Assessing Selected Shoulder Muscle Activity During Performance of Exercise on the Cuff Link Exercise Unit

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Assessing Selected Shoulder Muscle Activity During Performance of Exercise on the Cuff Link Exercise Unit

By

Kathleen Johnstone
Kathleen Wagner

THESIS

Submitted to the Department of Physical Therapy
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1998
Assessing Selected Shoulder Muscle Activity During Performance of Exercise on the Cuff Link Exercise Unit

ABSTRACT

The purpose of this study was to evaluate muscle activity of pectoralis major, serratus anterior, teres major, and latissimus dorsi during an exercise performed on the Cuff Link utilizing normal subjects. Forty-four subjects performed a rotation exercise in a clockwise direction at a speed of 58 beats per minute. Three trials were completed using the push-up handles and the large-diameter hemisphere. Surface electromyography recorded the activity of the four muscles. Recorded EMG values were normalized as a percentage of the maximal voluntary isometric contraction (MVIC). A two-way ANOVA was used to compare mean normalized muscle activity for each muscle and between muscle comparisons. The results showed that mean percent MVIC for latissimus dorsi was 7.8%, serratus anterior 19.3%, and teres minor 22.0%. Latissimus dorsi was found to be significantly lower than serratus anterior and teres minor. This study was an initial attempt at assessing the value of the Cuff Link in the rehabilitation process.
ACKNOWLEDGEMENTS

We would like to extend our thanks and appreciation to Brooks Millar and Don Walendzak for providing us with the Cuff Link to perform this research. We would also like to thank Arthur Schwarcz, committee chair, for his continued guidance in helping us write this paper. Thank you to committee members Cynthia Grapczynski and Gordon Alderink for their feedback and correction. We would also like to extend a special thank you to George Sturm who offered his expertise with the statistical analysis of our results. Thank you to all of the subjects who participated in this study. Our appreciation goes out to the engineering department at Grand Valley State University, namely Bob Bero, for his unconditional help and support throughout this study. We would also like to thank the student assistants in the computer labs at Grand Valley for all their technical support.

This study could not have been completed without the continued love and support of our family and friends. Thank you for your immeasurable patience with us and this project for the past year and a half.
DEFINITION OF TERMS

Closed kinetic chain- a kinetic chain where the distal extremity remains fixed and engages in partial or full weight bearing activities.

Concentric contraction- a condition in which the extended muscle contracts into a shortened position causing the distance from origin to insertion to decrease.

Eccentric contraction- a condition in which a contracted muscle lengthens.

Functional movements- movements that an individual performs on a regular basis in order to function in society.

Isometric contraction- a condition in which the muscle develops tension but does not change its length.

Mechanoreceptors- a type of sensory receptor which responds to mechanical deformation of the receptor and the surrounding tissue.

Open kinetic chain- a kinetic chain where the distal extremity is freely moveable and non-weight bearing with little to no resistance relative to an individuals repetition maximum.

Proprioception- sensation and awareness of body position and movements.

Plyometrics- exercises in which an eccentric muscle contraction is followed immediately by a concentric muscle contraction of the same muscle. This exercise links strength and speed of movement to produce an explosive-reactive type movement.

Repetition Maximum- the maximum amount of weight an individual can move one time through full range.
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CHAPTER 1
INTRODUCTION

Background of the Problem

As society becomes more fitness conscious, exercise activity levels have increased. As a consequence of increases in activity, health care providers are seeing a greater range and frequency of injuries. One particularly vulnerable location for increased injury is the shoulder girdle (Wilk & Arrigo, 1993). The shoulder girdle musculature provides the upper extremity with both mobility and stability. Due to the large amount of range of motion (ROM) the shoulder is predisposed to overuse injuries (Rodgers & Crosby, 1996). Other common injuries at the shoulder include acromioclavicular injuries, biceps tendinitis, scapulothoracic bursitis, shoulder impingement, and rotator cuff tendinitis (Jobe & Bradley, 1989; Ellenbecker & Derscheid, 1989). Clearly, the muscles of the shoulder girdle complex are a frequent site of rehabilitation.

The shoulder muscle complex is composed of two major subsets of muscles, the rotator cuff and the scapular stabilizers. The rotator cuff subset includes the supraspinatus, infraspinatus, teres minor, and subscapularis. The rotator cuff is enhanced by the surrounding musculature of the deltoid, biceps, triceps as well as the scapular stabilizers. The scapular stabilizers include the serratus anterior, rhomboid major and minor, the entire trapezius, levator scapulae, pectoralis minor, and pectoralis major (Paine & Voight, 1993; Bigliani, Kelkar, Flatlow, Pollock, & Mow, 1996; Jobe, Moynes, & Brewster, 1987; Townsend, Jobe, Pink & Perry, 1991). Another important muscle
facilitating shoulder movement is the latissimus dorsi. The latissimus dorsi, along with pectoralis major, acts as prime movers of the humerus (Jobe et al., 1987). The latissimus dorsi acts both as an accelerator, concentrically, and a decelerator, eccentrically. The eccentric movement of latissimus dorsi helps protect the shoulder against anterior instability in abduction and external rotation (Glousman, 1992; Dines & Levinson, 1995). Stability at the shoulder is maintained through the synchronistic action of both the scapular stabilizers and the rotator cuff muscles. When the rotator cuff and scapular stabilizers are functioning properly, maximum stability at the shoulder can be achieved during functional activities (Jobe et al., 1987).

Injury to any of the musculature of the shoulder girdle complex could cause improper placement of the scapula and the surrounding musculature. As injury continues to disrupt the scapular stability, strength declines and eventually results in a decrease in shoulder function. “When weakness is present in the scapular musculature normal scapular positioning and mechanics may become altered” (Paine & Voight, 1993, p. 386).

When treating shoulder pathology, the current trend is to treat with functional methods using techniques such as plyometrics, proprioceptive training, open kinetic chain exercises (OKC), and closed kinetic chain exercises (CKC). Research on these current treatment techniques is just beginning. Many studies investigated OKC exercise as it applies to the upper extremity (UE), but there is little data on CKC exercise for the upper extremity (Wilk, Arrigo, & Andrews, 1996; Dines & Levinson, 1995; Borsa, LePhart, Kocher & LePhart, 1994; Wilk & Arrigo, 1993). There is, however, abundant research on lower extremity (LE) CKC exercise using the Biomechanical Ankle Platform System (BAPS) board. The BAPS board is circular in shape, and is mounted on a hemisphere
that screws into the bottom of the board. This hemisphere creates an unstable environment in which individuals can perform exercises to assist in stabilizing the LE. The BAPS board has demonstrated CKC benefits. These benefits include co-contraction of muscles around a joint, as well as increases in proprioception (Tippett, 1992). The BAPS board is one of many CKC functional exercise tools but is just one example that has been used in rehabilitation.

Brooks Millar and Don Walendzak, physical therapists, developed the Cuff Link which is a device similar to the BAPS board, in 1996. The Cuff Link applies the LE closed kinetic chain principles to the shoulder girdle complex. The inventors claim that this rehabilitation tool will increase strength and improve stability about the scapula and the glenohumeral joint. The inventors suggest that application of an axial load, or force through the axis of the shoulder, in small rhythmic motions can facilitate a significant amount of cocontraction and trigger neurological patterns in the shoulder stabilizers. The Cuff Link was designed to combine therapy of the shoulder girdle and the core (trunk)(B.M., personal communication, June 11, 1997). It is hypothesized that the muscles and mechanoreceptors of the upper extremity and trunk are activated when using this piece of equipment. Due to limitations of this study the researchers will focus solely on the muscle activity of the shoulder girdle complex.

**Need for the Study**

Shoulder problems are a major treatment category in rehabilitative medicine. Due to the difficulty of maintaining stability while promoting mobility, the shoulder girdle complex is frequently injured. Due to the ever increasing pressure from insurance companies and employers to restore function in fewer visits, physical therapists are being
challenged to find more effective ways to rehabilitate their patients. One way to improve the efficacy of shoulder rehabilitation is to employ a variety of exercise techniques. In addition to equipment that is currently on the market, new exercise modalities are being invented regularly. The emergence of new rehabilitation equipment has provided therapists and managers the opportunities to examine products and their validity before any purchases are made. The Cuff Link is a new type of rehabilitation equipment specifically designed for closed kinetic chain (CKC) exercises of the upper extremity.

Research on the effectiveness of CKC exercise was limited in regards to UE shoulder rehabilitation. “Strength and endurance of the scapular rotators are not mentioned in the literature and may be an area of examination and therapeutic intervention that has been overlooked” (Matocks & Whitney, 1994). Furthermore, there have been no research studies that have determined the level of muscle activity when exercising with the Cuff Link; however at least three studies are currently underway. It is therefore appropriate that the Cuff Link be tested as a form of CKC exercise in order to verify its benefit to rehabilitation programs involving the shoulder.

Statement of the Problem

The inventors of the Cuff Link claim that using this tool in various positions will result in an increase in strength about the shoulder complex. However, no formal research has been completed that supports the claims that the Cuff Link increases muscular activation about the shoulder.

