1995

An EMG Analysis of Closed Kinetic Chain Exercise versus Open Kinetic Chain Exercise in the Upper Extremity

Bradley J. Neis
University of North Dakota

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AN EMG ANALYSIS OF CLOSED KINETIC CHAIN EXERCISE VERSUS OPEN KINETIC CHAIN EXERCISE IN THE UPPER EXTREMITY

by

Bradley J. Neis
Bachelor of Science in Physical Therapy
University of North Dakota, 1994

An Independent Study
Submitted to the Graduate Faculty of the
Department of Physical Therapy
School of Medicine
University of North Dakota
in partial fulfillment of the requirements
for the degree of
Master of Physical Therapy

Grand Forks, North Dakota
May
1995
This Independent Study, submitted by Bradley J. Neis in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

[Signatures]

(Faculty Preceptor)

(Graduate School Advisor)

(Chairperson, Physical Therapy)
PERMISSION

Title An EMG Analysis of Closed Kinetic Chain Exercise versus Open Kinetic Chain Exercise in the Upper Extremity

Department Physical Therapy

Degree Master of Physical Therapy

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Signature  Bradley J. Nii

Date  4/18/95
# TABLE OF CONTENTS

List of Figures .............................................. v
List of Tables ................................................ vi
Acknowledgments ............................................. vii
Abstract ....................................................... viii
Chapter 1. Introduction ..................................... 1
Chapter 2. Methods. .......................................... 4
Chapter 3. Results ........................................... 9
Chapter 4. Discussion ........................................ 15
Chapter 5. Clinical Implications ........................... 17
Appendices ..................................................... 18
References ...................................................... 24
LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Normalized EMG Activity During the Bench Press and Push-up</td>
<td>11</td>
</tr>
<tr>
<td>2. Duration of Muscle Activity in Bench Press and Push-up</td>
<td>13</td>
</tr>
<tr>
<td>3. Muscle Activity During Elbow Range of Motion, Bench Press vs. Push-Up</td>
<td>14</td>
</tr>
</tbody>
</table>
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Subject Characteristics</td>
<td>5</td>
</tr>
<tr>
<td>2. Percentage of Maximal Voluntary Contraction (Bench Press vs. Push-Up)</td>
<td>10</td>
</tr>
<tr>
<td>3. Percentage of Elbow ROM Muscle is Active (Bench Press vs. Push-Up)</td>
<td>12</td>
</tr>
</tbody>
</table>
ACKNOWLEDGMENTS

I would like to express my appreciation to my advisor, Tom Mohr, for his guidance, encouragement, and interest with this independent study. I also want to thank Scott Billing for his help in running the subjects through the experiment. To the faculty and staff of the University of North Dakota Physical Therapy Department for their assistance with this project and my entire education in this excellent department. To my family and especially Nancy Odegaard, for their support and confidence in me. To God, for making this all possible.
ABSTRACT

Both closed kinetic chain and open kinetic chain activities are common in rehabilitation involving the lower extremity and the upper extremity. Although closed chain activities are performed regularly in the rehabilitation setting for the upper extremity, there has been little or no research proving that these activities are better, worse, or the same as open chain activities. Therefore, the purpose of this research project was to compare muscle activity in both open and closed chain exercises in the upper extremity and determine if there is a difference in the two forms of exercise. Five healthy subjects without previous shoulder or elbow pathology volunteered for this study. The subjects performed a push-up exercise and a bench press exercise with 45% of their body weight while electromyographic data of four upper extremity muscles and elbow range of motion data was recorded. The muscles studied were the pectoralis major, the biceps brachii, the triceps, and the serratus anterior. The results showed that the triceps and biceps brachii had a higher percentage of maximal voluntary contraction (MVC) during the push-up than the bench press. However, the pectoralis major and serratus anterior had a higher percentage of MVC during the bench press than the push-up. It was concluded that elbow musculature was recruited in a higher percentage of MVC in the closed chain exercise than the open chain exercise. Likewise, the shoulder musculature was recruited in a higher percentage in the open chain than in the closed chain. However, in most of the cases the differences were quite small.
CHAPTER 1
INTRODUCTION

Closed kinetic chain activity by definition is the movement of the proximal segments of an extremity in relation to its fixed distal segment.\textsuperscript{1} An example of this would be the stance phase of gait in which the proximal knee and hip pass over the fixed foot. Open kinetic chain activity by definition is the movement of the distal segment of an extremity in relation to its fixed proximal segment. Using an example again, this is the swing phase of gait in which the distal foot and leg move in relation to the fixed hip. The use of closed kinetic chain and open kinetic chain activities are common in rehabilitation of the lower extremities and the upper extremities.

