EFFICACY OF THE SHARQ® SHOULD AND ROTATOR CUFF STRETCHING MACHINE FOR INCREASING INTERNAL AND EXTERNAL ROTATION

By

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The members of the Committee appointed to examine the thesis of MATTHEW D. ALBRIGHT find it satisfactory and recommend that it be accepted.

___________________________________
Chair

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EFFICACY OF THE SHARQ® SHOULDER AND ROTATOR CUFF STRETCHING MACHINE FOR INCREASING INTERNAL AND EXTERNAL ROTATION

Abstract

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Background and Purpose. To date, limited information exists regarding the effectiveness of the SHARQ® shoulder and rotator cuff stretching machine (SHARQ®) for increasing internal and external shoulder range of motion (ROM). The purpose of this study was to determine if a 15-day training period using the SHARQ® would be more effective in increasing internal and external shoulder ROM than a traditional passive static stretching protocol. Subjects. Fifteen subjects (14 females, 1 male), ages 23-60 yrs., with no significant history of pathology of the shoulder, were randomly assigned to one of three groups: 1) control, which did not receive a stretch training, 2) traditional towel stretch training and, 3) SHARQ® stretch training. Methods. Treatment groups participated in one stretching session, with eight trials, per day consisting of alternating internal and external shoulder rotation with 30-second rest intervals between stretches. Internal and external shoulder ROM were measured with a goniometer pre-, mid-, and post-training. Data were analyzed with a two-factor (group and time) analysis of variance with repeated measures on one factor (time). Internal and external ROM were also measured daily during stretching sessions, only for the SHARQ® group. These data were analyzed with a multiple regression for linear trends with dependant variables time and day. Results. Increases in shoulder internal and external rotation did not differ significantly between the traditional towel
and SHARQ® training groups. ROM significantly increased over time in all groups. Significant linear trends were also identified for increased internal and external ROM within daily training sessions and for internal ROM throughout the three-week training period in the SHARQ® training group. **Discussion and Conclusion.** This study using a small sample of healthy subjects provides preliminary evidence indicating the efficacy of the SHARQ® for increasing shoulder ROM. Although the SHARQ® protocol was not more effective in increasing ROM of the shoulder than the traditional passive static stretching protocol, the results indicated that the SHARQ® protocol used herein produced increases in ROM similar to that of traditional towel stretching. Future studies on the efficacy of SHARQ® stretch training using clinical populations are warranted.

**Key Words:** passive static stretching, traditional towel stretch training, SHARQ® stretch training
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CHAPTER ONE

INTRODUCTION

Decreased range of motion (ROM) of the shoulder rotator cuff muscles results from a variety of conditions including: physical inactivity, injury, surgical intervention, overuse, and deformity. Physical therapy intervention is often used to restore normal mobility to the shoulder to increase muscle flexibility. Improved muscle flexibility allows muscle tissue to accommodate imposed stress more easily and facilitates efficient and effective movement (4). Many stretching advocates believe that more efficient and effective movement due to enhanced muscle flexibility will help prevent or minimize injuries and will enhance physical performance (2, 3, 6, 7, 9).

There are several stretching methods used to increase the rotator cuff muscle group flexibility and shoulder ROM. Passive rotational static stretch is among the most frequently used stretching methods. The objective of passive rotational static stretch therapy is elongation of shortened muscle fibers and connective tissues that limit ROM of the rotator cuff muscles. Tissue elongation with passive rotational static stretch leads to increased ROM around the joint and improved muscle flexibility (26).

The SHARQ® shoulder and rotator cuff stretching machine (SHARQ®) is a newly designed machine that provides an alternative method for increasing rotator cuff muscle group flexibility. The SHARQ® utilizes the principles of passive rotational static stretching and limb isolation/orientation. To use the SHARQ®, an individual must first adjust the seat height in order for their shoulder to be properly aligned with the machine's shoulder cuff. The arm is then placed in the machine at a vertical abduction of 90° with an elbow flexion of 90°. In this position, the arm is then mobilized with forearm and upper arm cuffs. The shoulder is held into place with an inflatable bladder to prevent anterior or posterior translation. With the arm secure
and in the proper alignment, the individual then rotates the accompanying flywheel, on the opposite side of the machine, to initiate internal or external passive static stretching of the shoulder. The SHARQ® arm assembly completely rotates to facilitate rotation of the right or left shoulder. The SHARQ® is very easy to use. After an initial introductory stretching period with verbal feedback by an instructor, the individual can then stretch without a need for continual supervision or assistance.

Individuals with limited internal and external rotator cuff ROM would clearly benefit from frequent passive static stretching of this muscle group. To properly stretch the rotator cuff muscle group, the shoulder must be rotated with the arm abducted at a 90° angle. This position is not easily self-maintained during shoulder rotation and under most circumstances, the muscles of the shoulder must be contracted to hold this position. If a contraction takes place during the stretch than the benefits of the passive static stretch are negated. The SHARQ® shoulder and rotator cuff stretching machine allows the user to completely control the positioning of the stretch applied to the shoulder. It also allows the individual to isolate the shoulder without strain for internal and external passive static stretching.

According to empirical evidence, stretching with the SHARQ® may be a beneficial alternative to the more traditional stretching techniques. But, to date, there have not been any controlled experimental studies designed to examine the effects of SHARQ® stretching on increasing internal and external shoulder flexibility.

**Statement of Problem**

The principle of specificity of training states that the benefits of training are specific to the muscles used and to the anatomical position and ROM in which they are used (26). Lack of
flexibility, ROM, or muscle tightness is thought to make one more prone to injury. In the case of the shoulder, limited ROM can also make normal movement difficult. When the arm is moved into positions that exceed the shoulder's ROM, it damages the connective tissue of the rotator cuff, joint capsule, associated muscles, or tendons (26). If the shoulder is continually subjected to movement that exceeds its ROM, healing is impaired, and in turn, the likelihood of further damage to the shoulder increases (26).

Those individuals with limited internal and external rotator cuff ROM would clearly benefit from frequent passive static stretching in a position of shoulder rotation (26). It is extremely difficult to comfortably and properly stretch the shoulder into internal and external rotation with the arm abducted. The current available methods to achieve optimum improved shoulder rotation flexibility are limited to assistance from another person, hanging the arm in a rotated position with a weight, stretching the shoulder rotators with a stretching stick, or reaching behind the back with a towel grasped between the hands. All of these methods have limitations. With assisted stretching, the assistant must be careful not to over-stretch the shoulder, possibly injuring the shoulder or limiting gains in muscle flexibility. It is difficult for the individual being stretched to convey to another person to what point their shoulder should be stretched. Weight-assisted stretching often times elicits further damage because the muscle group is stretched past functional rotational flexibility due to improper selection of weight or improper technique. Stick and towel stretching require a minimum amount of shoulder flexibility just to attain the starting position. Most individuals undergoing rehabilitation for a shoulder injury cannot reach the initial starting position with a stick or towel. The SHARQ® shoulder and rotator cuff stretching machine eliminates the above problems by allowing the user to completely control the
positioning of the stretch applied to the shoulder. It also allows the individual to isolate the shoulder without strain for internal and external passive static stretching.

**Hypothesis**

A three-week flexibility training protocol using the SHARQ® shoulder and rotator cuff machine will result in significantly greater increases in internal and external shoulder range of motion than traditional passive static stretching.

**Delimitations**

The results of this study are limited to healthy individuals between the ages of 18 and 60 who do not present with a significant history of pathology of the shoulder.