Purpose of the Study

The primary purpose of this study was to examine the inventors’ claims that the Cuff Link significantly increases muscular activity about the shoulder. This claim was
investigated through electromyography (EMG) of the latissimus dorsi, teres minor, pectoralis major, and serratus anterior while performing one exercise on the Cuff Link. The secondary purpose of this study was to evaluate and compare the level of muscle activation in the shoulder complex of normal subjects when performing one exercise on the Cuff Link apparatus. The levels of muscle activation while exercising on the Cuff Link for latissimus dorsi, teres minor, pectoralis major, and serratus anterior were compared to one another. The tertiary purpose was to produce normative data for females aged 18-28 years old regarding muscle activity while exercising in the push up position on the Cuff Link.

**Significance**

If a significant increase in muscular activity is found during the Cuff Link exercise then there is the potential for utilizing the Cuff Link to increase strength in various muscles of the shoulder complex. This research will benefit both the patients using the device and the rehabilitation professional, as both will feel confident in the Cuff Link as a viable choice in rehabilitation of the upper extremity.

Research on this CKC rehabilitation device will also help the health care profession as a whole, because support is lacking in areas of CKC exercise for the upper extremity. Furthermore, this pioneering research can be used for additional studies involving the Cuff Link to determine its effectiveness in rehabilitation versus other well known rehabilitation tools. Research on tools that utilize full weight bearing is also needed to investigate the effects of proprioception on the shoulder girdle.
CHAPTER 2
LITERATURE REVIEW

Introduction to Literature Review

This review will discuss concepts relevant to a study of the shoulder girdle complex. First, a discussion of kinematic chains and the difference between open and closed kinematic systems will be presented. Following that the joints of the upper extremity including the shoulder, elbow, wrist, and how these joints comprise the UE kinetic chain and scapular complex will be addressed. The final areas to be discussed will include the muscles of the shoulder girdle, electromyography, an explanation of normative data, and the Cuff Link.

Kinematic Chains

Researchers have investigated the way in which segments of the body move and the forces behind these movements for some time. Kinetics describes “the forces acting on the body during movement and the interactions of sequence of motion with respect to time and forces present” (Thomas, 1989, p. 976). Using this definition, movements can be defined kinetically not only by what movement is occurring, but also by the amount of force required to produce a controlled movement of associated body parts.

The original use of kinematics can be found in engineering. A kinematic chain is composed of individual links of a rigid chain, connected in series by part of a larger system of joints (Snyder-Mackler, 1996; Wilk, Arrigo, & Andrews, 1996). The terms kinematic and kinetic chain are often used interchangeably throughout the literature.
They will also be used interchangeably in this study. The notion of kinematic chains was modified and applied to the human body by Steindler in the 1970's (Snyder-Mackler, 1996; Wilk et al., 1996; Dillman, Murray, Hintermeister, 1994; Andrews, Dennison, Wilk, 1996). An example of the kinematic chain concept is found “in the upper extremity, where the scapulothoracic articulation and the acromioclavicular, sternoclavicular, and glenohumeral joints can be defined as a kinetic chain” (Lephart & Henry, 1996, p. 71). Each of the above four joints are crucial in maintaining shoulder girdle stability while providing mobility, and thus define the importance of this kinetic chain. Motion occurring at one joint within a system would produce a predictable movement at all other joints within that system (Palmitier, An, Scott, Chao, 1996). Many rehabilitation programs utilize a kinetic chain concept for both the beginning and end stages of treatment in an effort to integrate functional activities. This type of treatment program is utilized because most functional activities involve a combination of open and closed kinetic chain concepts. A more specific discussion of kinetic chains and how they relate to rehabilitation will be presented later in this chapter.

**Open Kinetic Chain**

Various interpretations of Steindler’s original work regarding the concept of open kinetic chain (OKC) exist. Wilk et al. (1996), in summarizing Steindler’s thoughts, stated that an OKC existed when the distal extremity was freely movable. Specifically, “an OKC exists when the peripheral joint of the extremity can move freely, such as when waving the hand or moving the foot forward in the swing phase of gait” (Palmitier et al., 1991, p. 404). In the example of waving the hand when saying good-bye the distal segment, the hand, is able to move without causing movement at another joint.
Other authors have provided their own definition of OKC based on Steindler's original work. Dillman et al. (1994) interpreted Steindler's definition of OKC to mean the ability of the terminal segment to exhibit speed, be freely moveable, and have no external resistance imposed on it. Gray defined an OKC as an isolated movement where the distal segment is free and moves in a planar surface (Gray et al., 1992). Panariello (1994) defined an OKC movement as one in which the distal part of an extremity was not in contact with the ground. Lephart and Henry (1996) defined OKC as a condition of little external resistance, unsupported body weight, and no fixation of the distal segment in a chain. The literature appears to agree that the classification for an OKC activity is where the distal extremity is freely moveable and non-weight bearing with little to no resistance relative to an individual's repetition maximum. For the purpose of this study the authors will refer to OKC based on this last definition.

Closed Kinetic Chain

Many researchers have also discussed the concept of a closed kinematic chain. A closed kinetic chain (CKC) was described by Steindler (Wilk et al., 1996) as having both ends, proximal and distal, of the kinetic chain fixed to an immovable framework. Steindler's definition of a CKC was broadened to include conditions where the distal extremity met considerable amounts of resistance (Dillman et al., 1994; Wilk et al., 1996; Lephart & Henry, 1996). An example of this movement is when surgical tubing is used in upper extremity rehabilitation programs (Tippett, 1992). This example meets the above criteria as one end of the tubing is fixed to a wall, or other immovable device, while the other end of tubing is held by the upper extremity which meets considerable resistance as it moves through the available range of motion. The example of surgical
tubing completing the kinetic chain only holds true to CKC principles if the tubing itself is considered to be part of the UE chain. If the tubing was not considered part of the chain, the movement would be defined as open chain and would not fit the CKC definition.

Researchers again vary in their interpretations of Steindler's definition of a closed kinetic chain. Lephart and Henry (1996) defined a CKC as a situation where the external resistance was notable, the extremity was supporting body weight, and the distal segment of the chain was fixed. Gray described a closed chain as a situation where one or both extremities, upper or lower, supported the body weight (Gray et al., 1992). Panariello (1991) defined a closed chain in the lower extremity as a condition where the distal lower extremity was in contact with the ground. Snyder-Mackler (1996) stated that a CKC was when both ends of a system were fixed. Previous researchers appear to agree that the classification for a CKC activity is when the distal extremity remains fixed and engages in full or partial weight bearing activities. The authors will refer to CKC based on this consensus.

Open and Closed Kinetic Chain Activities

Whether a body part is freely moveable (OKC) or fixed (CKC), specific, but perhaps different, muscles are working to initiate or control the movement. Each type of kinetic model provides different benefits to the human body in activities of daily living and rehabilitation. "Both open and closed chain activities possess characteristics that are important in restoring neuromuscular control to an injured extremity" (Lephart & Henry, 1996, p. 83).
OKC exercise benefits may include quick movements with low resistive forces, as well as concentric accelerations and eccentric decelerations that produce functional movements in the extremities. The goal for OKC exercise in the shoulder girdle complex is “to provide proximal control of the scapulothoracic joint to facilitate a stable base of support for glenohumeral mobility” (Davies & Dickoff-Hoffman, 1993, p. 454). CKC exercise benefits may include slow movements with large resistance, joint congruency, and stimulation of mechanoreceptors through weightbearing on the extremity (Lephart & Henry, 1996). CKC exercise may address many needs for rehabilitation of shoulder pathologies including strengthening, stability, and proprioception (Tippett, 1992). It is hypothesized that closed chain activities address proprioceptive deficits through weightbearing which stimulates mechanoreceptors more readily than in OKC (Tippett, 1992). In the article on scapular muscle rehabilitation by Mosely et al. (1992), “the core four exercises that were thought to significantly challenge the scapular muscles consisted of two closed chain and two open chain exercises” (Hancock & Hawkins, 1996, p. 93). The exercises included scaption, which is scapular plane elevation, rowing, push-up with a plus (push-up with maximal protraction), and press-up or push up against the wall.

It is still unclear at what time in the rehabilitation process that OKC and CKC strategies should be implemented during a shoulder rehabilitation program. Some authors have suggested that certain weightbearing exercise can be utilized early in rehabilitation to enhance dynamic joint stability without applying heavy resistance that may irritate the joint. Others have suggested progressing shoulder rehabilitation from the initial use of OKC exercises, to the use of CKC exercises in the later stages of

When we perform kinesthetic rehabilitation techniques, we usually begin with closed kinetic chain exercises. Although there is limited research, closed kinetic chain exercise causes axial loading and compression in the joint, therefore, increasing noncontractile stability. This causes cocontraction of agonist/antagonist muscle groups, thereby creating increased dynamic joint stability (p. 453).