Closed Kinetic Chain vs. Open Kinetic Chain in the Lower Extremities

There has been a considerable amount of research done comparing closed kinetic chain activities to open kinetic chain activities in the lower extremities. Studies have shown that closed kinetic chain activities are more functional than open kinetic chain activities in the lower extremities and provide for multiplanar isometric, concentric, and eccentric contractions.\textsuperscript{2-5} In working with patellofemoral joint rehabilitation, closed kinetic chain activities have been shown to decrease the stress on the patellofemoral joint in functional ranges of motion compared to open kinetic chain activities.\textsuperscript{6-8} Also, studies have shown that closed chain exercises significantly decrease the anteroposterior tibial shear force compared to open kinetic chain activities.\textsuperscript{9,10} Closed kinetic chain exercises have also been shown to develop proprioception and neuromuscular coordination more effectively than open kinetic chain exercises.\textsuperscript{2}
Closed Kinetic Chain vs. Open Kinetic Chain in the Upper Extremities

Whereas the lower extremities function primarily in a closed chain environment, the upper extremities function predominantly in an open chain environment. Most activities of daily living (ADLs) and athletic events require open chain function of the upper extremities. However, the upper extremity must be able to function in a closed chain just as the lower extremities must be able to function in an open chain. During athletic events and ADLs, a person will fall, push, or swing from objects. This requires the shoulder to move around a fixed distal hand.

The dual role of the upper extremities complicates our goal of a return to normal function after injury. We must not only attempt to create a shoulder joint that is stable and mobile, we also need to create an upper extremity that can function well in an unstable environment as well as a mobile environment.

In looking at differences between open and closed chain activities in the upper extremity, it is necessary to include the effects of gravity. In the open chain, gravity creates a challenge to any imposing load by providing an invisible force that resists movement. This requires a concentric contraction to initiate movement against gravity and an eccentric contraction to return to the normal position. In the closed chain, gravity creates an acceleration of movement, that is gravity assists in closing the chain. This requires an eccentric contraction to decelerate the motion.

Another difference between open chain and closed chain activities is the different muscle actions produced by each activity. The biceps can be used to demonstrate this concept. In the open chain, the biceps creates elbow flexion of the forearm moving on the humerus as in a biceps curl. In the closed chain activity, the biceps creates elbow flexion with the humerus moving on the fixed forearm as in a push-up.
Closed kinetic chain exercises have been used extensively in the rehabilitation of the upper extremity. Unfortunately, closed kinetic chain activities have not been reported in the literature. A cadaver study by Warner et al.\(^1\)\(^2\) indicated that static glenohumeral stability was enhanced by a joint compressive force. There have been no specific studies which have looked at differences between upper extremity closed and open kinetic chain exercises. There have been studies that looked at electromyography (EMG) activity of scapular and glenohumeral muscles during specific exercises to determine the most effective exercise for each scapular and glenohumeral muscle.\(^{13,14}\) These studies however, did not compare closed and open kinetic chain exercises.

Therefore, with no difference between closed chain activities and open chain activities being stated in the literature, it is unknown if there is a difference. The purpose of this research study was to compare muscle activity during open and closed kinetic chain exercises in the upper extremity to determine if there is a difference in the two forms of exercise.
CHAPTER 2
METHODS

Subjects

Five healthy male subjects without previous shoulder or elbow pathology volunteered for this study. After approval from the Human Subjects Review Board (Appendix A1), the subjects were randomly selected from students currently enrolled in the Physical Therapy program at the University of North Dakota. The subjects (Table 1) were 22 to 28 years of age (mean = 23.6), weighed from 149.25 lbs. to 201 lbs. (mean = 180.8 lbs.), and were from 66 inches to 72 inches tall (mean = 70.05 inches). All of the subjects signed a statement of informed consent (Appendix A2).