**Limitations**

This study was limited by the number of individuals that participated in the study due to recruitment complications. This study was also limited by the ability to accurately measure ROM from hand goniometer measurement.
CHAPTER TWO
REVIEW OF LITERATURE

The Rotator Cuff and Range of Motion

When the rotator cuff muscles of the shoulder are injured often times this leads to decreases in internal and external range of motion (ROM). Under normal circumstances, physical therapy that incorporates some type of stretching regime is chosen to increase shoulder flexibility. The benefits of increased ROM include prevention or minimization of further injury, decreased muscle soreness, and enhanced physical performance (2, 3, 6, 7, 9). Increased muscle flexibility with stretch training may result from increases in musculotendinous length (20, 23), increased stretch tolerance (15, 16, 18, 19), alteration of muscle stiffness (12), and viscoelastic stress relaxation (10) (24, 32-34). This review will focus on the stretching technique utilizing passive rotational static stretch therapy. The main objective of passive rotational static stretch therapy is to elongate shortened muscle fibers and connective tissues that limit ROM of the rotator cuff muscles thereby increasing ROM around the joint and augmenting muscle flexibility.

The Rotator Cuff of the Shoulder

The rotator cuff is composed of four muscles: the supraspinatus, infraspinatus, teres minor, and subscapularis (13). Their tendons form a collagenous cuff around the most freely moving joint in the human body, the glenohumeral joint (13). The subscapularis facilitates internal rotation, while the infraspinatus, teres minor, and supraspinatus muscles assist in external rotation. The rotator cuff muscles depress the humeral head against the glenoid fossa. With a poorly functioning rotator cuff, the humeral head can migrate upward within the joint
because of an opposed action of the deltoid muscle. This can lead to less than normal ROM in both internal and external rotation. The rotator cuff muscles also have bursae that cushion their movement over bony articulations. The active range of shoulder joint motion is 0-90 degrees for both internal and external rotation (1, 13).

Stabilization of the Glenohumeral Joint and Rotator Cuff Loading

The muscles of the rotator cuff serve an important role in stabilizing the humerus in the glenoid fossa against the contractions of muscles that could otherwise dislocate the joint. For example, when the arm is abducted, the rotator cuff muscles counteract the deltoid by producing an opposite, downward shear force. The amount of force sustained at a particular joint of the body is referred to as joint loading (13). The glenohumeral joint sustains the most loads of all shoulder articulations because it provides direct mechanical support for the weight of the arm. Therefore, the greater the degree of internal or external shoulder rotation the greater the amount of load placed on the joint and musculature. During most rotational movements the arm is not fully extended. Rotational movement with the arm flexed at the elbow reduces the load on the joint; therefore, the joint is less susceptible to injury as compared with a fully extended arm.

Common Rotator Cuff Injuries

Shoulder injuries make up 8%-13% of all sports-related injuries (27). Shoulder injuries are classified as either traumatic injuries or overuse injuries and include dislocations, rotator cuff damage, and rotational injuries.

The glenohumeral joint has a loose structure that allows for mobility but little stability (13). Instability can lead to shoulder dislocation due to external forces on the shoulder that can
stretch the surrounding collagenous tissues beyond their elastic limits. Dislocations can occur in anterior, posterior, and inferior directions. Predisposition for dislocation can be due to inadequate size of the glenoid fossa, deficits in rotator cuff muscles, inadequate retroversion of the humeral head, capsular laxity, or anterior tilt of the glenoid fossa (37). Many times glenohumeral dislocations predispose an individual for future problems.

Forceful overhead arm abduction or flexion movements along with medial rotation can cause rotator cuff damage, such as rotator cuff impingement and shoulder impingement syndrome (26). Signs and symptoms of impingement are identified by hypermobility of the anterior shoulder capsule, hypomobility of the posterior capsule, excessive external rotation with limited internal rotation of the humerus, and/or laxity of the joint itself (37). The supraspinatus muscle is most commonly involved in impingements because its blood supply is the most susceptible to being limited by injury and subsequent local swelling. Inadequate blood supply to the injured area can lead to a longer recovery period. Signs and symptoms of impingement include tenderness and pain in the shoulder region when the humerus is rotated. Two mechanisms have been proposed to explain the biomechanical processes that cause rotator cuff problems, these mechanisms are known as the impingement and alternative theories (13). The impingement theory states that each time the arm is abducted the rotator cuff and associated bursa are pinched between the acromion, the acromioclavicular ligament, and the humeral head (13). Pinching the cuff and bursa leads to friction causing irritation and excessive wear. The alternative theory states that when the supraspinatus muscle-tendon unit is repeatedly overstretched, capsular laxity follows and the deltoid muscles become over utilized. Excessive use of the deltoid muscles elevates the humeral head during abduction and leads to impingement (13). Repeated, forceful rotation of the shoulder can lead to tearing of the rotator cuff muscles.
(13). These tears are normally located in the supraspinatus, and are due to the tension exerted by the deceleration of a high force rotational movement. Insufficient recovery time, ineffective rehabilitation, and chronic pain can lead to calcifications of the soft tissues of the joint, degenerative changes in the articulating surfaces, or bursitis (27).

**Range of Motion and Stretching to Increase Range of Motion**

ROM at anatomical joints is determined by unalterable and alterable factors (26). Unalterable factors include bone structure, age, and gender. Alterable characteristics include muscle and tendon length, surrounding facial sheath thickness, the tightness of the joint capsule and ligamentous structures surrounding the joint, the anatomical shape of articulating surfaces, the amount of fat, and skin tightness. The muscles, tendons, and surrounding facial sheaths are most often responsible for limiting ROM. A lack of shoulder activity due to injury, surgical intervention, or failure to use full ROM during daily activities can lead to shortening of connective tissue or muscle. Local injury can lead to pain, swelling, muscle spasm, and improper use of the muscle during injury recovery. Surgical intervention can lead to complete immobilization of ligaments and joint capsules that lose elasticity due to shortening. If the injury is not treated properly, deformity can occur leading to a decrease in ROM.

Clinical settings utilize different rehabilitation techniques for improving ROM of the rotator cuff muscles. Some examples are: joint mobilization and traction, strengthening exercises, and stretching routines. Of these, stretching receives the greatest emphasis for increasing restricted ROM (26). Stretching is utilized to increase the length of the musculotendinous unit and increase elastic properties of the muscle. There are currently three different stretching techniques: ballistic, proprioceptive neuromuscular facilitation (PNF), and
static stretching. Ballistic stretching incorporates a bouncing motion in which repetitive contractions of the agonist muscle are used to produce quick stretches of the antagonist muscle (muscle being stretched in response to contraction of the agonist muscle) (26). Ballistic stretching has not been supported in literature because it creates uncontrolled forces within the muscle that can exceed the extensibility limits of the muscle fiber and possibly produce microtears within the musculotendinous unit (2, 3). Proprioceptive neuromuscular facilitation (PNF) stretching involves some combination of alternating isometric or isotonic contractions and relaxation of both agonist (muscle that contracts to produce a movement) and antagonist muscles (26). Several authors identify PNF techniques as being superior to other stretching methods. PNF stretching normally requires training and practice to insure proper technique, which limits its suitability for independent and non-supervised stretching (3). Static stretching is one of the most widely used methods for increasing ROM because of the simplicity of execution and lower potential for tissue trauma (3, 28). According to Smith (31), this type of stretching has the least associated injury risk and is believed to be the safest and most frequent method of stretching. Static stretching, either active or passive, consists of a 30 second hold to discomfort of the antagonist muscle (3). Benefits of this slower stretching technique include prevention of the tissue from having to absorb great amounts of energy per unit time, non-elicitation of forceful reflex contractions, and alleviation of muscle soreness (4). Active static stretching uses a contraction of the agonist muscle to place the antagonist muscle in a position of stretch. Passive static stretching in which skeletal muscle remains relaxed, utilizes body weight, a partner, or equipment to facilitate stretching. Passive static stretch is the most commonly used procedure, and it is less prone to cause injury than ballistic stretching (26). Static stretching is also much
less complicated than PNF stretching because it only involves the stretch of the antagonist muscle and has only one specified stretching period per set.