Still, others have proposed that CKC upper extremity proprioception, or full weightbearing exercises, should appear later in the rehabilitation program due to the great amount of strength required to support body weight on injured extremities (Stone et al., 1994). However, there are several easy ways to decrease the amount of weightbearing to make it safer in early exercise, i.e. partial weightbearing. Many authors have suggested that CKC was safer than OKC, however “one cannot make a blanket statement that CKC exercises are inherently safer than OKC exercises” (Snyder-Mackler, 1996, p. 8). The clinician should remember that safety must always be considered when choosing an OKC or CKC exercise. “All treatments have their risks and rewards, advantages and disadvantages” (Davies, 1995, p. 13). It is obvious to most experienced therapists that both OKC and CKC exercise are required to successfully rehabilitate an upper extremity injury.

**Summary of Open and Closed Kinematic Chains**

There are numerous definitions regarding open and closed kinetic chains, thus no one definition has been accepted (Dillman et al., 1994; Snyder-Mackler, 1996; Lephart & Henry, 1996). In fact, many authors state that the definitions presently used are confusing, misleading, and inaccurate (Wilk et al., 1996; Dillman et al., 1994). In this
The authors will classify an OKC activity as one in which the distal extremity is freely moveable and non-weight bearing with little to no resistance relative to an individual's repetition maximum. The authors will refer to a CKC activity as one in which the distal extremity remains fixed and engages in full or partial weightbearing activities.

The importance of both OKC and CKC exercise is noted throughout the literature. “Once rehabilitation has satisfactorily progressed and the injured athlete has improved symptomatically, open and closed kinetic chain exercises should be integrated to replicate normal upper extremity function” (Wilk et al., 1996, p. 94). The combination of OKC and CKC exercises allows the patient to maintain interest and motivation while completing daily rehabilitation programs (Hillman, 1994, p.323).

**Kinematic Chain of The Upper Extremity**

The joints of the upper extremity kinematic chain include: scapulothoracic, acromioclavicular, sternoclavicular, glenohumeral, elbow, and wrist/hand (Lephart & Henry, 1996). A force or movement that affects one joint will affect the other joints in the chain (Snyder-Mackler, 1996). The kinematic chain of the upper extremity also includes the thoracic spine, costovertebral joint, costotransverse joint, costochondral joint, and sternocostal joint. However, the discussion of these components of the upper extremity kinetic chain was not included due to the focus of study.

**Shoulder Complex**

**Scapulothoracic Joint**

The scapulothoracic joint (ST) is comprised of the articulation between the scapula and the thoracic rib cage. The ST joint is important to the kinetic chain as it
attaches to the clavicle via the acromioclavicular joint (AC). The clavicle in turn attaches
to the manubrium of the sternum via the sternoclavicular (SC) joint (Norkin & Levangie,
1992). Both the SC and AC joints and their importance will be discussed in a later
section. The manubrium is the bony link connecting the clavicle and upper extremity to
the axial skeleton, which is the bony structure in the human body. Without this
connection of the axial skeleton to the clavicle, movement in the upper extremity is not
possible. It is the scapula that provides a stable base in order for the mobility of the
glenohumeral joint to occur. “Any movement of the scapula on the thorax must result in
movement at one or both of those joints (scapulothoracic or glenohumeral). The ST joint
is part of a true CKC with the acromioclavicular (AC) and sternoclavicular (SC) joints”
(Norkin & Levangie, 1992, p. 209, parentheses added). The stability of the scapula is
provided by the surrounding musculature including: serratus anterior, trapezius,
pectoralis minor, rhomboid major and minor, and levator scapulae. This scapular
stability is maintained through both the muscles that attach to the thorax and scapula, and
the connections at the AC and SC joints. “The ultimate function of scapular motion is to
orient the glenoid for optimal contact with the maneuvering arm, to add range to
elevation of the arm, and to provide a stable base for controlled rolling and sliding of the
articular surface of the humeral head” (Norkin & Levangie, 1992, p. 210). Paine and
Voight (1993, p.386) write, “When weakness is present in the scapular musculature,
normal scapular positioning and mechanics may be altered. Efficient concentric and
eccentric activity of the musculature surrounding the shoulder is dependent on having
strong anchor muscles to stabilize the scapula.” The description of the ST joint provided
above is an example of how a delicate balance of mobility and stability is preserved throughout a kinematic chain.

**Sternoclavicular Joint**

Movements in either the sternoclavicular (SC) joint or scapulothoracic joint inevitably create motion in the remaining joints of the upper extremity kinematic chain. The clavicle is an important component of the kinematic chain as it provides the scapula with an attachment to the axial skeleton. The SC joint is supported by an interarticular disk, which increases joint congruency and absorbs forces incurred on the medial end of the clavicle. The majority of support to the SC joint is dependent on three ligaments; the anterior and posterior SC ligaments, and the costoclavicular ligament. The anterior and posterior SC ligaments check excessive anterior and posterior translation of the clavicle. The third ligament, the costoclavicular ligament, provides the axis or fulcrum for clavicular movements and checks clavicular elevation. “The SC joint, the joint capsule, the ligaments, and the sternoclavicular disk combine to produce a joint that meets its dual function of mobility and stability well” (Norkin & Levangie, p. 214).

**Acromioclavicular Joint**

The acromioclavicular joint (AC) “is composed of a joint capsule and two major ligaments; an interarticular disk may or may not be present” (Norkin & Levangie, 1992, p. 214). The AC joint’s relationship to the UE kinetic chain is found in its ability to link the clavicle and scapula in early stages of elevation in the UE. The motions occurring at the AC joint are related to scapular rotation, winging, and tipping. Two of the three ligaments supporting the joint are the superior and inferior AC ligaments that control horizontal stability. The third ligament is the coracoclavicular ligament, composed of the
conoid and trapezoid ligaments. These ligaments further stabilize the connection between the clavicle and scapula by aiding in the prevention of superior dislocation of the clavicle on the acromion and limiting anterior rotation of the clavicle and winging motions of the scapula (Norkin & Levangie, 1992).

Glenohumeral Joint

The glenohumeral (GH) joint is a very important area in the UE kinematic chain. "Any motions of the scapula, and its interdependent SC and AC linkages, may affect GH joint function. The GH joint has sacrificed congruency to serve the mobility needs of the hand" (Norkin & Levangie, 1992, p. 218). The two articulating surfaces of the GH joint include the glenoid fossa of the scapula proximally and the head of the humerus distally.

The articular surface available on the glenoid fossa is enhanced through the glenoid labrum, a fibrocartilaginous structure that increases both depth and curvature of the surface. "The labrum increases the depth of the glenoid socket by approximately 50%" (Curl & Warren, 1996). The GH joint is surrounded by a "large, loose capsule that is taut superiorly and slack anteriorly and inferiorly" (Norkin & Levangie, 1992, p. 220). Furthermore, "the capsule of the glenohumeral joint is somewhat loose and redundant, with a surface area twice that of the humeral head, allowing substantial range of motion" (Curl & Warren, 1996, p. 55). This laxity in the capsule allows increases in mobility but provides little stability without adequate reinforcement of ligaments and muscles.

The two main groups of ligaments found at the GH joint are the glenohumeral ligaments and the coracohumeral ligaments. The glenohumeral ligaments are divided into three bands (superior, middle, and inferior) and provide checks to various movements to the humerus. The glenohumeral ligaments, however, provide little joint
stability due to areas of weakness. The coracohumeral ligament checks lateral rotation of
the humerus and provides passive support to the UE against gravity (Norkin & Levangie,

The rotator cuff provides a significant contribution to the static and dynamic
stability of the GH joint. There are three main forces that effect stability of the GH joint:
the gravitational force, the rotatory force and the translatory force. The gravitational
force is the weight of the extremity due to gravity acting on the limb (Inman, Saunders, &
Abbot, 1996). This force acts as a destabilizing force at the humerus in certain positions
(i.e. standing). The rotatory force causes compression of the humeral head into the
glenoid fossa resulting in stabilization of the joint. The translatory force is a combination
of three rotator cuff components that pull downward, plus the upward component
provided by the deltoid. These three forces combine to decrease the amount of sliding, or
shear, that occurs between the humeral head and the glenoid fossa.

Biomechanics of the Shoulder

The GH joint has 3 degrees of freedom: (1) flexion and extension, (2) abduction
and adduction, and (3) internal and external rotation. The ratio of motion that occurs
between the humerus and the scapula during abduction is 2:1. For every two degrees that
the humerus contributes to abduction the scapula contributes one degree. Since the GH
joint is an ovoid joint meaning one surface is convex and the other concave, this joint
follows the convex on concave principle. “In an ovoid joint, when a convex surface
moves on a stable concave surface, the sliding of the convex articulating surface occurs in
the opposite direction to the motion of the bony lever” (Norkin & Levangie, 1992, p. 70).
Therefore, movement of the humeral head consists of a combined rolling and gliding
movement such that as the humerus moves in a superior direction as in abduction, the head of the humerus rolls superiorly and glides inferiorly.

The Elbow and Wrist Complexes

The elbow and wrist are not the main focus areas of this study, however they are important parts of the upper extremity chain and need to be discussed briefly. “The elbow is an anatomic linkage bridging the shoulder to the hand, acting both to enhance flexibility in hand placement and to transmit and absorb generated forces” (Steinberg & Plancher, 1995, p.306). There are four articulations that comprise this modified hinge joint: humeroulnar, humeroradial, and the superior and inferior radioulnar joints. The humeroulnar joint, because of its bony structural congruency, is considered to be one of the most stable joints in the human musculoskeletal system (Stroyan & Wilk, 1993).