Instrumentation

The electromyographic data was collected using a Noraxon Telemyo8 telemetry unit (Noraxon USA, 13430 North Scottsdale Rd., Scottsdale, AZ, 85254). Elbow range of motion was measured using a Penny & Giles M180 electrogoniometer (Penny & Giles Inc., 2716 Ocean Park Blvd, Santa Monica, CA, 90405) and telemetried through the Telemyo8 unit. The telemetried information from the EMG electrodes, and the electrogoniometers was collected by a Noraxon Telemyo8 receiver and then digitized by a DT2801-Analog to digital interface board installed in a NET 486DX computer. The digitized EMG signals were analyzed using the Myosoft data collection software (Myosoft and Norquest) that accompanies the Telemyo8 EMG system. The Myosoft software allows for several forms of data analysis once the EMG signals are collected.
Table 1. Subject Characteristics

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age</th>
<th>Weight</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>28</td>
<td>184.5lbs.</td>
<td>71.0in.</td>
</tr>
<tr>
<td>#2</td>
<td>22</td>
<td>149.3lbs.</td>
<td>66.0in.</td>
</tr>
<tr>
<td>#3</td>
<td>23</td>
<td>179.3lbs.</td>
<td>71.8in.</td>
</tr>
<tr>
<td>#4</td>
<td>23</td>
<td>190.0lbs.</td>
<td>69.5in.</td>
</tr>
<tr>
<td>#5</td>
<td>22</td>
<td>201.0lbs.</td>
<td>72.0in.</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>23.6</strong></td>
<td><strong>180.8lbs.</strong></td>
<td><strong>70.05in.</strong></td>
</tr>
</tbody>
</table>
Procedure

This study measured EMG activity in four upper extremity muscles during both a closed kinetic chain and an open kinetic chain exercise. The closed kinetic chain exercise was a push-up and the open kinetic chain exercise was a bench press. The four muscles in which EMG activity was measured were: 1) biceps brachii, 2) triceps, 3) serratus anterior, and 4) pectoralis major.

To record the EMG activity, surface electrodes were placed over the motor points of each of the muscles studied. The EMG signals were transmitted to the receiver unit and then into a computer for display and recording of the data. The EMG information for each subject was recorded and stored on disk for later analysis.

For the experiment, the subjects were fitted with electrodes and the electrogoniometer device. The motor point of each tested muscle was found using a direct current (DC) stimulator. The skin over the motor point was prepared by shaving the any hair with an electric razor and cleansing it with alcohol before attachment of the EMG electrodes. Two electrodes (Multi Bio-Sensors, El Palso, TX, 79913), coated with pre-gelled adhesive, were then attached to the skin distally and proximally to the motor point parallel to the muscle fibers with two centimeters separating them. A ground electrode was placed over the acromion process of the right extremity.

An electrogoniometer was used to measure elbow range of motion (ROM) during both the push-up and the bench press activities. The proximal end of the goniometer was attached to the skin of the right upper arm along the shaft of the humerus, the distal end was attached to the right forearm along the shaft of the radius. The goniometer was attached to the skin using double sided adhesive tape. The goniometer was attached so that the joint axis was midway between
the two attachments of the goniometer. To insure accuracy, it was calibrated by finding each subject's anatomical zero position in elbow extension.

The EMG and electrogoniometer Telemyo8 units were contained in a belt worn by each subject. The Telemyo8 unit telemetried the information to the receiver and computer.

Prior to performing the exercises, the subjects were asked to perform a maximal voluntary contraction (MVC) of each of the four muscles involved in the study. This MVC was performed against manual resistance. This was performed while collecting EMG data from each of the four muscles. This MVC was considered 100% EMG activity for each muscle tested. This procedure was done to normalize the EMG data for analysis.

Donkers et al\textsuperscript{15} showed that when push-ups were completed using a "normal" hand position it was equivalent to pushing up 45% of a person's body weight. They described "normal" hand position as when the hands were placed on the floor directly beneath the acromion processes. Thus, it was determined that the subjects would complete the bench press using 45% of their body weight to compare it to the push-ups.

Prior to the trials, each subject's age, weight, and height was recorded. Also, the subject's shoulder width was measured by using the distance from one acromion process to the other acromion process. This measurement was recorded and used for the hand separating distance for both the bench press and the push-up exercises.

The subjects were then given a 10 to 15 minute warm-up and stretching period. The subject's shoulder width was marked using tape on the floor for the push-up and tape on the barbell for the bench press. The subjects were then allowed to practice the push-up exercise to get in time with a metronome. This was done to assure consistency of movement, since EMG activity is somewhat
velocity dependent. The metronome was set so that the subject had to perform one repetition (up and down) in two seconds.

