, Brooks (1983) noted
that weak reciprocal inhibition permits cocontraction of opposing muscles, which stabilizes the joint. Trombly (1983) defined reciprocal inhibition as the state in which "the antagonist muscle is automatically inhibited, due to the 'wiring' of the nervous system which includes inhibitory interneurons, when the agonists and synergists are facilitated" (p. 64). The 'wiring' to which Trombly referred is described by Brooks (1983) as the "process of interaction of spinal motor and interneuron outputs setting the appropriate levels of length tension (tone) relations of opposing muscles on a joint" (p. 672). The degree to which opposing muscles contract is dependent on the degree of adduction and abduction, flexion and extension, and rotation of the limbs (Brooks, 1983).

The concept of facilitating groups of proximal muscles as the result of a "shortened held resisted contraction" (SHRC) of phasic muscles has been described in the literature as "recruitment" (Basmajian, 1978; Pedretti, 1985; Trombly, 1983; Voss, Ionta & Meyers, 1985; Wellock, 1958). According to Trombly (1983) "the use of shortened, held, resisted contraction (SHRC) to rebias the spindles of these muscles [proximal] is used to prepare for assumption of a weight-bearing posture" (p. 70). However, the effectiveness of this technique in securing the shoulder joint directly through the resistance of grasp while in the prone-on-elbows position has not been documented. Therefore, the following null hypothesis will be tested:

There will be no significant change in electrical output of the middle deltoid muscle and pectoralis major muscle, (clavicular portion) ipsilaterally during resistance to
grasp of the nondominant hand while in the prone-on-elbows position.

This information is related to Rood's principles of developmental sequencing. Rood (in Trombly, 1983) proposed four phases essential to the development of motor control:

1. [Mobility]. Muscles contract through their range with reciprocal inhibition of the agonists.

2. [Stability]. Muscles around the joint contract simultaneously (cocontraction) to provide stability.

3. [Mobility Superimposed on Stability]. Proximal muscles contract to do heavy work superimposed on distal cocontraction.

4. Skill [light work]. At this level of motor control, the proximal segment is stabilized and the distal segment moves. (p. 78)

According to Rood, these four phases of motor control establish a foundation of normalized movement essential to the ability to develop skills that can be generalized to other areas of motor skills (Trombly, 1983). Generalization is the ability to use these basic postural patterns to explore, master and adapt to the environment (Kephart, 1969). Kephart further noted that on the basis of generalization, behavior becomes more efficient and learning broader based. The inability to generalize a skill level to many areas of fine motor application is considered by many authors to be an indication of a developmental problem (Ayres, 1979; Gesell, 1946; Kephart, 1969; Pedretti, 1985; Trombly, 1983).

Purpose

The present study will measure the electrical activity of the
middle deltoid muscle (abductor) and the pectoralis major muscle, clavicular portion (adductor), ipsilaterally during resisted grasp of the nondominant hand while the subjects are in the prone-on-elbows position. The purpose is to determine if maximum resisted grasp while in the prone-on-elbows position facilitates cocontraction ipsilaterally of the muscles which help stabilize the glenohumeral joint.
CHAPTER II

REVIEW OF SELECTED LITERATURE

Developmental Sequencing

The idea of an ontogenetic developmental sequence to outline the key motor patterns of the human organism's development to a fully mobile posture has been described by various authors (Gessel, 1946; McGraw, 1943; Piaget, 1972). Rood has identified eight ontogenetic skeletal motor sequences which are postures that occur during the normal human organism's skeletal motor development. According to Rood, an individual must progress through the eight ontogenetic motor sequences and simultaneously progress through the four stages of motor control: (a) mobility, (b) stability, (c) mobility superimposed on stability, and (d) skill for normal movement to develop fully (Trombly, 1983).