During closed chain activities at the elbow, the humerus moves on the ulna and radius. The stability of the elbow arises from a combination of articulation of the ulna and humerus as well as ligamentous constraints (Steinberg & Plancher, 1995). The medial side of the elbow is supported by the medial collateral ligament. The lateral side of the elbow is supported by the lateral collateral ligament, the annular ligament, the accessory lateral collateral ligament, and the lateral ulnar collateral ligament.

“The wrist is an anatomic linkage bridging the hand to the forearm” (Steinberg & Plancher, 1995, p. 299). While the shoulder provides a dynamic base of support and the elbow and forearm adjust the approach of the hand, the wrist helps maintain length-tension relationships of the hand muscles and permits fine adjustment of the hand (Norkin & Levangie, 1992). The two compound joints that make up the wrist complex include the radiocarpal and the midcarpal joints. The radiocarpal joint consists of the distal
radius and radioulnar disk proximally and the scaphoid, lunate, and triquetrum distally. The midcarpal joint is formed by the scaphoid, lunate, and triquetrum proximally and the trapezium, trapezoid, capitate, and hamate distally. The distal ulna does not have a direct articulation with any of the carpal bones. It is separated from the carpal bones by a fibrocartilage disk called the triangular fibrocartilage or radioulnar disk. This disk originates from the ulnar notch of the radius, covers the distal end of the ulna, envelopes the ulnar styloid process, and continues distally to attach to the triquetrum, the hamate, and the base of the fifth metacarpal (Norkin & Levangie, 1992). The triangular fibrocartilage not only acts as a sling for the ulnar aspect of the carpus, but it also provides a cushion and stabilization to the distal radioulnar joint (Norkin & Levangie, 1992). Stability of the wrist occurs in the articulation of the distal carpal row (trapezium, trapezoid, capitate, and hamate) with the metacarpals, whereas mobility of the wrist occurs in the proximal carpal row. During closed chain movements the radius moves on the proximal carpal bones.

**Shoulder Musculature**

The muscles of the shoulder complex are numerous and of great importance to maintaining stability while providing mobility to the GH joint. "There are 26 muscles controlling the shoulder girdle; however, only one third are thought to play a significant role in dynamic stability of the glenohumeral joint" (Wilk & Arrigo, 1992, p. 339). In order to narrow the scope of this research only four of the 26 muscles were studied. The four muscles chosen include the teres minor, serratus anterior, latissimus dorsi, and pectoralis major (lower portion). These particular muscles were chosen because they are
superficial muscles, and play a significant role in maintaining shoulder girdle and GH stability.

Besides these four muscles the researchers also considered supraspinatus, infraspinatus, subscapularis, biceps, all three parts of the deltoid (anterior, middle, and posterior), all three parts of the trapezius (upper, middle, and lower), pectoralis minor, teres major, and the rhomboids. All of these muscles are also important in shoulder stability. However, the motor points could not be reached with surface electrodes, and/or the authors were forced to limit the scope of the study.

Teres Minor

Teres minor laterally rotates the GH joint and assists in adduction. In combination with the other rotator cuff muscles (infraspinatus, supraspinatus, and subscapularis), the teres minor helps in stabilizing the head of the humerus in the glenoid fossa during shoulder girdle movements (Kendall, McCreary, & Provance, 1993; Moore, 1992).

Serratus Anterior

With a fixed origin, serratus anterior acts to protract the scapula and helps in holding the medial border of the scapula against the thoracic wall. Because serratus anterior stabilizes the scapula, this muscle allows other muscles to use the scapula as a fixed point of pull to produce movement at the humerus. The serratus anterior can be separated into two parts: inferior fibers and superior fibers. The inferior fibers help to elevate the scapula when moving the arm above the head. The superior portion may assist in depressing the scapula. When the humerus is fixed in flexion and the hands are fixed at the distal end, serratus anterior acts to displace the thorax posteriorly. Examples
of this motion can be seen in various limb loading conditions such as a push-up and a press up. When used in rehabilitation these exercises recruit muscular activity in the serratus anterior, along with upper trapezius, levator scapula, and pectoralis minor (Wilk et al., 1996; Paine & Voight, 1993). If the insertion of serratus anterior is fixed (the scapula is stabilized in adduction by the rhomboids), it can assist in forced inspiration by elevating the ribs.

Latissimus Dorsi

The latissimus dorsi is helpful in performing activities when the body needs to be lifted toward fixed arms. This muscle is also important in performing forceful arm movements that are used for swimming, rowing, and chopping, and may act as an accessory muscle in respiration. When the origin of latissimus dorsi is fixed, it medially rotates, adducts, and extends the humerus. Latissimus dorsi can also depress the shoulder girdle and assist in lateral flexion of the trunk. When the insertion is fixed, latissimus dorsi can assist in tilting the pelvis anteriorly and contralaterally. “Acting bilaterally, this muscle assists in hyperextending the spine and anteriorly tilting the pelvis, or in flexing the spine, depending upon its relation to the axes of motion” (Kendall, 1993, p. 279).

Pectoralis Major

Pectoralis major consists of two parts. The upper fibers are responsible for flexing and medially rotating the GH joint and horizontally adducting the humerus towards the opposite shoulder when the origin is fixed. The lower fibers are involved in depressing the shoulder girdle, obliquely adducting the humerus toward the opposite iliac crest, and extending the humerus from a flexed position. If the insertion is fixed, pectoralis major might assist in elevating the thorax during forced inspiration and may
also assist in supporting the weight of the body during certain activities such as parallel-bar work or crutch walking.

**Electromyography**

**Electromyograph/Force Relationship**

Electromyography (EMG) is simply described as the "electrical manifestation of the contracting muscle" (Hillstrom & Triolo, 1995, p. 272). EMG represents the level of muscle activation at a given time. Leisman, Zenhausern, Ferentz, Tefera, & Zemcov (1995) state:

> The neural (re-)activation of a given muscle or groups of muscles can be a primary source of information for the therapist and patient in assessing clinical improvement. The control of a muscle’s electrical output by the subject may also be useful in developing a “muscle sense,” after which the attention may be shifted towards the training of more functional output, e.g., force, movement. (p. 963)

Only within the last few years have researchers begun to look at the EMG output of muscles during specific exercises. The goal of this latest research has been to determine how exercises specifically work certain muscles. According to Moseley, Jobe, Pink, Perry, & Tibone (1992),

> Most of the information available on how to exercise specific shoulder girdle muscles is based on anatomic knowledge rather than quantifiable data such as electromyography. This is particularly true of the scapular muscles. There are no studies that have quantifiably determined which exercises generate the greatest muscle activity for the vital and individualistic scapular muscles. (p.128-9)

Ballantyne et al. (1993) suggested that EMG clinical experience, knowledge of the functional anatomy, and biomechanics could help to establish exercise protocols with regard to the shoulder.
Surface Electrodes

Surface electrodes that are placed on top of the skin, overlying specific muscles, are typically used to record activity of muscles whose fibers are close to the skin surface. There are advantages and disadvantages to using this kind of electrode (Soderberg & Knutson, 1995). Comfort is probably the number one reason surface electrodes are used in research along with the fact that they are easy to apply.

Disadvantages also arise when considering the use of surface electrodes. If researchers are studying deep muscles, surface electrodes cannot be used since the activity of deep muscles will be covered up by the activity of the more superficial muscles. Another major disadvantage of using surface electrodes is the potential for 'cross talk' (Soderberg & Knutson, 1995; Perry, 1992). Cross talk is electrical activity coming from surrounding muscles and recorded at the electrode sight. This information can give researchers false readings of the muscle or muscles being recorded. Cross talk has been confirmed in studies using simultaneous wire and surface recordings. One study showed that the EMG activity recorded at the soleus by a surface electrode was 36% soleus activity and 64% cross talk or EMG output of other muscles (Perry, 1992). Perry (1992) believes that because of cross talk, surface electromyography should be limited to studying group muscle action.

Indwelling Electrodes

Indwelling electrodes are typically used to measure the EMG activity of small muscles or ones that lie deep to superficial muscles. Indwelling or fine wire electrodes can more easily record the activity of muscles that are adjacent to one another while eliminating most of the cross talk that can occur with the use of surface electrodes. A
review of the literature investigating EMG of the shoulder girdle suggested indwelling electrodes as the primary measuring tool (Jobe, Tibone, Perry, & Moynes, 1983; McCann, Wootten, Kadaba, & Bigliani, 1992; Ballantyne, O’Hare, Paschall, Pavia-Smith, Pitz, Gillon, & Soderberg, 1993; Kronberg & Brostrom, 1995; Glousman, Jobe, Tibone, Moynes, Antonelli, & Perry, 1998).