The first testing procedure began by having the subject perform 5 push-ups in time with a metronome while EMG and electrogoniometer data was collected. The subject was then given a 3 minute rest period. The subject was then asked to perform 5 more push-ups, again while EMG and electrogoniometer data was collected. After another 3 minute rest period, the subject was allowed to practice performing the bench press with 45% of their body weight to get in time with the metronome, which was at the same rate as for the push-up. For this testing procedure, each subject performed 5 bench press repetitions in time with the metronome. They were given a 3 minute rest period, and then performed 5 more repetitions of the bench press. After completion of the last set of 5 bench presses, the electrodes and electrogoniometer were removed and the subject was dismissed.

Data Analysis

The EMG and electrogoniometer data was analyzed using the Myosoft and Norquest software packages (Noraxon USA, etc.) to determine muscle recruitment patterns and amount of EMG activity. The EMG activity in each of the four muscles was compared to the MVC EMG activity to normalize the data. The normalized data and the recruitment patterns were then used to compare the muscle activity in a bench press versus a push-up.
CHAPTER 3
RESULTS

The results show that the biceps brachii and triceps had a higher percentage of MVC during the push-up than the bench press (Table 2 and Figure 1). However, the pectoralis major and serratus anterior had a higher percentage of MVC during the bench press than the push-up (Table 2 and Figure 1).

When looking at the total percentage of elbow ROM each muscle was active during the two exercises, the triceps and pectoralis major were active through a greater percentage of total elbow ROM during the push-up than the bench press (Table 3 and Figure 2). Whereas, the serratus anterior and biceps brachii were active through a greater percentage of elbow ROM during the bench press than the push-up (Table 3 and Figure 2). Muscle activity during elbow ROM is also shown in Figure 3. This was computed by taking the average on and off times of each muscle during the elbow ROM. With some of the subjects, there were two on and off times throughout the ROM. Figure 3 is an estimate of all the subjects' on and off times throughout the ROM.
Table 2. Percentage of Maximal Voluntary Contraction 
(Difference between Bench Press vs. Push-Up)

<table>
<thead>
<tr>
<th>Type of Exercise</th>
<th>Pectoralis Major</th>
<th>Serratus Anterior</th>
<th>Biceps Brachii</th>
<th>Triceps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Push-up</td>
<td>54.14%</td>
<td>88.50%</td>
<td>12.94%</td>
<td>100.00%</td>
</tr>
<tr>
<td>Bench Press</td>
<td>56.44%</td>
<td>90.06%</td>
<td>12.07%</td>
<td>73.60%</td>
</tr>
</tbody>
</table>

| Percentage Difference | 2.29% (B.P.)\(^a\) | 1.57% (B.P.)\(^a\) | .87% (P.U.)\(^b\) | 27.81% (P.U.)\(^b\) |

\(^a\) Bench Press has higher percentage.  
\(^b\) Push-Up has higher percentage.
Figure 1. Normalized EMG Activity During the Bench Press and Push-Up.
Table 3. Percentage of Elbow ROM Muscle is Active (Difference between Bench Press vs. Push-Up)

<table>
<thead>
<tr>
<th>Type of Exercise</th>
<th>Pectoralis Major</th>
<th>Serratus Anterior</th>
<th>Biceps Brachii</th>
<th>Triceps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Push-up</td>
<td>88.40%</td>
<td>62.16%</td>
<td>66.12%</td>
<td>88.46%</td>
</tr>
<tr>
<td>Bench Press</td>
<td>66.86%</td>
<td>77.06%</td>
<td>78.18%</td>
<td>78.76%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Percentage Difference</th>
<th>(P.U.)a</th>
<th>(B.P.)b</th>
<th>(B.P.)b</th>
<th>(P.U.)a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Push-Up</td>
<td>21.54%</td>
<td>14.90%</td>
<td>12.06%</td>
<td>9.70%</td>
</tr>
<tr>
<td>Bench Press</td>
<td>(B.P.)b</td>
<td>(B.P.)b</td>
<td>(B.P.)b</td>
<td>(P.U.)a</td>
</tr>
</tbody>
</table>

a. Push-Up has higher percentage.
b. Bench Press has higher percentage.
Figure 2. Duration of Muscle Activity in Bench Press and Push-Up.
Figure 3. Muscle Activity During Elbow Range of Motion, Bench Press vs Push-Up.