**Passive Stretch for Rehabilitation**

Passive static stretching is utilized in clinical settings as an effective way to gain increased mobility around the shoulder joint and increase shoulder range of motion (25). The tissue response to the strain of passive stretch is very complex. Several structures contribute to the relationship between the passive stretch and the muscle-tendon unit. These include: the connective tissue (epimysium, perimysium, and endomysium), the sarcolemma, the muscle fiber contents, the tendons, the adhesion to adjoining structures, and the friction of the shoulder joint (11). These structures influence the passive length-tension changes of the muscle-tendon unit due to the force of stretch (11). Although the relative contribution of each of these structures is not known specifically, these biomechanical aspects do facilitate and resist the stretch. A proper balance in facilitation and resistance can lead to positive rehabilitation results.

When a muscle is passively stretched, the force is transmitted from the perimysium and endomysium of the connective tissue to the muscle fiber (25). In order to facilitate this force load, properties of the muscle such as stretch tolerance or sarcomere length must change (17, 25). A change is stretch tolerance is considered an acute change whereas a change in sarcomere length would be labeled a chronic change. Acutely, a single session of passive stretch (30 seconds) has been shown to increase muscle mobility (3, 18). This acute change from only one stretching session is temporary and the muscle has been shown to return to pre-stretch status one hour post-stretch (17). This is most likely attributed to a change in stretch tolerance during this acute stretching session. In response to chronic stretching, it is believed that the muscle actually
becomes longer by adding sarcomeres in series (8, 26). The greater the force load of the stretch on the muscle, the greater the stimulus for the muscle to undergo myofibrillogenesis. Investigators have shown that this chronic change can be attained following a 3-week stretching program where stretching is done 3-5 times per week to improve muscle flexibility (13, 14, 34, 36). Chronic ROM maintenance after weekly repetitive sessions of passive stretch can be sustained for up to two weeks even after a specific rehabilitation protocol has stopped (3, 39). Unfortunately, after this two-week period, clinical observation indicates that patients who stop a stretching program lose ROM (38, 39). In order to maintain chronic increases in muscle flexibility, passive stretching activities must be performed at least once a week following stretch training (3, 13, 17, 18, 22, 26, 32, 36).

There are a number of different muscle-tendon system facilitation properties that allow the acute strain of passive stretch to increase ROM about a joint. When muscles undergo passive stretch, they react viscoelastically and will deform according to their own material properties. Viscous behavior is the property of a structure to elongate when a load is applied, but the elongation is rate change dependent (18, 32). Elasticity refers to the property of a structure to elongate when a force is applied, and to return to its original length when the force is taken away (10, 30). Due to these properties, elongation of a muscle is determined by the exerted force and force rate (11).

When the muscle-tendon system is stretched to a fixed length in succession, the acting force and passive tension at that length decreases over time (21). This force decrease has been reported in vitro (29, 32). For example, while investigating the behavior of the muscle-tendon unit when exposed to repeated stretch to a constant length, Taylor et al. (32) showed a significantly reduced peak tension the first four of ten stretches. In cases when force is relatively
low and sustained for periods of time (30 seconds), tissue deformation is based on a time-
dependent principle called "creep" (3, 17, 18, 22). Creep is the behavior of a structure under a
fixed force when that force is either held or reached successively in a cyclic manner (29, 32).
When this force is applied, the structure becomes deformed and asymptotically approaches a
new length based on the viscoelastic elements of the muscle (32). The longer the period of time
of the stretch, the more deformation occurs. When low force is released the tissue will return to
its original length in a time-dependent manner. The muscle does not quickly return to its
previous position after a stretch is released, rather return to original length is controlled and slow
in order to avoid injury. Muscles also display stretch characteristics of "force-relaxation" and
"hysteresis". Force-relaxation is the amount of stress at a given muscle length that gradually
declines when the stretch is held (32). When a stretch is sustained over time, the internal muscle
stress decreases and a lower amount of force is needed to maintain a tissue at a set amount of
displacement or deformation. Hysteresis is the variation in the load-deformation relationship
that takes place between initiation and release of the stretch (32). In the muscle, greater energy
is absorbed during initiation than is dissipated during release of the stretch (32). The greater the
difference between the absorbed energy during initiation and the dissipated energy during
release, the greater the hysteresis value.

An important factor in acute stretch facilitation is stretch tolerance. Halbertsma et al.
(11) suggest that stretch tolerance in fact functions as pain tolerance. Increased ROM after acute
stretching may not be due to changes in the structure of the muscle or connective tissue, but
possibly an increase in the tolerance to stretch/pain (10, 18). It has been theorized that passive
stretch may alter the muscle spindle (Ia and IIa afferents) and the Golgi tendon organ (Ib
afferents) outputs to the central nervous system (25, 26). Within the central nervous system
there are mechanoreceptors located within the muscle that sense the muscle stress of stretch. The muscle spindles are the initiators of the stretch response. When a change in muscle length is sensed, muscle contraction reflex is initiated to resist the stretch and prevent muscle damage. The Golgi tendon organs are the secondary messengers in response to tension. When muscle strain of a stretch elicits a greater response the Golgi tendon organs will negate the signaling of the spindles and initiate a reflex relaxation of the antagonist. Reflex relaxation facilitates the stretch by allowing the muscle to lengthen through relaxation without exceeding the extensibility limits that could damage the muscle fiber (35). A change in stretch tolerance due to passive stretch in afferent drive could influence the activity of the alpha motoneurons. A dampening of muscle spindles or accentuation of the Golgi tendon organ could facilitate the stretching process. These central nervous system influences are effective in producing a stretch tolerance in passively stretched muscle leading to an increase in ROM (18).

Other characteristics of muscle are its ability to resist stretch and protect against damage that could lead to injury during stretch (26). Both muscle and tendon are composed largely of noncontractile collagen and elastin fibers. Collagen is a major structural protein that forms strong, flexible, inelastic structures that hold connective tissue together (26). Collagen is a load-bearing element that resists mechanical forces and deformation. Depending upon its direction of orientation, collagen accommodates tensile force, but not shear or compressive forces. Elastin fibers are highly elastic tissues that assist in the recovery from deformation. Unlike tendon, muscle also has active contractile components that make up the muscle fiber itself. An important determinant of the elastic property of a given muscle fiber is titin. Titin is found in the sarcomere of striated muscle and forms a scaffolding of elastic fibers that are important for correct assembly of the sarcomere. Each titin molecule spans from M line to Z disc. The elastic
properties of this protein help facilitate passive resistance of the muscle fiber to stretch. These elements determine the muscle and tendon capability to resist and recover from the strain of passive stretch. The amount of their individual contribution in resisting deformation depends on the degree that the muscle is lengthened and the velocity of stretch. The noncontractile components are primarily resistant to the degree of lengthening, while the contractile elements limit high-velocity deformation. An example of high-velocity deformation would be ballistic stretching. The greater the stretch, the larger amount the noncontractile components contribute. The faster the stretch, the more the contractile components contribute.

**Passive Static Stretching Efficiency and Effectiveness**

As described above, increases in range of motion following passive static stretching results from a combination of biomechanical, neurological, and cellular mechanisms. The ongoing study of these mechanisms, through experimental investigation, continues to be emphasized in order to determine the specific tissue response to passive static stretching. In the clinical setting, investigators continue to explore ways to more efficiently and effectively use passive static stretching to increase joint ROM. As with any other mode of rehabilitation, the efficiency and effectiveness of stretching are based upon frequency, duration, and intensity.