Although manageable with the proper equipment, there are some disadvantages to using indwelling electrodes (Hillstrom & Triolo, 1995). Discomfort felt by the subjects is a major disadvantage. Second, a question arises as to whether or not the sampling area (the area of the muscle where the indwelling electrode is placed) is representative of activity of the whole muscle. Thirdly, there is some increased risk of artifacts or “unwanted” noises occurring with the use of indwelling electrodes due to the conducting wires being exposed to the environment. Fourth, with extreme movement of the muscles surrounding the needle site, there is a chance of displacing the wire and therefore getting false readings. Indwelling electrodes were not chosen as a primary tool for this research due to these disadvantages.

**Normative Data**

One of the purposes of this study is to establish normative data regarding exercise on the Cuff Link, for female’s aged 18-28. This section of the literature review will provide a brief explanation of what normative data is and how it is used.

The purpose of normative research is to describe typical or standard values for characteristics of a given population (Portney & Watkins, 1993). The sample used to establish normative data should be large, random, and representative of a certain age group, sex, occupation, or disability. The large sample and repeated testing helps in
proving the reliability and validity of a normative study. Norms are usually expressed as an average, or mean, within a range of acceptable values (Portney & Watkins, 1993).

**Cuff Link**

The Cuff Link was developed by Brooks Millar and Don Walendzak and is manufactured and distributed by Integrated Functions. The inventors claim that the Cuff Link is a dynamic tool that enhances stability during closed chain upper extremity activities by strengthening the muscles of the shoulder complex and glenohumeral joint (Millar & Walendzak, 1997). This is a tool that can be used at any stage of the rehabilitation process. The inventors intentionally designed the Cuff Link to be used from initial rehabilitation of any population up to extreme strength demands of athletes at the end of their rehabilitation (B.M., personal communication, June 11, 1997). Increased muscular activity may occur by changing the amount of weight bearing through the shoulder. Millar and Walendzak (1997) have used the concept of dynamic stability to hypothesize what was happening to the body while performing exercises on the Cuff Link. The inventors believed that stabilization occurred through the shoulder complex and core (trunk), while also having motion through both. Since the invention of the Cuff Link no formal research has been performed to back up the inventors' claims that it increases muscular activity and in the end actually strengthens muscles. This lack of formal research supports the purpose of this study.

**Summary of Literature Review**

When reviewing the information on using open and closed kinetic chain concepts for treatment, it is obvious that both techniques have benefits and drawbacks. The original definitions proposed by Steindler (Steindler, 1977) are somewhat confusing,
however they do establish a basic framework when discussing treatment ideas. It has been suggested that CKC exercise provides significant benefits in physical therapy treatment, including joint congruency and stimulation of mechanoreceptors through weightbearing on the upper or lower extremities (Lephart & Henry, 1996). Weightbearing exercise on the upper extremity involves many joints that comprise the upper extremity kinetic chain. These joints, including the scapulothoracic, sternoclavicular, acromioclavicular, glenohumeral, elbow, and wrist were discussed previously in detail in this chapter for their role in CKC exercise.

The literature also revealed that the shoulder complex relies heavily upon muscle support for stability, particularly at the ST and GH joint. Approximately 26 muscles control the shoulder girdle, while only one third contribute significantly to the dynamic stability of the glenohumeral joint (Wilk & Arrigo, 1992). The muscles included in this literature review were chosen for their role in scapular or shoulder movements. The latissimus dorsi, teres minor, serratus anterior, and pectoralis major (lower portion) all affect UE movement. Although the researchers believe that many muscles contribute significantly to the stability and mobility of the GH joint, only four muscles were chosen for this initial investigation. These particular muscles were chosen because they are easily accessible to surface electrodes and play a significant role in maintaining shoulder girdle and GH stability.

The literature discusses the role of normative data and when it is appropriate for use. This proposed study fits well into that description, as it will develop a starting point for research on a new rehabilitation tool that currently has not established norms for muscle activity patterns. This rehabilitation tool, the Cuff link, was discussed and is
further described in more detail in chapter three. The application of how this piece of equipment can support CKC exercise should be clear at this point.

After reviewing the literature, it is clear that there are no research studies on upper extremity CKC exercise, and no research on the Cuff Link rehabilitation device. There were three purposes to this investigation. The primary purpose of this study was to examine the inventors’ claims that the Cuff Link significantly increased muscular activity about the shoulder. This claim was investigated through electromyography (EMG) of the latissimus dorsi, teres minor, pectoralis major, and serratus anterior while performing one exercise on the Cuff Link. The secondary purpose of this study was to evaluate and compare the level of muscle activation in the shoulder complex of normal subjects when performing one exercise on the Cuff Link apparatus. The levels of muscle activation while exercising on the Cuff Link for latissimus dorsi, teres minor, pectoralis major, and serratus anterior were compared to one another. The tertiary purpose was to produce normative data for females aged 18-28 years old regarding muscle activity while exercising in the push up position on the Cuff Link.
CHAPTER 3
METHODOLOGY

Study Design

This descriptive study was considered a quasi-experimental design, as the researchers did not utilize a control group. More specifically this research was based on Creswell's description of a one-shot case study. In a one-shot case study an experimental group is exposed to a single treatment followed by a measure (Creswell, 1996).

Independent variables, typically used in an experiment, are controlled by the researcher and usually result in changes in the dependent variable. The independent variable in this study was performing the exercise on the Cuff Link apparatus. For this research muscle activity, as measured by surface electromyography, served as the dependent variable.

The researchers used a two-way Analysis of Variance to compare the differences between two means. Further statistical analysis will be discussed in the Data Analysis section.

Subjects and Study Site

Forty-four female volunteers, between the ages of eighteen and twenty-eight (mean age = 22.6), were recruited from the student population at Grand Valley State University. Exclusion criteria included the following: (1) A current history of upper extremity, neck and/or back pathology, pathology that has persisted for over one year, or pathology for which the participant was required to seek medical attention within the last year, (2) those who
performed resisted upper extremity exercises more than three hours a week, (3) those participants with less than 175° of shoulder flexion and abduction, (4) those who did not have full elbow extension, (5) those who could not perform the exercise correctly within the allotted practice period, and (6) those who were unable to maintain a push-up position and weight shift from side to side for approximately thirty seconds.

Prior to obtaining subjects, the study was approved by the Human Subjects Review Board at Grand Valley State University. Informed consent (Appendix A) was obtained from every participant prior to testing. The study was conducted in the Physical Therapy Department at Grand Valley State University.

Instrumentation

The exercise instrument used in this study was the Cuff Link®, which is a metal circular shaped tube with a cross bar directly through the center of it (see Figure 1). There are three different pairs of handles that can be easily attached: the push up handles, the 45° handles, and the isolator handles (see Figure 2). Depending on the desired exercise, the

![Figure 1. The Cuff Link.](image1)

![Figure 2. (Left to right) Isolator handles, push up handles, 45° handles. (At top) Two inch and one inch hemispheres.](image2)

handles can be placed along any of the five holes that are on top of the cross bar. There is also an option to place only one handle directly in the center of the cross bar. The Cuff Link comes equipped with two different sized mobilization hemispheres, a one-inch hemisphere and a two-inch hemisphere (see figure 2). The hemisphere is screwed into a hole on the underside of the cross bar directly in the middle. The hemisphere provides the Cuff Link with an unstable base of support allowing the apparatus to move in a circular direction and thus increases the difficulty of exercise.

The electrodes used in this study were SnapEase brand, manufactured by Empi®. The electrodes were one inch, round, single patient use, non-sterile, reusable, self-adhering, snap connector electrodes. There were four dual lead electrodes and one grounding electrode (total of 9 electrodes) that led back to the Myosystem 1200 signal analyzer box®. From there, the EMG data were recorded, analyzed, and normalized by the Myosoft EMG Software®.

The hardware used for this study is a Zenith 486 computer with 66 MHz, a color monitor, and printer attachments.

Reliability and Validity

There are many factors that must be considered when using EMG including skin preparation, whether to use surface or indwelling electrodes, and issues concerning cross talk, artifacts, and spacing of electrodes. Other factors might include the depth of the muscle, the activity the individual engages in when recording data, the amount of subcutaneous tissue on an individual, and the type of software available to analyze the EMG results. These factors

* Empi, St. Paul, Minnesota 1997
* Noraxon, Scottsdale AZ
may affect the reliability and validity of EMG data. Soderberg and Knutson (1995) suggested that the size and type of electrode, the preparation of the recording site, the interelectrode spacing, and the standardized location of electrodes relative to anatomical landmarks are factors that must be considered to improve the reliability of the measure. Soderberg and Knutson (1995) also stated that anatomical variation within and between sexes is more difficult to assess and control. For this reason, only female subjects were used in this study. Across muscle comparisons and between-subject comparisons should be avoided due to differences in body tissues from one recording area to another and individual differences in body types (Soderberg & Knutson, 1995). To help make comparisons and to keep EMG as reliable as possible, all EMG data were normalized for each subject.

The researchers studied the operator's manual for the Noraxon unit and software extensively prior to initiating the procedure on actual participants. Repeated testing on four volunteers was used as a pilot study to ensure that the researchers were comfortable with handling the equipment and that the order of events and directions to the subjects was smooth and clear.