BENCH PRESS
- PECTORALIS MAJOR
- SERRATUS ANTERIOR
- BICEPS BRACHII
- TRICEPS BRACHII

PUSH-UP
- PECTORALIS MAJOR
- SERRATUS ANTERIOR
- BICEPS BRACHII
- TRICEPS BRACHII

ELBOW RANGE OF MOTION (Degrees)
CHAPTER 4
DISCUSSION

The results of this study do show some differences between closed kinetic chain exercise and open kinetic chain exercise in the upper extremity. Because of the small number of subjects, statistical tests were not done to determine if these results are significant.

It appears that the greatest difference in percentage of MVC was shown in the triceps (27.81%) with the push-up having the higher percentage. The other muscles showed a small difference in percentage of MVC between the two exercises. The pectoralis major had a difference of 2.29% (bench press higher), the serratus anterior a 1.57% difference (bench press higher), and the biceps a .87% difference (push-up higher). It is hard to generalize what the reason for this would be. Moseley et al\textsuperscript{13} found that the push-up was a prime exercise for the serratus anterior. Why then was the serratus anterior more active during the bench press than the push-up? It could be that 45\% body weight for the bench press is not comparable to doing a push-up.

In looking at the portion of the ROM that each muscle is active, it appears that the pectoralis major (21.54\%) and the triceps (9.70\%) were active throughout more range in the push-up and the serratus anterior (14.90\%) and biceps brachii (12.06\%) were active throughout more range in the bench press. It would appear that closed chain exercises recruit the triceps and pectoralis major to a greater extent than open chain exercises. Likewise, using an open chain exercise would result in activity in the serratus anterior and biceps
throughout more of the range than a closed chain exercise. Once again, it should be noted that the differences in most of the cases were quite small.
CHAPTER 5
CLINICAL IMPLICATIONS

The purpose of this study was to compare open and closed kinetic chain exercises in the upper extremity. The results show some difference with the two exercises. Muscle activity and the ROM muscles were active showed differences. Due to the small number of subjects, no statistical tests were done to determine if these differences were significant.

It appears that when looking at the percentage of MVC, the elbow musculature (triceps and biceps brachii) was more active during the closed chain exercise (push-up). In contrast, the shoulder musculature (pectoralis major and serratus anterior) was more active in the open chain exercise (bench press). However, the differences in the percentage of MVC were quite small in most of the muscles.

This study only looked at one exercise from each kinetic chain group. It is not known whether these differences would be the same if other closed and open kinetic chain exercises were compared using EMG.

More research is needed to compare a larger amount of exercises from each kinetic chain group to make a generalization more accurately. Also important to note is that this study used only five subjects. More studies with a larger amount of subjects and statistical tests being done is needed to give justice to the question of closed versus open kinetic chain exercises.
APPENDIX

Appendix A1. Human Subjects Review Form

EXPEDITED REVIEW REQUESTED UNDER ITEM 3.7. (NUMBER[S]) OF HHS REGULATIONS
EXEMPT REVIEW REQUESTED UNDER ITEM (NUMBER[S]) OF HHS REGULATIONS

UNIVERSITY OF NORTH DAKOTA
HUMAN SUBJECTS REVIEW FORM
FOR NEW PROJECTS OR PROCEDURAL REVISIONS TO APPROVED
PROJECTS INVOLVING HUMAN SUBJECTS

PRINCIPAL INVESTIGATOR: Bradley J. Neis
TELEPHONE: 777-2831 DATE: 10-8-94

ADDRESS TO WHICH NOTICE OF APPROVAL SHOULD BE SENT: P.O. Box 9037, University of North Dakota

SCHOOL/COLLEGE: Medical DEPARTMENT: Physical Therapy PROPOSED PROJECT DATES: 10-94 to 1-95

PROJECT TITLE: An EMG Analysis of Closed Kinetic Chain Exercises vs. Open Kinetic Chain Exercises in the Upper Extremity

FUNDING AGENCIES (IF APPLICABLE):

TYPE OF PROJECT:
NEW PROJECT _____ CONTINUATION _____ RENEWAL _____ DISSERTATION OR THESIS RESEARCH
X STUDENT RESEARCH PROJECT _____ CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT

DISSERTATION/THESIS ADVISER, OR STUDENT ADVISER: Dr. Thomas M. Mohr

PROPOSED PROJECT: _ INVOLVES NEW DRUGS (IND) _ INVOLVES NON-APPROVED USE OF DRUG
_ INVOLVES A COOPERATING INSTITUTION

IF ANY OF YOUR SUBJECTS FALL IN ANY OF THE FOLLOWING CLASSIFICATIONS, PLEASE INDICATE THE CLASSIFICATION(S):
_ MINORS (<18 YEARS) _ PREGNANT WOMEN _ MENTALLY DISABLED _ FETUSES
_ MENTALLY RETARDED _ PRISONERS _ ABORTUSES _ X UND STUDENTS (>18 YEARS)

IF YOUR PROJECT INVOLVES ANY HUMAN TISSUE, BODY FLUIDS, PATHOLOGICAL SPECIMENS, DONATED ORGANS, FETAL MATERIAL, OR PLACENTAL MATERIALS, CHECK HERE __

1. ABSTRACT: (LIMIT TO 200 WORDS OR LESS AND INCLUDE JUSTIFICATION OR NECESSITY FOR USING HUMAN SUBJECTS).
Closed kinetic chain activity by definition is the movement of the proximal segments of an extremity in relation to its fixed distal segment. An example of this would be the stance phase of gait in which the proximal knee and hip pass over the fixed foot. Open kinetic chain activity by definition is the movement of the distal segment of an extremity in relation to its fixed proximal segment. Using an example again, this is the swing phase of gait in which the distal foot and leg move in relation to the fixed hip. Both closed kinetic chain and open kinetic chain activities are
common in rehabilitation involving the lower extremity and the upper extremity. Research of the lower extremity has shown that closed chain activities are more functional, safer and offer more joint stability through weight bearing and muscular co-contractions than open chain activities. Although closed chain activities are performed regularly in the rehabilitation setting for the upper extremity, there has been little or no research proving that these activities are better, worse, or the same as open chain activities. The purpose of this research project is to compare open and closed chain exercise in the upper extremity and determine if there is a difference in the two. Because these exercises are performed by patients in everyday rehabilitation settings, it is necessary to use human subjects in this project.

PLEASE NOTE: Only information pertinent to your request to utilize human subjects in your project or activity should be included on this form. Where appropriate attach sections from your proposal (if seeking outside funding).

2. PROTOCOL: (Describe procedures to which humans will be subjected. Use additional pages if necessary.)

SUBJECTS:

It is anticipated that approximately 10 healthy male subjects without previous shoulder or elbow pathology will be used. These subjects will be randomly selected from students currently enrolled in the Physical Therapy program at the University of North Dakota. The prospective subjects will fill out a questionnaire asking them about their age, frequency of physical activity, and past pathology of the shoulder and elbow. Any subject with past pathology will be excluded from the study. The anticipated age range of subjects is from 20 to 35 years of age.

METHODS:

This project will measure electromyography (EMG) activity in four upper extremity muscles during both a closed kinetic chain exercise and an open kinetic chain exercise. The closed kinetic chain exercise will be a push-up and the open kinetic chain exercise will be the bench press. The four muscles in which EMG activity will be measured are: 1) biceps 2) triceps 3) serratus anterior and 4) pectoralis major.

Surface electrodes will be used to record EMG activity by placing them over the motor points of each muscle. To effectively find the motor points, a small electrical stimulator will be used. In order to receive appropriate EMG signals from the electrodes, the subjects skin will be prepared by shaving any hair with a disposable razor and removing the oil on the skin by wiping it with alcohol before the attachment of the electrodes. The electrodes are pre-gelled and self-adhesive. The described methods of finding motor points and skin preparation are common in clinical practice.

An electrogoniometer will be used to measure elbow range of motion during the two exercises. It will be attached above and below the elbow using the same landmarks as used during manual goniometer measurement. This will be attached using double sided adhesive tape. It will be calibrated before each exercise to guarantee accuracy.

The EMG and electrogoniometer electrodes will be attached to the subjects dominant upper extremity. The EMG and electrogoniometer units will be attached to a belt worn by the subject. The data will be transmitted via telemetry to a receiver and then fed into a computer for display, recording, and analysis.
Prior to each trial, the subjects age, weight, and height will be recorded. Also, each subject will be asked to perform a maximal voluntary contraction (MVC) of each of the four muscles involved in the study. This MVC will be performed using manual muscle testing (MMT) techniques common in the clinic. There will be three trials for each muscle that will be averaged to derive the MVC of each muscle. This MVC will be considered 100% EMG activity for each muscle to which the EMG collected during the two exercises can be compared. This is done to normalize the EMG data for analysis.