Frequency of stretching is based upon the number of sessions per week and the number of stretches in a session. It has been shown that stretching performed 3-5 times per week for three weeks significantly improves flexibility (13, 26, 36). Bandy and Irion (3) concluded that there is no difference in improvement of ROM between protocols requiring one versus three stretches a day. McNair et al. (22) reported that there was no statistical significance between the
changes in muscle stiffness, tension, and force relaxation for three different daily frequencies (4, 2, 1) of passive static stretch with constant duration.

Duration of stretching refers to a specific stretching trial or the length of time it takes to significantly report acute increases in ROM or long-term tissue physiology changes. Currently, clinical investigators agree that the suggested time for enhancing muscle flexibility for a specific session is 30-60 seconds (3-5, 17, 18, 22, 32). The duration of stretching for long-term changes remains unknown at this point and time.

The intensity of passive static stretching has been universally accepted to be a slow, passive movement until mild discomfort is felt (13, 26). Limited research exists regarding the rate of passive stretch. Few studies have been conducted on the intensity of discomfort of stretch due to the individualistic rating of this perceived stress. Static stretching protocols used for the purposes of rehabilitation vary with the unique needs of each patient. Although consistent findings in the literature support the implementation of static stretching to increase ROM, benefits based upon an optimal protocol for frequency, duration, and intensity is not known.

Few research investigations have focused on the efficacy of passive stretching and shoulder ROM. The majority of stretching studies focus on lower body joints, such as the hip and knee. Notably, in comparison to the shoulder, the joint ROM at the hip and knee have small intra- and inter-subject variance (1). Due to the complex physiological structure of the shoulder joint, ROM measurements can be highly variable even in a healthy populace. This makes it much more difficult for investigators to prove significance of stretch training. This limited research leads to the acceptance of less effective stretching protocols and inefficient shoulder ROM rehabilitation stretch training sessions. Therefore, individuals with limited internal and external rotator cuff ROM would clearly benefit from a controlled experimental study designed
to examine the effects of SHARQ® stretching on increasing internal and external shoulder flexibility.
CHAPTER THREE
METHODS AND PROCEDURES

Research Design

The effects of 15 days of chronic passive static stretching on the internal and external rotator cuff ROM of the shoulder were examined using a randomized design. Subjects were randomly assigned to one of three separate groups consisting of five individuals per group: 1) control, 2) traditional stretching protocol, or 3) stretching using the SHARQ® shoulder and rotator cuff stretching machine. The control group had no change in current active daily living activities (ADLs). The traditional stretch group underwent a traditional, individualistic, static stretch exercise for both external and internal rotation of the shoulder to mild discomfort. The traditional stretch consisted of "towel pulls". For external rotation, test subjects held a towel in the hand of the shoulder being stretched while standing. They then tossed the towel over the shoulder to be stretched, not letting go, and reached behind the back, below the shoulder, with the other hand and grabbed the other end of the towel. With each hand holding each end of the towel, the towel was pulled down to mild discomfort. For internal rotation, test subjects held the towel in the hand of the shoulder not being stretched while standing. They then tossed the towel over the shoulder not being stretched, not letting go, and reached behind the back with the other hand, below the shoulder, and grabbed the other end of the towel. With each hand holding each end of the towel, the towel was pulled up to mild discomfort. The SHARQ® group underwent a passive static stretch for both external and internal rotation of the shoulder to mild discomfort using the SHARQ® shoulder and rotator cuff stretching machine.
Selection of Subjects

Subjects (n=15) were recruited from the WSU Spokane health sciences community via posters and faculty recruitment. Subjects were required to be between the ages of 18 and 60 years. To qualify for the study, subjects had to present with no significant history of pathology of the shoulder. In addition, subjects who did not regularly exercise agreed to avoid upper-extremity exercise and activities other than those prescribed by the research protocol. Subjects who regularly exercise agreed not to increase the intensity or frequency of the activity during the three weeks of training.

Subject Testing and Training

Approximately one week prior to the commencement of the study, subjects were chosen from the volunteers for the study. These subjects were assigned to a group and given an orientation to the testing and training procedures. They were also asked to read and sign a consent form to participate in the study. All testing was conducted in the Human Exercise Physiology Laboratory at Washington State University Spokane Riverpoint Campus. Preliminary testing took place on Day 1 between 0800-1700 hours, on the first day of training. On this day, subjects were tested for height, body mass, and internal and external rotation via supine shoulder ROM technique prior to stretching.

Testing for internal and external rotation was conducted with the subject lying on a table in the supine position with 90° of shoulder abduction and the elbow in 90° of flexion. The table did not support the elbow and a goniometer fulcrum was centered over the olecranon process. The goniometer-moving arm was aligned with the ulnar styloid and the stationary arm was
perpendicular to the floor. The subject was asked to relax the arm while the tester rotated it internally or externally to end ROM.

Subject training for the traditional and SHARQ® groups commenced on Day 1 and ended on Day 19. Subjects were assigned to one 30-minute daily stretching period between 0800-1700 hours. During this period, subjects completed eight one-minute stretching trials at the point of mild discomfort, with a 30 second rest in between each stretching trial. Each trial during the daily stretching session began with external rotation and ended with internal rotation. The total time for each stretching period was 11 minutes and 30 seconds.

On Day 10 (Mid-Training) and prior to stretch training, subjects were tested for internal and external rotation via the supine shoulder ROM technique described above. On day 22, subjects underwent a similar battery of post-training measurements.

Throughout the entire study, subjects assigned to the SHARQ® shoulder and rotator cuff stretching machine were monitored daily for post-stretch measurements recorded from ROM markers on the machine. For every stretching trial within a session, ROM was recorded. These measurements took place during the stretch without notifying the subject and no special treatment was given to the SHARQ® treatment group.

**Statistical Analyses**

Reliability of internal and external shoulder ROM measurements was determined using an intraclass correlation coefficient (ICC) on the pre- and post-training measurements of the control group (33). Data from the supine shoulder ROM measurements were tested for normality and equal variance, and were analyzed to determine whether significant differences existed between the values of the three groups. A two-factor (group and time) analysis of
variance (ANOVA) with repeated measures on one factor (time) was performed. Means and standard deviations for the pre-, mid-, and post-training measurements were calculated for each group, as well as the mean differences between the pre, mid-, and post-training data (gain scores), for the dependent variable, internal and external shoulder ROM (in degrees). Significance for all statistical tests was accepted at the 0.05 level of probability. If significant interaction existed, appropriate post hoc analyses were performed. If not, post hoc analyses were performed on significant main effects. In addition, daily measurements recorded from the SHARQ® shoulder and rotator cuff stretching machine were analyzed for significant day and time quantitative linear trends.
REFERENCES


EFFICACY OF THE SHARQ® SHOULDER AND ROTATOR CUFF STRETCHING MACHINE FOR INCREASING INTERNAL AND EXTERNAL ROTATION

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ABSTRACT

**Background and Purpose.** To date, limited information exists regarding the effectiveness of the SHARQ® shoulder and rotator cuff stretching machine (SHARQ®) for increasing internal and external shoulder range of motion (ROM). The purpose of this study was to determine if a 15-day training period using the SHARQ® would be more effective in increasing internal and external shoulder ROM than a traditional passive static stretching protocol. **Subjects.** Fifteen subjects (14 females, 1 male), ages 23-60 yrs., with no significant history of pathology of the shoulder, were randomly assigned to one of three groups: 1) control, which did not receive a stretch training, 2) traditional towel stretch training and, 3) SHARQ® stretch training. **Methods.** Treatment groups participated in one stretching session, with eight trials, per day consisting of alternating internal and external shoulder rotation with 30-second rest intervals between stretches. Internal and external shoulder ROM were measured with a goniometer pre-, mid-, and post-training. Data were analyzed with a two-factor (group and time) analysis of variance with repeated measures on one factor (time). Internal and external ROM were also measured daily during stretching sessions, only for the SHARQ® group. These data were analyzed with a multiple regression for linear trends with dependant variables time and day. **Results.** Increases in shoulder internal and external rotation did not differ significantly between the traditional towel and SHARQ® training groups. ROM significantly increased over time in all groups. Significant linear trends were also identified for increased internal and external ROM within daily training sessions and for internal ROM throughout the three-week training period in the SHARQ® training group. **Discussion and Conclusion.** This study using a small sample of healthy subjects provides preliminary evidence indicating the efficacy of the SHARQ® for increasing shoulder ROM. Although the SHARQ® protocol was not more effective in
increasing ROM of the shoulder than the traditional passive static stretching protocol, the results indicated that the SHARQ® protocol used herein produced increases in ROM similar to that of traditional towel stretching. Future studies on the efficacy of SHARQ® stretch training using clinical populations are warranted.