There are a variety of reasons why individuals do not develop normal skeletal motor control (Spreen, Typper, Risser, Tuokko & Edgell, 1984). Cortical connections of the pyramidal tracts begin to develop very soon after birth, but further maturation and differentiation of tissues and cells continue into childhood (Spreen et al., 1984). The development of the tracts and cells of the extra-pyramidal system, reticular activating system and cerebellum continue to develop into childhood (Spreen et al., 1984). Slower or delayed maturation of these central nervous system tissues
may be responsible for the lack of development of motor control (Spreen et al., 1984).

Muscle Spindle Influences

Understanding the muscle spindle is important to understanding how the concepts of gamma biasing and recruitment work in attaining cocontraction of muscles surrounding the glenohumeral joint (Kolb & Whishaw, 1985; Trombly, 1983). The muscle spindle, as a sensory organ, plays an important role through its proprioceptive action in simplifying the work of the cortex in the control of movements (Carlson, 1981; Kolb & Whishaw, 1985). When the gamma efferent beings firing, there is a contraction of the intrafusal fibers and a stretching of the central portion of the spindle occurs. When the spindle is stretched it becomes more sensitive to stretch on the central portion of the spindle and the gamma afferents are activated (Lehmkuhl & Smith, 1983; Carlson, 1981).

When the message from the cortex commands the movement of a limb, alpha and gamma motor neurons are stimulated into action. If, during this movement, the muscles contract against resistance, the spindle contracts faster than the muscle as a whole and the gamma afferents fire and cause a reflexive strengthening of the contraction (Carlson, 1981). This is apparently accomplished through the stimulation of polysynaptic connections in the spinal cord via interneurons (Trombly, 1983). The process of excitation of many neurons within the spinal cord recruits more and more muscle units through the feedback mechanism of the muscle spindle (Trombly, 1983).
The rate at which gamma neurons fire is a major contributing factor in establishing the degree of muscle tone (Carlson, 1981). The role of secondary endings of the muscle spindle is not clear. It was previously believed that secondary afferents, when stimulated, facilitated flexor muscles and inhibited extensor muscles (Knuttgen, 1976; Schotz & Campbell, 1980; Stockmeyer, 1967; Urbanseit, 1979; Zimney, 1979). Urbanseit (1979) claims this concept is oversimplified and subject to criticism based upon experimental evidence that these afferent fibers can evoke several different reflexes under different conditions. It is now understood that the central nervous system input to alpha motor neurons is greater than peripheral stimulation and that the central nervous system has more power of control which easily overrides peripheral power (Bizzi, Dev, Morasso & Polit, 1978).

Neural Organization

A comprehension of the organization of neurons is important to understanding how motor information is transferred to different parts of the central nervous system. The motor neurons are located in two areas of the ventral columns of the spinal cord: those in the dorsolateral area and those in the ventromedial area. The dorsolateral neurons innervate the distal musculature of the arm and the ventromedial neurons innervate the more proximal musculature of the shoulders and trunk (Kolb & Whishaw, 1985). Studies suggest that muscles tend to move in groups and the interneurons and motor neurons are organized in pools to interact through polysynaptic connections to control these
groups of muscles (Kolb & Whishaw, 1985; Trombly, 1983). Once a neuron begins firing, for example in response to the cortex's request for the nondominant hand to grasp against the resistance of a hand dynamometer, a series of events are set in motion. The firing of one neuron spreads to many others in the pool and possibly to other segments as well. Once these neurons begin firing in larger numbers to overcome the resistance, more muscles are recruited to join in automatically. The phenomenon is described as a "motor program" by Kolb and Whishaw (1985) and described by Trombly (1983) simply as "recruitment." The more proximal muscles are automatically recruited when distal muscles contract against resistance in a process Rood refers to as "recruitment" (Trombly, 1983). When an individual's attention is focused on purposely moving, the proximal muscles of the upper extremities respond automatically through various subcortical mechanisms (Carlson, 1981; Kolb & Whishaw, 1985; Trombly, 1983). These subcortical mechanisms include the muscle spindle, gamma motor neurons, interneurons, cerebellum and reticular activating system (Kolb & Whishaw, 1985).