**Procedure**

The volunteers were a sample of convenience, recruited by word of mouth at Grand Valley State University. Data collection occurred in February 1998. When establishing an appointment time with possible subjects, the researchers asked subjects, either by phone or in person, to answer the questions on the subject information sheet (Appendix C). A phone screen helped to determine if subjects qualified for the study prior to initiating the testing session. Each subject was made aware that there was a possibility that she might not be selected for this particular study. The participant was
also told that if this does happen the researchers would be sure to explain why she was not selected. The researchers ensured that the volunteer knew exactly why she was not able to participate in this particular study and answered any questions that the volunteer might have had. However, only one subject was dismissed from the study after completing the subject information sheet (Appendix C) secondary to a recent injury. All subjects who qualified based on the phone interview were notified of dress requirements for the test session. Subjects were asked to wear a sports bra to expose the shoulder girdle muscles and non-slip shoes for safety while exercising on the Cuff Link.

At the beginning of the testing session, the subjects viewed a video demonstration of the testing procedure and received a written explanation of the purpose of the study (Appendix A). Participants then had the opportunity to sign informed consent (Appendix A) for participation in the study. After the participant gave informed consent, an upper quarter scan (Appendix B) was performed to identify upper extremity limitations that may have precluded participation in the study. Again, the researchers provided the participant with a detailed explanation if there was any reason why she could not complete the study.

Each subject was positioned in the push-up position on the Cuff Link. The researchers believed that the push up position would demonstrate the greatest degree of muscle activation due to the increased amount of weightbearing required in the UEs. The subject was instructed to maintain leg extension, a straight back, elbows locked in extension, and shoulders directly above their hands while holding onto the push up handles (see Fig. 3). The subject was parallel to the ground with the scapula in neutral position (neither protracted nor retracted). The push-up position required their feet to be
perpendicular to the floor; therefore their lower extremities were slightly elevated. The push up handles were in a perpendicular direction with respect to the crossbar. The above position was monitored throughout the exercise through observation and corrected through verbal cueing to make necessary changes.

Each subject was then instructed to practice maintaining the predetermined rotation velocity with the help of a metronome (Ballantyne et al., 1993). The metronome was set at a constant rate of 58 beats/minute. When the metronome beat, the subject attempted to contact the ground with the part of the Cuff Link underneath her dominant arm. This control of the velocity helped to ensure that participants exercised in a clockwise direction at a constant speed and thus avoided large differences in muscle activity. The subject was then allowed to practice, taking breaks when necessary to prevent fatigue, for a total of one and one-half minutes. All subjects were able to perform the exercise correctly and maintain the required velocity. The researchers used observation and verbal cueing to ensure that all subjects were able to perform the exercise correctly.

![Figure 3. Exercise test position.](image)
After the practice session, while the subjects rested, surface electrodes were placed on the dominant side of the body over the following four muscles: latissimus dorsi, teres minor, serratus anterior, and pectoralis major (sternal portion). The skin was prepared using the technique described by Bagg and Forrest (1986). The skin was gently rubbed with a 3M fine grain, finishing sander sheet followed by a skin cleansing with a cotton ball soaked in alcohol. Bagg and Forrest reported that this would keep the impedance level of the skin below 3000 ohms. Electrode placement was performed according to Introduction to Surface Electromyography for latissimus dorsi, serratus anterior, and pectoralis major (sternal portion) (Cram et al., 1998). The electrode placement for teres minor was placed according to The Anatomical Guide for the Electromyographer: The Limbs and Trunk (Perotto, 1994). Each muscle had two surface electrodes, spaced one cm apart, to record electrical activity (Basmajian & Deluca, 1985). The electrodes were placed parallel to the muscle fibers. A grounding electrode was placed on the acromion process of the shoulder being tested. The same tester applied the electrodes on all subjects to decrease intertester differences. To ensure proper contact of the electrodes to the skin, various half-inch wide strips of Johnson & Johnson, hypoallergenic clear tape was placed over the electrodes.

With the subject on a plinth, the first maximum voluntary isometric contraction (MVIC) muscle test (Kendall et al., 1993) was administered. Each MVIC was held for three seconds. The first MVIC was also used to ensure the electrodes were recording muscular activity. MVIC muscle tests were then performed one time on each muscle. After testing two subjects the researchers discontinued monitoring pectoralis major (sternal portion) due to equipment failure. This failure could not be corrected due to time
constraints. The mean peaks of the EMG readings were then recorded for serratus anterior, teres minor, and latissimus dorsi and used as the reference or the 100% value. The same consistent commands were given to each subject for each muscle test (Appendix G). The integrated EMG values for the levels of muscle activation during the Cuff Link exercise test session was normalized to the MVIC as a percentage. During the muscle test, the researcher assumed a position of mechanical advantage and did not break the subject's contraction or allow the subject to move the examiner.

The subject then assumed the four-point position for the exercise. When the examiners were ready, examiner #1 instructed the subject to “assume the push-up position” for exercise on the Cuff Link. The same examiner, then said “and...go”, and proceeded to monitor the subject's exercise position as well as their ability to stay consistent with the metronome set at 58 beats/min throughout the exercise.

The testing time for the exercise was ten seconds. This time span provided the researchers with enough data without causing fatigue in a subject. This also allowed the researchers to throw out the first and last movements of the exercise. Literature suggests that the initial movement pattern of an exercise can be an unreliable measure and should be excluded from usable data (Cram et al., 1998). The time span was monitored through the use of a stopwatch that counted down and sounded with an alarm when finished. At that time, the subject relaxed for approximately 15 seconds, while information was saved on the EMG system. The subject repeated this procedure for two additional trials. If for any reason the EMG signal did not record, the subject was given a fourth trial to record the needed data with the same verbal instructions.
While examiner #1 instructed the subjects on the proper exercise technique, examiner #2 manipulated the EMG software. When examiner #1 said, “assume the push-up position”, examiner #2 started the recording of the EMG output. When examiner #1 said, “and...go”, examiner #2 placed a marker on the data to signal the beginning of useable EMG information and stopped the EMG recording when the alarm sounded for the subject to stop exercising. A marker is a line placed by the computer to signal a particular section of the EMG recording. Markers can be placed at certain time intervals, or at the beginning and end of a time period depending on the needs of the researchers. Placing markers in this fashion allowed the examiners to use any EMG recorded within the ten-second period.

After all three trials of exercise were completed, examiner #2 manipulated the information in order to utilize the middle eight seconds of recorded EMG data. The researchers determined this time span would help eliminate initial exercise errors, as well as possible fatigue at the end of the ten seconds of exercise time.
CHAPTER 4
RESULTS/DATA ANALYSIS

Data Analysis

The researchers recorded the muscle output of serratus anterior, teres minor, and latissimus dorsi on 44 subjects. Data were recorded for pectoralis major on only two subjects due to equipment failure in one of the four channels that could not be repaired prior to the time period available for data collection. The collected EMG data were normalized for comparison between subjects. Current literature suggests that the preferred method normalizing data is to express the amount of muscle EMG output as a percentage of a reference value (Ballantyne et al., 1993; Moseley et al., 1992; Townsend et al., 1991; Bradley & Tibone, 1991; Kronberg & Brostrom, 1994; Glausman et al., 1988). The reference value was generated by the subject’s maximum voluntary isometric contraction (MVIC) during the performance of the manual muscle test for each muscle and represented their 100% value. The mean peak of the exercise was then recorded for each muscle during each trial. The percent MVIC was obtained by dividing the mean peak during the exercise by the mean peak for the MVIC, or manual muscle test, then multiplied by 100. The mean peaks for both the MVIC and exercise trials were entered into the Excel program and further analyzed by SPSS, a statistical software package.

Results

The mean %MVIC for serratus anterior, teres minor, and latissimus dorsi were, respectively: 19.3% (SD = 13.1%), 22.0% (SD = 15.7%), and 7.8% (SD = 6.2%) (see
Table 1). A two-way Analysis of Variance (ANOVA) revealed a significant difference, *p* < .05, between the mean %MVIC of all three muscles.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Mean</th>
<th>Median</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serratus Anterior</td>
<td>19.3%</td>
<td>17.1%</td>
<td>13.1%</td>
</tr>
<tr>
<td>Teres Minor</td>
<td>22.0%</td>
<td>18.9%</td>
<td>15.7%</td>
</tr>
<tr>
<td>Latissimus Dorsi</td>
<td>7.8%</td>
<td>5.9%</td>
<td>6.2%</td>
</tr>
</tbody>
</table>

To test the differences between %MVIC among the three muscles (serratus anterior, teres minor, and latissimus dorsi), a two-way ANOVA model as described below was used:

\[
\%\text{MVIC} = \text{Average Muscle} + \text{Person} + \text{Muscle} + \text{Person} \times \text{Muscle} + \text{Random Output (\(\mu V\)) Effect} + \text{Effect} + \text{Error}
\]

The two-way ANOVA model was used for its ability to compare two simultaneous independent variables. In this study the two independent variables were muscle and person. The subject (or person) effect was treated as a random effect component because each subject was randomly recruited based on inclusion criteria. The muscle effect was considered a fixed, or constant, effect as the researchers chose which specific muscles to investigate and kept this constant throughout the testing.