**Key Words:** passive static stretching, traditional towel stretch training, SHARQ® stretch training
INTRODUCTION

Flexibility is the extensibility of periarticular tissues that allows normal or physiological motion of a joint or limb (2). Improved muscle flexibility allows muscle tissue to accommodate imposed stress more easily and promotes efficient and effective movement (6). Many stretching advocates believe that more efficient and effective movement due to enhanced muscle flexibility will help prevent or minimize injuries, decrease muscle soreness, and enhance physical performance (4, 5, 7, 10, 13). Increased flexibility from stretching may result from increases in musculotendinous length (22, 23, 30), increased stretch tolerance (18-21), alteration of muscle stiffness (15), and viscoelastic stress relaxation (14, 16, 24, 29, 31).

There are currently three different stretching techniques used to increase flexibility: 1) ballistic, 2) proprioceptive neuromuscular facilitation (PNF), and 3) static stretching. Ballistic stretching incorporates a bouncing motion in which repetitive contractions of the agonist muscle are used to produce quick stretches of the antagonist muscle (26). Ballistic stretching to increase flexibility has not been supported in literature because it creates uncontrolled forces within the muscle that can exceed the extensibility limits of the muscle fiber and possibly produce microtears within the musculotendinous unit (4, 5). Proprioceptive neuromuscular facilitation (PNF) is a group of stretching procedures that involve alternating contraction and relaxation of the muscles being stretched (17). Bandy and Irion (5) identify PNF techniques as being superior to other stretching methods for increasing flexibility but one must be properly trained in this procedure to insure its efficacy. Static stretching is one of the most widely used methods for increasing flexibility because of its simplicity of execution and low risk for tissue trauma (5, 27). According to Smith (28), static stretching has the least associated injury risk of these popular methods and static stretching is believed to be the safest
and most frequent method of stretching. Static stretching, either active or passive, consists of a 30 second hold to discomfort of the antagonist muscle (3). There are many benefits of the static stretching technique. Static stretching prevents damage to the muscle being stretched due to overstretching because it is a slow and controlled exercise. Due to this controlled nature of static stretching, forceful reflex contractions are also not elicited. Static stretching has also been proven to alleviate muscle soreness more effectively than other stretching techniques (6). Active static stretching uses a contraction of the agonist muscle to place the antagonist muscle in a position of stretch. Passive static stretching, in which skeletal muscle remains relaxed, utilizes body weight, a partner, or equipment to facilitate stretching. In terms of all stretching techniques, passive static stretch is the most commonly used procedure, and is less prone to cause injury than ballistic stretching (26).

The SHARQ® shoulder and rotator cuff stretching machine (SHARQ®) was recently designed as an alternative to static stretching techniques used to increase internal and external shoulder range of motion (ROM). The SHARQ® embodies the principles of limb isolation/orientation and self-selected tolerance for passive static stretching (Figure 1). To use the SHARQ®, an individual must first adjust the seat height in order for their shoulder to be properly aligned with the machine's shoulder cuff. The arm is then placed in the machine at a vertical abduction of 90° with an elbow flexion of 90°. In this position, the arm is then mobilized with forearm and upper arm cuffs. The shoulder is held into place with an inflatable bladder to prevent anterior or posterior translation. With the arm secure and in the proper alignment, the individual then rotates the accompanying flywheel, on the opposite side of the machine, to initiate internal or external passive static stretching of the shoulder. The SHARQ® arm assembly completely rotates to facilitate rotation of the right or left shoulder. The
SHARQ® is very easy to use. After an initial introductory stretching period with verbal feedback by an instructor, the individual can then stretch without a need for continual supervision or assistance.

Due to the complex physiological structure of the shoulder joint, ROM measurements can be highly variable even in a healthy populace. The active range of shoulder joint motion has been established as 0-90 degrees for both internal and external rotation (3, 17). However, Boone and Azen (9) evaluated 109 male subjects (ages 1-55 yrs.) and observed internal shoulder ROM was 68.8° ± 4.6° (mean ± SD) and external shoulder ROM was 103.7° ± 8.5°. Bell and Hoshizaki (8) measured shoulder rotation in 190 males and females between the ages of 18 and 88 yrs. and reported that the average standard deviation for shoulder rotation was 27.8°. This large inter- and intra-individual variance of shoulder ROM makes it difficult to establish baseline ROM values for subjects prior to stretch training and may confound interpretation of the efficacy of stretch training on shoulder ROM.

Individuals with limited internal and external rotator cuff ROM would clearly benefit from frequent passive static stretching of this muscle group. To properly stretch the rotator cuff muscle group, the shoulder must be rotated with the arm abducted at a 90° angle. This position is not easily self-maintained during shoulder rotation and under most circumstances, the muscles of the shoulder must be contracted to hold this position. If a contraction takes place during the stretch than the benefits of the passive static stretch are negated. Conventional methods used to improve shoulder rotation include assistance from another person, or hanging the arm in a rotated position with a weight, or stretching the shoulder rotators with a stretching stick, or reaching behind the back with a towel grasped between the hands. All of these methods have limitations. With assisted stretching, the assistant must be careful not to over-stretch the
shoulder possibly injuring the shoulder or limiting gains in muscle flexibility. It is difficult for
the individual being stretched to convey to another person to what point their shoulder should be
stretched. Weight-assisted stretching often times elicits further damage because the muscle
group is stretched past functional rotational flexibility due to improper selection of weight or
improper technique. Stick and towel stretching require a minimum amount of shoulder
flexibility just to attain the starting position. Most individuals undergoing rehabilitation for a
shoulder injury cannot reach the initial starting position with a stick or towel. The SHARQ®
shoulder and rotator cuff stretching machine eliminates the above problems by allowing the user
to completely control the positioning of the stretch applied to the shoulder. It also allows the
individual to isolate the shoulder without strain for internal and external passive static stretching.