Before actually performing the exercises, each subject will be measured from one acromion process to the other acromion process. This measurement will be recorded and used for the hand width during both the push-ups and bench press exercises. The weight used during the bench press will be 45% of the subjects body weight. A previous study has shown that during a push-up, a person is lifting 45% of their body weight with the hands at shoulder width. The rate of performing the bench press and push-ups will be one repetition every 3 seconds and will be controlled with an audible metronome.

The experiment will begin after each subject has been given a 10 to 15 minute stretching and warm-up period. This warm-up period will include repetitions of the bench press and push-ups. After the subject is ready, they will begin by performing 5 push-ups in time with the metronome while EMG and goniometric data is collected. The subject will then be given a 5 minute rest period. After the rest period, the subject will perform 5 repetitions of the bench press in time with the metronome while EMG and goniometric data is collected. After completion of the second exercise, the EMG electrodes and electrogoniometric electrodes will be removed.

The data will be analyzed using descriptive statistics. The following variables will be measured: 1) integrated EMG, 2) electrogoniometric measurements, and 3) timing of muscle contraction compared to goniometric readings. The EMG data will be expressed as a percentage of the MVC, which was collected using MMT before the trials. All of the data will be analyzed to determine if it is statistically significant. Comparisons will then be made between the data from the push-up and the bench press exercises.

3. Benefits: (Describe the benefits to the individual or society.)

The results of this study will help to determine if there is a difference between closed kinetic chain and open kinetic chain exercises in the upper extremity. There has been no research comparing them in the past. If there are indeed differences and if those differences can be identified, it can lead to the development of specific indications or contraindications to help the clinician decide which type of exercise is appropriate or inappropriate in a given clinical situation.

4. Risks: (Describe the risks to the subject and precautions that will be taken to minimize them. The concept of risk goes beyond physical risk and includes risks to the subject's dignity and self-respect, as well as psychological, emotional or behavioral risk. If data are collected which could prove harmful or embarrassing to the subject if associated with him or her, then describe the methods to be used to insure the confidentiality of data obtained, including plans for final disposition or destruction, debriefing procedures, etc.)

It is the investigators opinion that the risks in this experiment are minimal. Push-ups and bench press exercises are common exercise in a normal physical workout and because of the use of normal healthy subjects without upper extremity pathology the risk of injury will be minimal.
There is a chance of post-exercise soreness, but due to the small duration of physical exertion by
the subject this is minimized. The EMG and electrogoniometer equipment are both monitoring
only devices and will cause no discomfort to the subjects. The subjects will be asked to wear
comfortable gym shorts or sweat pants for the experiment. In order to correctly attach and monitor
the electrodes, the subject will need to have his shirt off during the trial. With this experiment
using only males, this should prevent the subject form any loss of dignity or embarrassment.

5. CONSENT FORM: A copy of the CONSENT FORM to be signed by the subject (if applicable) and/or any statement to be read to
the subject should be attached to this form. If no CONSENT FORM is to be used, document the procedures
to be used to assure that infringement upon the subject's rights will not occur.

Describe where signed consent forms will be kept and for what period of time.

The consent forms will be kept by my advisor, Thomas Mohr in the Department of Physical
Therapy,
Room 148, Medical Science North for a period of two (2) years. A copy of the consent form is
attached.

6. For FULL IRB REVIEW forward a signed original and thirteen (13) copies of this completed form, and where applicable,
three (3) copies of the proposed consent form, questionnaires, etc. and any supporting documentation to:

Office of Research & Program Development
University of North Dakota
Box 8138, University Station
Grand Forks, North Dakota 58202

On campus, mail to: Office of Research & Program Development, Box 134, or drop it off at Room 101 Twamley Hall.

For EXEMPT or EXPEDITED REVIEW forward a signed original and a copy of the consent form, questionnaires, etc. and any
supporting documentation to one of the addresses above.

The policies and procedures on Use of Human Subjects of the University of North Dakota apply to all activities involving use
of Human Subjects performed by personnel conducting such activities under the auspices of the University. No activities are
to be initiated without prior review and approval as prescribed by the University's policies and procedures governing the use
of human subjects.