When the proprioceptive stimulus is of sufficient magnitude, there are two spinal projections which help spread and integrate responses that involve many spinal segments. The first is known as the intersegmental system and consists of fibers that come from other segments of the spinal cord, many of which are collaterals from sensory afferents. The second is known as the propriospinal system and consists of fibers and cell bodies which originate wholly within the spinal cord. Both of these systems communicate intimately with
motor neurons, either directly or via interneurons (Kolb & Whishaw, 1985).

A complex system of influences on muscle cocontraction has emerged. Central nervous system control can easily override peripheral input. It is clear that for cocontraction to occur, the stimulus must be of sufficient magnitude to stimulate the interneurons and motor neurons to overcome reciprocal inhibition. This high activity of neuronal pools is apparently responsible for proximal muscles cocontracting to stabilize the joint (Kolb & Whishaw, 1985).

Repeated high magnitude stimulus produces an effect known as post-tetanic potentiation (Fischer, 1967). Post-tetanic potentiation lowers the threshold of neuronal pools facilitating muscular contraction (Fischer, 1967).

Anatomical and Histological Influences

The mechanical and histological factors that influence shoulder cocontraction include: (a) organization of origins and insertions of muscles; (b) gravity; (c) girth and length of all structures involved, especially tendons and bones; (d) percentage of tonic versus phasic muscle fibers present in the muscles being facilitated to cocontract; and (e) body and joint position in space that influences reflex patterns (Kuo & Clamann, 1981; Payton, Hirt, & Newton, 1978; Tesch & Karlson, 1983).
CHAPTER III

DESIGN AND METHODOLOGY

Overview

The electrical activity of the pectoralis major muscle (clavicular portion) and middle deltoid muscle were monitored while subjects were in the prone-on-elbows position grasping the Jamar Hand Dynamometer (JHD). The experimental group grasped the JHD with the nondominant hand and alternated between relaxation and maximal contraction of grasp. The control group subjects were measured in the same manner but they were not asked to contract the hand in any way. The data for statistical analysis in the study consisted of the difference in electrical activity in these two muscles from relaxation to contraction. There were two trials of the procedure, each measured. Other information gathered on the Raw Data Collection Sheet (see Appendix A) was not analyzed (Bruning & Kintz, 1977; Norusis, 1985).

Type of Design

A two-factor mixed design study was employed (Bruning, 1977; Norusis, 1985). The independent variable was the use of maximally resisted grasp of the hand versus no resistance to grasp of the hand (see Figure 1). All subjects were also subjected to twice-repeated identical trials of the procedure. The dependent variable was the
Figure 1. Research Design Illustration

measure of the amount of change in electrical activity of the two muscles measured in this study. The following null hypothesis was tested statistically:

There will be no significant change in electrical output of the middle deltoid muscle (MD) and pectoralis major muscle, clavicular portion (PMCP) ipsilaterally during maximal resistance to grasp of the non-dominant hand while lying in the prone-on-elbows position.

Subjects

This study included forty-two male and mostly female subjects. One male was tested in the experimental group and two males were tested in the control group. Volunteers were obtained from among Western Michigan University faculty and students. Subjects (a) were between the ages of 18 and 32, (b) had no known neurological impairments, (c) had no known orthopedic impairments, (d) had never been diagnosed as hypertensive, (e) had never been diagnosed as having a cardiovascular impairment, (f) were not currently taking any medications, and (g) were not allergic to the topical application of isopropyl alcohol and electrode gel.

The informed consent of the participants was obtained before
they began participating in the study (see Appendix B).