According to empirical evidence, stretching with the SHARQ® may be a beneficial
alternative to the more traditional stretching techniques. But, to date, there have not been any
controlled experimental studies designed to examine the effects of SHARQ® stretching on
increasing internal and external shoulder flexibility. Therefore, the purpose of this study was to
determine if a 15-day stretching period using the SHARQ® shoulder and rotator cuff stretching
machine was more effective in increasing internal and external range of motion of the shoulder
than a traditional passive static stretching protocol. The hypothesis to be tested was that
flexibility training using the SHARQ® shoulder and rotator cuff stretching machine would
produce greater increases in internal and external shoulder range of motion than traditional
passive static stretching.
MATERIALS AND METHODS

Research Design

The effects of 15 days of chronic passive static stretching on the internal and external rotator cuff ROM of the shoulder were examined using a randomized design. Subjects were randomly assigned to one of three groups consisting of five individuals per group: 1) control, 2) traditional stretching protocol, or 3) stretching using the SHARQ® shoulder and rotator cuff stretching machine. The control had no change in current active daily living activities (ADLs). The traditional stretch group underwent a traditional, individualistic, static stretch exercise for both external and internal rotation of the shoulder to mild discomfort. The traditional stretch consisted of "towel pulls". For external rotation, test subjects held a towel in the hand of the shoulder being stretched while standing. They then tossed the towel over the shoulder to be stretched, not letting go, and reached behind the back, below the shoulder, with the other hand and grabbed the other end of the towel. With each hand holding each end of the towel, the towel was pulled down to mild discomfort. For internal rotation, test subjects held the towel in the hand of the shoulder not being stretched while standing. They then tossed the towel over the shoulder not being stretched, not letting go, and reached behind the back with the other hand, below the shoulder, and grabbed the other end of the towel. With each hand holding each end of the towel, the towel was pulled up to mild discomfort. The SHARQ® group underwent a passive static stretch for both external and internal rotation of the shoulder to mild discomfort using the SHARQ® shoulder and rotator cuff stretching machine.
Selection of Subjects

Subjects (n=15) were recruited from the Spokane community. Subjects were between the ages of 18 and 60 years. To qualify for the study, subjects had to present with no significant history of pathology of the shoulder. In addition, subjects who did not regularly exercise agreed to avoid upper-extremity exercise and activities other than those prescribed by the research protocol. Subjects who regularly exercise agreed not to increase the intensity or frequency of the activity during the three weeks of training.

Subject Testing and Training (Figure 2)

Approximately one week prior to the commencement of the study, subjects were chosen from the volunteers for the study. These subjects were consented, assigned to groups, and given an orientation to the testing and training procedures. All testing was conducted in the Human Exercise Physiology Laboratory at Washington State University Spokane Riverpoint Campus. Preliminary testing took place on Day 1 between 0800-1700 hours, on the first day of training. On this day, subjects were tested for height, body mass, and internal and external rotation via supine shoulder ROM technique prior to stretching.

Testing for internal and external rotation was conducted with the subject lying on a table in the supine position with 90° of shoulder abduction and the elbow in 90° of flexion. The table did not support the elbow and a goniometer fulcrum was centered over the olecranon process. The goniometer-moving arm was aligned with the ulnar styloid and the stationary arm was perpendicular to the floor. The subject was asked to relax the arm while the tester rotated it internally or externally to end ROM.
Subject training for the traditional and SHARQ® groups commenced on Day 1 and ended on Day 19. Subjects were assigned to one 30-minute daily stretching period between 0800-1700 hours. During this period, subjects completed eight one-minute stretching trials at the point of mild discomfort, with a 30 second rest in between each stretching trial. Each trial during the daily stretching session began with external rotation and ended with internal rotation. The total time for each stretching period was 11 minutes and 30 seconds.

On Day 10 (Mid-Training) and prior to stretch training, subjects were tested for internal and external rotation via the supine shoulder ROM technique described above. On day 22, subjects underwent a similar battery of post-training measurements.

Throughout the entire study, subjects assigned to the SHARQ® shoulder and rotator cuff stretching machine were monitored daily for post-stretch measurements recorded from ROM markers on the machine. For every stretching trial within a session, ROM was recorded. These measurements took place during the stretch without notifying the subject and no special treatment was given to the SHARQ® treatment group.

Pilot Study

A separate pilot study was conducted to evaluate the validity and reliability of the SHARQ® shoulder and rotator cuff stretching machine to passively stretch the rotator cuff of the shoulder internally and externally. Two subjects (ages 21 and 35) with normal shoulder function participated in the study. Machine, subject arm, and subject torso motion was measured using an Optotrak 3020 computer-aided motion analysis system (Northern Digital, Inc., Waterloo, Ontario). Six infrared light emitting diode markers were placed on the base of the machine, four markers were placed on the arm of the machine, two markers were placed on the arm of the test
subject (styloid process and olecranon process), and two markers were placed on the torso of the
test subject (midpoint of clavicle and at the clavicle/coracoclavicular junction) (Figure 3). Three
infrared cameras acquired the marker trajectories. The test session consisted of internal and
external shoulder rotation to the point of discomfort by the test subject. Data were collected
every five degrees of rotation, and compared with a goniometric scale placed on the SHARQ®
rotator cuff stretching machine.

Statistical Analyses

Reliability of internal and external shoulder ROM measurements was determined using
an intraclass correlation coefficient (ICC) on the pre- and post-training measurements of the
control group (33). Data from the supine shoulder ROM measurements were tested for
normality and equal variance, and were analyzed to determine whether significant differences
existed between the values of the three groups. A two-factor (group and time) analysis of
variance (ANOVA) with repeated measures on one factor (time) was performed. Means and
standard deviations for the pre-, mid-, and post-training measurements were calculated for each
group, as well as the mean differences between the pre, mid-, and post-training data (gain
scores), for the dependent variable, internal and external shoulder ROM (in degrees).
Significance for all statistical tests was accepted at the 0.05 level of probability. If significant
interaction existed, appropriate post hoc analyses were performed. If not, post hoc analyses were
performed on significant main effects. In addition, daily measurements recorded from the
SHARQ® shoulder and rotator cuff stretching machine were analyzed for significant day and
time quantitative linear trends.
For the sensory motion pilot study each five-degree data collection consisted of 7 to 30 data recordings per marker. These data recordings were averaged for each marker for each five-degree increment. The effectiveness of the SHARQ® rotator cuff stretching machine was analyzed with these averages. The average internal and external rotation of the SHARQ® arm was compared to each subject with the assumed five-degree change per measurement using a one-sample students t-test. The absolute difference in change per five degrees of rotation was also compared for both internal and external ROM between the SHARQ® arm and subject arm using a one-sample students t-test. The variation of the two torso markers from each marker's average set point distance was analyzed for translation of the upper body during internal and external rotation.

RESULTS

Shoulder internal (Figure 4) and external (Figure 5) ROM were determined at pre-training, mid-training, and post-training. The ICC value calculated for pre-training to post-training internal and external shoulder rotation data of the control group was .03 and -.09.

Changes in ROM, expressed as percent change from pre- to post-training are given in Table 1. All data were normally distributed with equal variance. Subject age was not a significant covariate in the study. Results of the two-factor ANOVA with repeated measures found no significant difference in the group by time interaction for internal ($df = 4, 24; F = 2.54; \ p = 0.066$) or external ROM ($df = 4, 24; F = 1.05; p = 0.404$). No significant difference was found for main effect group for internal ($df = 2, 12; F = 0.17; p = 0.848$) or external ROM ($df = 2, 12; F = 1.22; p = 0.330$). A significant difference was shown for main effect time for both
internal \((df = 2, 12; F = 7.62; p = 0.003)\) and external rotation \((df = 2, 12; F = 13.35; p < 0.001)\) for all groups.

In order to interpret the significant main effect of time a Bonferroni (All-Pairwise) Multiple Comparison test was utilized. Significant differences in internal rotation were identified between pre-training and mid- and post-training. Significant differences in external rotation were identified between pre-, mid- and post-training. Visual analyses indicated that shoulder ROM increased throughout the training period. To investigate this significant increase in ROM over time for all groups, multiple regression analysis was used to differentiate those groups that showed significant increasing linear trends for shoulder internal and external rotation. For internal shoulder rotation only the SHARQ® group elicited a positive linear trend over time \((df = 1, 13; F = 4.98; p = 0.044)\) (Figure 6). For external shoulder rotation the SHARQ® group \((df = 1, 13; F = 4.76; p = 0.048)\) and the traditional stretch group \((df = 1, 13; F = 6.45; p = 0.025)\) elicited a significant positive linear trend over time (Figure 7). An analysis of covariance (covariate-initial internal or external shoulder ROM) was also run for further post hoc analysis. No significant difference of the covariate was found.