The analysis of this model showed a significant difference between muscles (*p* = 0.0001) using an alpha level (*α*) of 0.05. The analysis also showed an R-square value of 31.8%. This meant that 31.8% of the total %MVIC was explained by the muscle,
person, and muscle by person effects. Therefore, 68.2% of the total %MVIC was due to random error. Possible contributors to that random error will be discussed in Chapter 5. Although significance was shown, the basic assumptions of normality and constant variance of error terms were both violated (see Figures 4 and 5). Ideally, the standardized residuals on a normal probability plot should follow a linear path. This would show that the error terms are normal. Likewise, in an ideal residual plot, one would want the variance of the standardized residuals to be equal across the three muscle categories. Notice that the variability in latissimus dorsi is much less than the other two muscles (see Figure 5).

**Figure 4.** Normal probability plot for score/max. Plot used to examine the data for departures from normality. Optimally data for normal subjects should fall close to a straight line, unlike the data shown here.
To overcome the violations to normality and constant variance, the data were transformed using a -log (score/max) function. This is a monotonic function, which means that if significant differences between muscles are found in the transformed scores then significant differences between muscles also exist in the original data. Using a two-way ANOVA on the transformed data, a significant difference between muscles (p=0.0000, α=0.05) was found. The R-square value of the converted data was 49.5%. Therefore, 49.5% of the variation in the transformed %MVIC scores was explained by the muscle and person effects. The assumptions of normality and constant variances were then sufficiently satisfied (see Figures 6 and 7).
Figure 6. Normal probability plot for $-\log(\text{score}/\text{max})$. Plot to show normality of data following the determination of logarithms. These data better satisfies the first assumption of normality.

Figure 7. Residual plot for $-\log(\text{score}/\text{max})$. This figure shows equal variance among the data following the logarithm adjustments.

Overall, the results showed that the %MVIC was approximately the same for serratus anterior and teres minor, but significantly less for latissimus dorsi (see Figure 8).
Figure 8. Box and Whisker Plot diagram. Depicting the %MVIC output for the latissimus dorsi (lats), serratus anterior (sa), and teres minor (tm). These differences are shown as the mean (+ symbol on box), median (straight line in middle of box), standard deviation (horizontal line from edge of box to vertical line), and significant outliers (small boxes after standard deviation).
CHAPTER 5
DISCUSSION AND IMPLICATIONS

Discussion of Findings

The primary purpose of this study was to examine the inventors' claims that the Cuff Link significantly increased muscular activity about the shoulder. This claim was investigated through electromyography (EMG) of the latissimus dorsi, teres minor, pectoralis major, and serratus anterior while performing one exercise on the Cuff Link. The secondary purpose of this study was to evaluate and compare the level of muscle activation in the shoulder complex of normal subjects when performing one exercise on the Cuff Link apparatus. The levels of muscle activation while exercising on the Cuff Link for latissimus dorsi, teres minor, pectoralis major, and serratus anterior were compared to one another. The tertiary purpose was to produce normative data for females aged 18-28 years old regarding muscle activity while exercising in the push up position on the Cuff Link.

The most significant trend found in this research project was the difference between the muscular output in serratus anterior and teres minor compared to the muscular output in latissimus dorsi. This trend, the researchers feel, could be a result of many factors. The following discussion reviews these factors.

Teres minor was found to have had the highest mean value of muscular output acting at 22.0% of its MVIC. The main action of teres minor is to act as a lateral rotator
of the upper extremity. Other functions of this muscle are to stabilize the head of the humerus in the glenoid fossa and assist in adduction of the humerus. Stabilization of the humerus and arm adduction are believed to contribute to teres minor having the highest EMG output values found in this study. The push up exercise position forced the subject’s UE to remain in an adducted position in order to maintain control of the Cuff Link. This fact may have forced the teres minor to recruit more muscle fibers to keep the UE in the adducted position. Also, because the elbow was kept in an extended position while the shoulder complex was generating the motion involved in manipulating the Cuff Link, the teres minor was thought to have used its stabilization component in securing the head of the humerus.

Serratus anterior had the second highest significant mean muscular output, 19.3%, while exercising on the Cuff Link. This muscular activity was significant in that it was only a few percent less than the value obtained from teres minor. The main factor accounting for this increased value, was most likely the testing position. Each subject had to support the weight of her body while maintaining neutral scapular positioning. Therefore, the serratus anterior was more readily activated through the stabilization required at the scapula to maintain the exercise and scapular position.

Latissimus dorsi was the final muscle to be considered in this analysis of muscular output. The results showed that latissimus dorsi was acting at a mean average of 7.8% of its MVIC, which was significantly lower (approximately 12 to 13% points) than the other two muscles studied. One explanation for this low muscular output might have been the handle position chosen for the study. As mentioned before, the Cuff Link has five holes across the center cross bar in which the accessory handles can be placed. For this study
the middle holes were chosen to keep the UE slightly adducted and maintain a relatively narrow base of support for the subjects while exercising. When the origin is fixed the action of the latissimus dorsi is to medially rotate, adduct, and extend the humerus. The testing position provided a relative fixation of the origin in that the trunk was not actively moved throughout the exercise. Furthermore, the testing position did not require the shoulder to be in an extended position, but in a flexed position (90 degrees) and only slightly adducted. This may have also accounted for the low EMG values recorded for this particular muscle.

In the initial design of the study the researchers were attempting to look at a fourth muscle, the pectoralis major. After collecting data on two subjects, the researchers experienced technical difficulties with the first electrode lead and a reliable EMG signal could not be obtained. Of the four muscles being investigated, the researchers decided that pectoralis major was the most appropriate muscle to eliminate. This was based on the researchers' experience in clinical affiliations and the low census of patients with pectoralis major injuries.

The scope of the study was limited to the investigation of muscles that were accessible with surface electrodes. Initially the examiners set out to investigate eight muscles that all played a significant role in shoulder movement. This was not possible secondary to the majority of the muscles lying to deep beneath the skin and/or beneath other muscles. They were therefore inaccessible by surface electrodes without the potential for significant amounts of crosstalk.
Application to Practice

Although the Cuff Link is a new rehabilitation tool the researchers believe that it has potential, based on the results shown, to effectively work the serratus anterior and teres minor using this specific CKC exercise. Results of 19% and 22% MVIC does not show significant muscular activity and therefore may not be adequate for strength gains. However, low levels of exercise target tonic muscle stabilizers and thus may benefit patients in rehabilitation programs. Due to the amount of strength required to support weight on injured extremities, as suggested by Stone et al. (1994), weightbearing in specific CKC exercises should be performed in the later stages of rehabilitation. However, modifying the exercise used in the study by reducing the amount of weightbearing could allow for the safe use of the Cuff Link at a much earlier stage in the rehabilitation process.

Although the researchers did not investigate the effects of training on the Cuff Link on the core trunk, subjects reported increased abdominal use. If this holds true the Cuff Link could be used with traditional exercises to strengthen the trunk. The researchers also did not investigate the possible benefits of exercise on the Cuff Link for proprioceptive stimulation of mechanoreceptors. Some of these benefits might include decreased pain and decreased muscle guarding. Other benefits that might arise when exercising on the Cuff Link include: reestablishment of muscle synergy, co-contraction of muscles for joint stabilization, and cartilage regeneration.

Limitations

There were several limitations in this study. First, surface electrodes inherently increased the risk of obtaining crosstalk or "contaminated" data in any of the pairs of
electrodes. Thus, it is likely that crosstalk comprised the majority of the 52% error reported. Indwelling electrodes, might have minimized the crosstalk, however, due to the researchers’ skill levels this was not a viable option.

When using surface electrodes intratester reliability is also a factor, however this was not formally assessed. Therefore, the reliability of electrode placement from one subject to the next could be questioned. The researcher who applied the electrodes, however did follow the guidelines for electrode placement as outlined in the methodology section.

An additional point to consider when using surface electrodes is muscle differences between subjects. Because muscle size and position vary from individual to individual, the guides for electrode placement may not have been appropriate for all subjects.

Second, a sample of convenience was not optimal but was the best option due to the research environment. This type of sample has the potential to be biased, based on the principle of self-selection or those who offer themselves as subjects voluntarily. It is uncertain how much the outcomes from this study can be generalized to a greater population (Portney & Watkins, 1993).

Third, establishment of normative data usually requires a large sample size. As stated by Portney and Watkins (1993), “samples for normative studies must be large, random, and representative of the population’s heterogeneity.” The sample size was limited in this study due to time restrictions imposed on the researchers and malfunction of the EMG electrode leads. Because our subject pool was a small representation of Grand Valley State University, the researchers did not believe that 44 individuals was
sufficient to establish normative data. Our subject sample (n=44), consisted of 18-28 year old females with a mean age of 22.6. For this reason reporting the results as normative data may not be a reasonable assumption.