SIGNATURES:

Principal Investigator

DATE: ________________________

Project Director or Student Adviser

DATE: ________________________

Training or Center Grant Director

DATE: ________________________

(Revised 8/1992)
Appendix A2. Informed Consent Form

INFORMATION AND CONSENT FORM

TITLE: An EMG Analysis of Closed Kinetic Chain Exercises vs. Open Kinetic Chain Exercises in the Upper Extremity.

You are invited to participate in a study conducted by Brad Neis, a Graduate Student in the Physical Therapy Department at the University of North Dakota. The purpose of this study is to compare closed kinetic chain exercises with open kinetic chain exercises in the upper extremity. You will be asked to perform a push-up and a bench press exercise. I hope to learn if there is a difference between the two exercises and what that difference is, if any. Only normal, healthy males are being asked to participate in this study.

You will be asked to complete five repetitions of each exercise. The push-up will be a normal push-up with hand width being the same as shoulder width. The bench press will involve lifting 45% of your body weight with your hand width again at shoulder width.

This study will take approximately 45 minutes to one hour of your time. You will be asked to report to the Physical Therapy research lab in Medical Science North at an assigned time. You will then be asked to change into gym shorts or sweat pants and a T-shirt for the experiment. I will first record your age, height and weight. During the experiment, I will be recording the amount of muscle activity you have when you complete the two exercises and the amount of movement that occurs in your elbow joint.

In order for me to record the muscle activity, I will be placing four electrodes on your upper extremity. Before applying the electrodes, I will use a small stimulator to electrically stimulate the muscles to find the best spot to place the electrodes. The stimulator will cause a mild tingling sensation. Those areas identified with the stimulator will be shaved with a disposable razor and cleaned with alcohol. The recording electrodes are self-adhesive and will be attached to the skin. I will also attach a measuring device to your elbow with adhesive material. Both the EMG electrodes and the measuring device will be attached to units on a belt worn around your waist. None of these electrodes or devices penetrate the skin and should not cause discomfort. The devices only record information from your muscles and joints and will not cause discomfort.

Before the actual experiment you will be allowed to stretch and warm-up by practicing push-ups and bench press exercises. I will then perform a manual muscle test (MMT) to the muscles involved in this study. This MMT involves contracting certain muscles against my resistance while EMG data is collected. After that you will begin the experiment. You will be asked to perform five push-ups at a rate controlled by an audible metronome. Following that, you will be given a rest period. You will then perform five repetitions of the bench press, again with the rate controlled by a metronome. I will then remove the electrodes and measuring device. This will conclude your participation in the study.

The testing of physical activity always involves some degree of risk, although the investigator feels the risk of injury or discomfort is minimal. The electrical stimulator used to find electrode placement causes only minimal discomfort, and the electrodes used to monitor the muscle activity and movement should not cause any discomfort at all. The number of repetitions you will be asked to complete will be minimal compared to an actual exercise work-out.

Your name will not be used in any reports of the results of the study. Any information that is obtained in this study and can be identified with you will remain confidential and will be disclosed only with your permission. The data will be identified with a number known only by the investigator. Your decision whether or not to participate will not prejudice your present or future relationship with the Physical

Therapy Department or the University of North Dakota. If you decide to participate, you are free to discontinue participation at any time without prejudice.

The investigator is available to answer any questions you have concerning this study. In addition, you are encouraged to ask any questions concerning this study that you may have in the future. Questions may be asked by calling Brad Neis at 701-795-5163 or his advisor Dr. Thomas Mohr at 701-777-2831. A copy of this consent form is available to all participants in the study.

In the event that this study results in a physical injury, medical treatment will be available, including first aid, emergency treatment, and follow up care as it is to a member of the general public in similar circumstances. Payment for any such treatment must be provided by you and your third party payor, if any.

ALL OF MY QUESTIONS HAVE BEEN ANSWERED AND I AM ENCOURAGED TO ASK ANY QUESTIONS THAT I MAY HAVE CONCERNING THIS STUDY IN THE FUTURE. MY SIGNATURE INDICATES THAT, HAVING READ THE ABOVE INFORMATION, I HAVE DECIDED TO PARTICIPATE IN THE STUDY.

I have read all of the above and willingly agree to participate in this study explained to me by ________________

______________________________    ________________________
Participant's Signature          Date

______________________________    ________________________
Witness (not the scientist)       Date
REFERENCES