Data collected daily from post-stretch measurements of internal and external ROM using the SHARQ® shoulder and rotator cuff stretching machine were analyzed with multiple regression testing to assess whether a significant linear trend existed for variables time and day. All data were normally distributed with equal variance. The multiple regression tests on internal \((df = 1, 298; F = 4.65; p =0.032)\) and external \((df = 1, 298; F = 10.77; p = 0.001)\) time indicated a significant increasing trend (Figure 8). Also, the multiple regression tests on internal \((df = 1, 298; F = 7.52; p = 0.008)\) and external \((df = 1, 298; F = 29.07; p < 0.001)\) day indicated a significant increasing linear trend (Figure 9).
Sensory motion data analysis for internal and external passive rotational stretching using the SHARQ® shoulder and rotator cuff stretching machine was utilized to measure stretching effectiveness. The one-sample t-tests ($H_0$: 5) calculated on the assumed (five degrees per movement) versus absolute true (SHARQ® Arm vs. SHARQ® base degree change per movement) internal and external rotation for subject indicated significant differences in internal rotation (internal 1: $t = 8.948, p > 0.05$; internal 2: $t = 9.6824, p > 0.05$) and external rotation (external 1: $t = 7.3611, p < 0.05$; external 2: $t = 7.2485, p < 0.05$) (Figure 10 & 11). The one-sample t-tests ($H_0$: 0) calculated on the difference between SHARQ® arm and subject arm internal and external rotation for each subject indicated significant differences in internal and external rotation (internal 1: $t = 4.1950, p < 0.05$; internal 2: $t = 5.1283, p < 0.05$; external 1: $t = 11.9433, p < 0.05$; external 2: $t = 11.6057, p < 0.05$; external 3: $t = 12.0496, p < 0.05$) (Figure 12). Movement of the torso markers throughout internal and external ROM from initial set point was significant (Figure 13 & 14).

**DISCUSSION**

Normal ROM for both internal and external shoulder rotation has been established at 90° (3), with an average standard deviation for shoulder rotation between 5° to 30° (3, 8, 9, 12, 25). This large inter- and intra-individual variance of shoulder ROM makes it difficult to establish baseline ROM values for subjects prior to stretch training and may confound interpretation of the efficacy of stretch training on shoulder ROM. This study was the first experimental investigation to study the effects of the SHARQ® shoulder and rotator cuff stretching machine passive rotational stretching technique in relationship to a traditional stretching technique and a control group. Few research investigations have focused on the efficacy of passive stretching and
shoulder ROM. The majority of stretching studies focus on lower body joints, such as the knee. Notably, in comparison to the shoulder, the joint ROM at the hip and knee have small intra- and inter-subject variance (3). In the present study, the fact that the training-induced change in internal and external shoulder ROM did not differ significantly between groups appeared to be due to intra- and inter-subject variation. Consequently, the coefficient of variation for internal ROM was 23.8% and 15.3% for external ROM. Although there was equal variance among the groups, the standard deviation (SD) about the mean would, under most circumstances, be considered high. But, previous research indicated that measures of shoulder rotation in large populations have SD = 4-29%, therefore, the SD observed in this study is acceptable (3, 8, 9, 12, 25).

It is possible that variation in shoulder ROM in this study could be attributed to the large age range of subjects. Subjects were between 25-60 years old. Boone (9) measured internal and external shoulder rotation in active male subjects using a universal goniometer, and reported that males aged 60 and older exhibited a slight trend for lower shoulder ROM and larger SD for ROM than younger males aged 20-39 yrs. The larger standard deviation in the older group appeared to indicate that shoulder ROM is more varied in the older men than in the younger men. However, in this study, 14 of the 15 subjects were females and females are known to maintain greater shoulder ROM with aging than do males (8, 12). Furthermore, the equal variance for ROM across groups in this study, which had mean ages of 40.8 ± 15.2 yrs. for control, 40.8 ± 11.7 yrs. for traditional stretch, and 45.8 ± 11.6 yrs. for SHARQ® stretch, and the lack of significance for age as a covariate in the study would support the argument that the age of the subjects did not confound the effect of stretch training.
Etnyre and Lee (12), examined the relationship of shoulder stretching to ROM and concluded that females (university population with mean age = 20.1 yrs. and SD = 3.84) who undergo static stretching of the shoulder for a 12-week period showed significant decreases in shoulder ROM at numerous points throughout the study even though ROM increased from pre-to post-training. Therefore, changes in shoulder ROM with stretch training, for a given subject, are not necessarily progressive and linear, but may advance and regress over the course of an extended training period. Insufficient evidence exists to determine the expected course for the positive and negative changes over time and the optimum sequence for assessing an individual’s ROM during this pattern. Protocols that include testing all subjects on the same day for pre-, mid-, and post-training measures would likely assess some subjects during an improving ROM cycle whereas, other subjects may be in a regression cycle and thereby confound the ability to identify statistically significant increases in ROM with stretch training.

An important finding of the present study was that the SHARQ® training elicited a positive linear trend for internal shoulder ROM improvement while traditional stretch training and the control did not. SHARQ® training also elicited a significant positive linear trend (p=0.048) for increases in external ROM. Although the SHARQ® training did not induce greater increases in shoulder ROM than did the traditional stretch training, linear trend analysis with multiple regression identified that passive rotational stretching with the SHARQ® significantly increased internal and external shoulder ROM within a given day and across the training period. Interpretation of the significant linear trend for time showed that increasing frequency of stretching to four trials throughout one stretching session would lead to increased shoulder ROM. Recommendations regarding the specific frequency and duration for increased internal and external rotation while utilizing the SHARQ® shoulder and rotator cuff stretching
machine cannot be made, but analysis shows that with four, 11.5 minute stretching sessions, ROM continued to increase significantly. Interpretation of the significant linear trend for day showed that increasing daily stretching to five days a week for three weeks would lead to increased shoulder ROM. Again, recommendations regarding the number of stretching days required for increased internal and external rotation while utilizing the SHARQ® cannot be made, but stretching five days per week for three weeks significantly increased ROM.

While progressively increasing shoulder ROM, the SHARQ® shoulder and rotator cuff stretching machine has many additional benefits to the user. This machine was designed to isolate the shoulder in a position that cannot be maintained or possibly attained under normal shoulder rotation stretching techniques. The SHARQ® is a self-selected stretching apparatus that allows an individual to establish a point of mild discomfort during stretching and to hold that position without subjecting the muscle group to further stretch. The position of stretching is comfortable and allows for support of the arm and shoulder so that the individual can relax and take full advantage of the passive static stretching technique that is being utilized with this machine. The arm is mobilized through the movements of stretch and the SHARQ® is very easy to use. As mentioned earlier, there is a very quick and efficient process of training an individual to use this machine for smooth and effective transition to stretching without a supervisor. This ultimately will lead to individual compliance with shoulder ROM stretching and improved results.