Fourth, subjects were monitored throughout the exercise period. However, it was difficult to ensure that each subject maintained a neutral scapular position, neither scapular protraction nor scapular retraction. The researcher monitored only obvious changes in the testing position and told subjects to correct their position. Even then it may have taken the subjects a fraction of a second to make the needed adjustments to their body position. The variations in scapular positioning might have been slight to the researchers eye, however, due to the limited time data were collected the muscular output might have increased or decreased dramatically and therefore may account for the varied EMG values.

Fifth, the data collected in this study may have been affected by an additional lead that was broken and repaired half way through data collection. This lead was checked numerous times prior to continuing with data collection. It was not possible to test the reliability of the EMG signal, only that the Myosoft analyzer box was receiving the signal. This might have contributed to the random error given in our results. However, the researchers feel that this contribution if present, was very minute.

Sixth, the researchers performed only one repetition of the manual muscle test or value used as the 100%. This was performed because the researchers were concerned about fatigue of the subjects. A more accurate approach might be to take multiple trials of the MVIC value and then average the results in order to more adequately represent a subject's true 100% value.
Seventh, the researches attempted to monitor the velocity of the exercise through the use of a metronome. The middle eight seconds of exercise data was used for analysis. Although the subjects began exercising in the same position, it is unsure whether all subjects finished the exercise in the same position. This is important because depending on the position of the dominant extremity during the exercise, muscle activation may vary considerably. For example, if a subject ended the eight second exercise time with the non dominant arm, the total average of mean EMG output would be different than the subject who ended the exercise time directly after the dominant arm contacted the ground.

Suggestions for Further Research

The Cuff Link is a new rehabilitation tool that needs to continue to be examined. If researchers have the capabilities, using indwelling electrodes would allow a more detailed study of the muscles about the shoulder. In the current study only three muscles were examined, and as stated by Wilk and Arrigo (1992), approximately nine muscles play a significant role in controlling the shoulder girdle.

A future research investigation could also include changing the position of the exercise to a lower level of weightbearing on the upper extremity. This could include standing with the Cuff Link on a table, and progressively moving the subject’s feet away from the table, then moving to a kneeling position, before ending up in the push up position. This way, researchers can look at muscle output and how it changes according to exercise position and the amount of weightbearing. A change in position could also effect which muscles are being activated.
Another research idea would be to change either the type of handle being used, the position of the handles in the crossbar, or both simultaneously. Again, this could not only change which muscles are firing, but how much they are firing.

It would also be interesting to examine the muscular activity of the abdominals and back extensors while exercising in a push up position on the Cuff Link. In this position the body requires an increased amount of stability in the trunk in order for the upper extremities to engage in this CKC exercise. Trunk stability is required for many types of daily activities and therefore would be of use to investigate.

Another idea to improve the surface electrode validity in this study might be to find the motor point for each muscle, using electrical stimulation, and placing the electrode directly over it. This would ensure that the surface electrodes are over the appropriate motor point and would thus account for muscle differences between subjects.

Conclusion

Injury to the shoulder occurs frequently and is therefore a target of many rehabilitation programs. This study examined a closed chain rehabilitation tool proposed to strengthen the shoulder complex. Through use of CKC exercise a patient can address many aspects required in the rehabilitation of shoulder pathologies including strengthening, stability, and proprioception (Tippett, 1992). It is hypothesized that closed chain activities address proprioceptive deficits through weightbearing which stimulates mechanoreceptors more readily than in OKC (Tippett, 1992). The Cuff Link is a tool that can provide patients with an opportunity to perform many CKC exercises as part of their rehabilitation program. However, it should not be thought of as the "cure all", but
instead as an additional tool that can be utilized by rehabilitation professionals in the treatment of their patients.
References


Appendix A

Patient Consent Form

This study investigates shoulder musculature activity while performing one exercise in a push up position on the Cuff Link. Muscle activity will be recorded by surface electrodes and analyzed by a computer software program.

Surface EMG is a noninvasive tool used to record electrical activity of muscles. This electrical activity is normally found in all human bodies and is elevated with an increase in movement of the body. Under no circumstances will the investigators be sending electrical current to the subjects’ bodies; EMG strictly measures existing electrical current in the body.

Subjects will not directly benefit from this study. However, it is reasonable to assume that if a large increase in muscular activity does in fact occur, the Cuff Link can become a valid choice in rehabilitation of the shoulder.

If questions arise concerning the purpose and/or methods used in this study, the investigators will be available throughout the entire testing session. The subject will be instructed that she is free to withdraw her consent and to discontinue participation in this study at any time.

I understand that this is a study of muscular activity of the shoulder during exercises performed on the Cuff Link and that the knowledge gained is expected to help rehabilitation professionals in designing an optimal program for treatment of shoulder injuries.

I also understand that:

1. Participation in this study will involve one 60 minute testing session regarding the recording of muscular activity about the shoulder.

2. I have been selected for this study because I am between the ages of 18-28, I do not have a history of upper extremity, neck, and/or back pathology that has persisted over one year or in which I was required to seek medical attention within the last year. I also do not perform resisted upper extremity exercises more than three hours per week, I am one of fifty (50) subjects, and I am female.

3. My skin will be prepared for electrode placement by using an abrasive pad and cotton swab soaked in alcohol.

4. It is not anticipated that this study will lead to physical and emotional risk to myself.
5. The information that I provide will be kept strictly confidential and the data will be coded so that identification of individual participants will not be possible.

6. A summary of the results will be made available to me upon my request.

7. There is a chance that I might not be able to complete this study due to guidelines set up by the researchers. If I am dismissed, I understand that the researchers will explain to me in detail the reason for my dismissal.

I acknowledge that:

“I have been given an opportunity to ask questions regarding this research study and that these questions have been answered to my satisfaction.”

“In giving my consent, I understand that my participation in this study is voluntary and that I may withdraw at any time without penalty.”

“I hereby authorize the investigators to release the information obtained in this study to scientific literature. I understand that I will not be identified by name.”

“I have been given Kathy Johnstone and Kathy Wagner’s phone numbers so that I may contact them at any time if I have questions.”

“I acknowledge that I have read and understand the above information, and that I agree to participate in this study.”

_________________________  ___________________________
Witness                          Participant’s Signature

_________________________  ___________________________
Date                          Date

____ I am interested in receiving a summary of the study results (please address envelope).

If you have any questions or concerns regarding the procedure done today, please feel free to contact us at:
Kathy Johnstone   (616) 531-7183
Kathy Wagner       (616) 892-6827

You can also contact Arthur Schwarcz, thesis chairperson, professor in the Physical Therapy Department at Grand Valley State University at (616) 895-2675 or 895-3356.

If you have any questions regarding the rights of participants please contact Paul Huizenga, Chair of Human Subject Review Committee at Grand Valley State University, at: (616) 895-2472.
Appendix B

Upper Quarter Scan

OBSERVATION/INSPECTION
- posture
- scapular positioning

JOINT SCAN
- cervical ROM-active
- shoulder girdle ROM-active with overpressure
- elbow and forearm joint ROM-active with overpressure
- wrist/hand ROM-active with overpressure
- wrist flexion/extension
- gross grip strength
Appendix C

Subject Information Sheet

Name: __________________ Subject Number: ______________

Age: ______

Do you exercise more than three hours per week? ______ What does your exercise program consist of?_____________________________________________________

Have you experienced a problem with your shoulders, neck, elbow, wrist/hand, and/or back? Yes__ No__ If yes, how long ago?_____________. Please explain: ______

_______________________________________________________________

Can you maintain a push-up position and shift your weight from side to side for approximately thirty seconds? Yes_____ No_____ Not sure______

Do you have any heart conditions that limit your ability to exercise? ________ If yes, please explain: _________________________________

_______________________________________________________________

Do you have any circulation problems that may limit your ability to exercise?______ If yes, please explain: _________________________________

_______________________________________________________________

Do you have any problems with sensation?______ If yes, please explain location and type:____________________________________

_______________________________________________________________

Do you have any joint problems or conditions that limit your ability to exercise?______ If yes, please explain: ____________________________

_______________________________________________________________
Appendix D

Muscle Recording Sheet

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<th>subject number</th>
<th>side tested</th>
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<table>
<thead>
<tr>
<th></th>
<th>Pectoralis Major</th>
<th>Serratus Anterior</th>
<th>Teres Minor</th>
<th>Latissimus Dorsi</th>
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<tr>
<td>MVIC (mean peak)</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Trial 1</td>
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<td>Trial 3</td>
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<tr>
<td>Mean muscle activity</td>
<td></td>
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<tr>
<td>% of MVIC</td>
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### Appendix E

**Daily Subject Appointment Sheet**

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<th>Name:</th>
<th>Date:</th>
<th>Appt time:</th>
<th>Phone interview: Yes or No</th>
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</table>
Appendix F

Contact Numbers

If you have any questions or concerns regarding the procedure done today, please feel free to contact us at:
Kathy Johnstone (616) 531-7183
Kathy Wagner (616) 892-6827

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Appendix G

Commands for Manual Muscle Testing

I am going to place your arm in the position in which I need it for the muscle test. When my thesis partner says go, I will try to move your arm. Don’t let me do that. My thesis partner will also say stop, at that time try to relax as much as possible. Understand what we want you to do?