Instrumentation

Electrical activity was measured with two J and J M-55 electromyographs (EMG) along with two LGS-150 data integrators and two DS-02 strip adhesive electrodes. These instruments were set on the A-filter (100-200 Hz), a 50 microvolt range with results being displayed at two-second intervals. Hand contraction was measured by the Jamar Hand Dynamometer (JHD).

Procedures

Testing was conducted in the Occupational Therapy Department at Western Michigan University, Kalamazoo. The room temperature was in the 70-74°F range and incandescent light was provided in the research room. All subjects were instructed to refrain from any strenuous activity for at least one hour before testing. They were also instructed to wear loosefiting, comfortable clothing, which permitted access to the shoulder and upper chest for electrode placement. Hand dominance of all subjects was determined by asking with which hand they write. The muscles monitored were determined by palpation according to Lehmkuhl and Smith (1983). The skin was prepared before electrode placement by rubbing it vigorously with gauze dampened with diopropyl alcohol until the skin was pink. The three spots where the electrode disks rested over the skin were marked with a watercolor marker. A cotton tipped applicator dipped in electrode gel was twirled onto the skin at spots marked with the watercolor marker.
Strip adhesive silver-silver chloride electrodes were coated with electrode gel and were placed on the prepared skin over the MD muscle and the PMCP muscle.

The subjects were asked to push against resistance offered by the examiner to determine if the electrodes had been properly placed. They were instructed to assume the prone-on-elbows position, looking straight ahead at a target placed on the wall at eye level in front of them. The subjects were then measured with a goniometer to place the humerus in a perpendicular alignment with the floor. They were then asked to grasp the JHD in a relaxed manner with their non-dominant hand for one minute period. The measurement of electrical activity was recorded and formed the resting baseline for the first contraction. The experimental subjects were asked to squeeze the JHD as hard as they could for eight seconds, as timed by the examiner. The measurement of electrical activity at the end of the eight second period was recorded. The amount of change in electrical activity in each muscle from relaxation to contraction formed the first measurement used for data analysis. An identical second trial of measuring the amount of change in electrical activity from one minute of relaxation to eight seconds of contraction was immediately repeated. The difference in electrical activity during the second trial formed the second measurement of data analysis.

The subjects were reminded to breathe normally at all times throughout the study in order to avoid any unnecessary increases in blood pressure as noted by Smith and Lukens (1983). The control group underwent the same twice-repeated trial, except they were not
asked to squeeze the JHD. The measurements of electrical activity for each muscle were recorded for the same time intervals as the experimental group. The amount of change in electrical activity in each trial formed the two measurements for data analysis for the control group.

Analysis of Data

Individuals' data were identified only by code number on the Raw Data Collection Sheet (see Appendix A). All data were analyzed only in group form. Data to test the null hypothesis were submitted to a T-test to compare the means of the experimental and control groups. Significance of the differences between trial one and trial two was analyzed on the Western Michigan University computer with a T-test.

Significance

The technique of proprioceptive facilitation using unilateral resistance of grasp to stabilize the glenohumeral joint in the prone-on-elbows position can be traced to Sattely and Kandel (1962). There are a number of activities suggested in occupational therapy literature that are claimed to produce this facilitation through purposeful movement (Ayres, 1974; Pedretti, 1985; Sattely & Kandel, 1962; Stockmeyer, 1967; Trombly, 1983), but there is no direct experimental evidence to support its use. Trombly (1983) suggested that the question of whether or not this technique does facilitate cocontraction is "opened for research" (p. 76)
When one considers that this technique is being used with cerebro-vascular hemiplegics, developmentally disabled, and cerebral palsied patients who collectively represent 53.9% of the population treated by occupational therapists (Reed & Sanderson, 1983) it is vital to both the profession and the patients we serve to verify this technique through controlled research.
CHAPTER IV

FINDINGS

An informal review of the raw data revealed large changes between the differences of electrical activity from baseline between the experimental and control groups for each muscle. A T-test for the PMCP comparing the differences between the experimental and the control groups on the basis of change from baseline was significant at the .001 level for the first trial and significant at the .002 level for the second trial (see Table 1).