Although these positive attributes of the SHARQ® rotator cuff stretching machine seem to far outweigh any negative aspect of the machine, there were also factors in this study that limited the effectiveness of the SHARQ®. Segregation of the shoulder for internal and external rotational passive stretching was very limited. Because of the importance of shoulder
segregation in relation to the passive stretching that took place in this analysis, a separate pilot study was conducted to measure the effectiveness of the SHARQ® to rotate the shoulder internally and externally. Analyses of these data identified that the SHARQ® did not fully immobilize the arm or torso as individuals stretched internally and externally. The internal and external ROM measurements in relation to the subject’s forearm did not consistently agree with the change in movement of arm of the SHARQ® (Figure 12). In the majority of instances, the subject’s forearm was at a lesser ROM than the machine. These differences between the subject and machine arms led to inflated ROM measurements when reading the SHARQ® goniometric legend. Also, a comparison of the absolute SHARQ® arm internal and external ROM measurements to the SHARQ® goniometric measures indicated that internal and external rotation differed significantly (Figure 10 & 11). During shoulder rotation the torso of test subjects also moved, most significantly at the higher ROMs (Figure 13 & 14). These above examples of ineffective immobilization can be attributed to the inadequate arm and shoulder cuffs designed to immobilize the forearm and upper arm, and brace the shoulder during rotation. It can also be attributed to the lack of a rigid back brace to support the spine and neck during rotation of the shoulder.

In summary, the use of SHARQ® shoulder and rotator cuff stretching machine increased internal and external shoulder ROM, but it did not result in a significant increase in internal and external shoulder ROM in comparison to the traditional stretching technique. The results of this study indicated that the SHARQ® increased ROM within a daily training session and over the course of a three-week training period. Subject variation in shoulder ROM may have confounded the ability to discriminate the effects of training on shoulder ROM. This is a very important factor to take into consideration for future shoulder ROM studies with the SHARQ®.
By taking this variance into account, better guidelines for stretching duration on a daily and weekly basis can be established. Also, a redesign of this machine must take place before future studies are initiated. Once the shoulder has been isolated and the torso is supported, it is likely that the variance in shoulder ROM may be reduced. The SHARQ® shoulder and rotator cuff stretching machine has many benefits that would justify its use for improving shoulder ROM. The results of this study provide preliminary evidence that a 15-day training period using the SHARQ® increased internal and external shoulder rotation in healthy subjects.
REFERENCES


Table 1. Changes in Internal and External Shoulder Rotation Over Time

<table>
<thead>
<tr>
<th>Group</th>
<th>Internal (% change)</th>
<th>External (% change)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTROL</td>
<td>7.5 ± 4.5</td>
<td>4.4 ± 4.7</td>
</tr>
<tr>
<td>TRADITIONAL</td>
<td>3.9 ± 5.8</td>
<td>14.6 ± 4.1</td>
</tr>
<tr>
<td>SHARQ®</td>
<td>16.3 ± 3.5</td>
<td>14.1 ± 3.3</td>
</tr>
</tbody>
</table>

Each group consisted of five individuals and measurements were taken with a goniometer with test subjects lying in a supine position. Values for each subject were based on the average of two measurements taken by two different testers.
Figure 1. SHARQ® shoulder and rotator cuff stretching machine. Invented by Dr. John Quintinskie. Utilized for internal and external stretching of the rotator cuff.

Figure 2. Study Timeline.

Figure 3. Location of Infrared Light Emitting Diode Markers on Test Subject. Sensory motion analysis to measure effectiveness of SHARQ® shoulder and rotator cuff stretching machine. Sensory motion analysis is performed with an Optotrak 3020 made by Northern Digital, Inc., Waterloo, Ontario.

Figure 4. Changes in Internal Shoulder Rotation. The average internal degrees of shoulder rotation recorded by a goniometer at a specific measurement time of five test subjects per group. Standard deviations from the mean are included.

Figure 5. Changes in External Shoulder Rotation. The average external degrees of shoulder rotation recorded by a goniometer at a specific measurement time of five test subjects per group. Standard deviations from the mean are included.

Figure 6. Internal Rotation Linear Time Trend. Linear trend analysis for time of each group with five subjects per group and three difference time measurement periods (Pre-Training, Mid-Training, and Post-Training).
Figure 7. External Rotation Linear Time Trend. Linear trend analysis for time of each group with five subjects per group and three difference time measurement periods (Pre-Training, Mid-Training, and Post-Training).

Figure 8. Linear Trend for Daily Stretching Sessions with SHARQ® Internal & External ROM. Linear trend analysis for daily stretching sessions, four per day, for SHARQ® training. All linear trend lines have a positive slope.

Figure 9. Linear Trend for Days of Stretch Training with SHARQ® Internal & External ROM. Linear trend analysis for days of stretching, 15 days, for SHARQ® training. All linear trend lines have a positive slope.

Figure 10. Pilot Study: Degree Variance from 5-Degree Movement Increments for Internal Rotation using the SHARQ®. Average internal rotation degree change of SHARQ® arm per 5° movement from goniometer markings. Solid line with zero slope at 5° represents the expected change per 5° increments.

Figure 11. Pilot Study: Degree Variance from 5-Degree Movement Increments for External Rotation using the SHARQ®. Average external rotation degree change of SHARQ® arm per 5° movement from goniometer markings. Solid line with zero slope at 5° represents the expected change per 5° increments.
Figure 12. Pilot Study: Degree Difference of SHARQ® Arm Vs. Subject Arm Per 5 Degree Movement. Average internal and external degree difference from a baseline of 0°.

Figure 13. Chest Marker Movement During Internal Rotation using the SHARQ®. Chest markers used to measure anterior translation of the upper torso from the initial set point (0°) for all internal rotational movements. Marker 1 is located at the midpoint of the clavicle and Marker 2 is located at the clavicle/coracoclavicular junction.

Figure 14. Chest Marker Movement During External Rotation using the SHARQ®. Chest markers used to measure posterior translation of the upper torso from the initial set point (0°) for all external rotational movements. Marker 1 is located at the midpoint of the clavicle and Marker 2 is located at the clavicle/coracoclavicular junction.
Figure 1. SHARQ® shoulder and rotator cuff stretching machine.
The study lasted 22 days. Day 1 was for pre-training ROM measurements. Days 1-19 were the training period. Days 6, 7, 13, 14, 20, 21 were no training days. Day 10 was for mid-training ROM measurements. Day 22 was for post-training ROM measurements.

* no stretch
Figure 3. Location of Infrared Light Emitting Diode Markers on Test Subject.
Figure 4. Changes in Internal Shoulder Rotation

[Graph showing changes in internal shoulder rotation between pre-training, mid-training, and post-training stages for three groups: Control, Traditional, and SHARQ.]
Figure 5. Changes in External Shoulder Rotation
Figure 6. Internal Rotation Linear Time Trend
Figure 7. External Rotation Linear Time Trend
Figure 8. Linear Trend for Daily Stretching Sessions with SHARQ® Internal & External ROM.

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Subject: 1  2  3  4  5

Internal Degrees of Rotation:

0.0  1.0  2.0  3.0  4.0

Daily Stretching Session:

80.0  90.0  100.0  110.0  120.0  130.0  140.0  150.0  160.0  170.0  180.0

Subject: 1  2  3  4  5

External Degrees of Rotation:

0.0  1.0  2.0  3.0  4.0

Daily Stretching Session:

70.0  77.0  84.0  91.0  98.0  105.0  112.0  119.0  126.0  133.0  140.0

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Figure 9. Linear Trend for Days of Stretch Training with SHARQ® Internal & External ROM.
Figure 10. Pilot Study: Degree Variance from 5-Degree Movement Increments for Internal Rotation using the SHARQ®.
Figure 11. Pilot Study: Degree Variance from 5-Degree Movement Increments for External Rotation using the SHARQ®.
Figure 12. Pilot Study: Degree Difference of SHARQ® Arm Vs. Subject Arm

![Figure 12](image-url)

- Subject P1
- Subject P2

ROM values from SHARQ

Internal Rotation  |  External Rotation
Figure 13. Chest Marker Movement During Internal Rotation using the
Figure 14. Chest Marker Movement During External Rotation using the...