A T-test for the DM comparing the differences between the experimental and control group on the basis of change was found to be significant at the .001 level for the first and second trials (see Table 1).

The means (M) of trials one and two combined were determined for each group for both muscles. A T-test for the PMCP and DM comparing the differences between the experimental and control group means for both trials combined was performed. The difference between the two groups was found to be significant at the .001 level for both muscles (see Table 1).

There was an increase in electrical output during trial two when the means of the trials were compared to each other which may be due to post-tetanic potentiation. However, this increase was not found to be statistically significant based on the T-test results comparing the differences between trial one and trial two.
Table 1

Comparison of Electrical Output of the PMCP and DM Following Resistance to Grasp and Non-resistance to Grasp

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<tr>
<th></th>
<th>Trial #1</th>
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* Mean  ** Standard deviation
CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The results of this study showed significantly that cocontraction of the PMCP and DM does occur ipsilaterally during unilateral maximal resistance to grasp in the prone-on-elbows position, thus rejecting the null hypothesis.

It should be noted that all experimental subjects were assumed to have produced maximal resisted contraction of the nondominant hand when requested to do so.

Twenty-one subjects were randomly assigned to the experimental and control groups. Initial random selection of the subjects would help give the results of this study more validity. The subjects were normal college students 18 to 32 years of age and the results of this study apply only to this population. Differences for sex were not analyzed. It is suggested that this study be repeated with other populations to see if results are similar.

The results are not clear how much the prone-on-elbows position contributed to the degree of cocontraction in the shoulder. Perhaps maximal resistance to grasp while the subjects were sitting or standing would produce significant cocontraction. The angle of humerus to the trunk would have to be carefully monitored and maintained during the testing procedure to produce conclusive results. These positions might be more useful for populations unable to sustain the prone-on-elbows position for extended periods of time.
There are not many occupational therapy activities which provide the opportunity for sustained maximal contraction of the hand. It is suggested this same study be done with an activity offering moderate resistance to grasp such as clay, which could be easily incorporated into a treatment program of occupational therapy.

The PMCP and DM were the muscles chosen for this study. Muscles which oppose each other and have the potential to stabilize the shoulder joint could also be monitored in a future study.

Differences from baseline for the experimental group were much larger than those of the control group who assumed the prone-on-elbows position with no contraction of the hand. It is, therefore, suggested that when the prone-on-elbows position is used for facilitating cocontraction of the shoulder, some degree of contraction of the hand ipsilaterally should also be incorporated for greater effectiveness.
APPENDIX A

RAW DATA COLLECTION SHEET
### Raw Data Collection Sheet

<table>
<thead>
<tr>
<th>Person #</th>
<th>Musc.</th>
<th>1 (1 min.)</th>
<th>2 (8 sec.)</th>
<th>JHD</th>
<th>3 (1 min.)</th>
<th>4 (8 sec.)</th>
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APPENDIX B

INFORMED CONSENT FORM
Informed Consent Form

Dear Sir or Madam,

I am a graduate student at Western Michigan University and I am currently conducting a graduate research project. I am especially interested in finding out more about healthy people between the ages of 18 and 32.

A skin surface electrode EMG machine will be used to measure the electrical activity of your shoulder muscles. You will experience no pain or discomfort of any kind during this activity. The study will be conducted in Room 129, Wood Hall and will require about 15 minutes of your time. The information gathered will be coded so that no one will be able to relate the information to you in any way.

You will be helping occupational therapists learn more about shoulder muscles and how they work during therapy.

If you have any questions please call 345-6358. You are free to stop participating in this study any time you want to.

Sincerely,

Bryan J. Wodaski

I have read and understood all the above information. All of my questions have been answered and I agree to participate in this study.

X _______________________________    Date ___________
BIBLIOGRAPHY


