
ORIGINAL RESEARCH

SUSTAINED ISOMETRIC SHOULDER CONTRACTION ON MUSCULAR STRENGTH AND ENDURANCE: A RANDOMIZED CLINICAL TRIAL

Natalie L. Myers, MS, ATC¹
Jenny L. Tbonstra, PhD, ATC²
Jacob S. Smith, MS, ATC³
Cooper A. Padgett, MS, ATC³
Tim L. Uhl, PhD, ATC, PT, FNATA¹

ABSTRACT

Background: The Advanced Throwers Ten Exercise Program incorporates sustained isometric contractions in conjunction with dynamic shoulder movements. It has been suggested that incorporating isometric holds may facilitate greater increases in muscular strength and endurance. However, no objective evidence currently exists to support this claim.

Hypothesis/Purpose: The purpose of this research was to compare the effects of a sustained muscle contraction resistive training program (Advanced Throwers Ten Program) to a more traditional exercise training protocol to determine if increases in shoulder muscular strength and endurance occur in an otherwise healthy population. It was hypothesized that utilizing a sustained isometric hold during a shoulder scaption exercise from the Advanced Throwers Ten would produce greater increases in shoulder strength and endurance as compared to a traditional training program incorporating a isotonic scapular plane abduction (scaption) exercise.

Study Design: Randomized Clinical Trial.

Method: Fifty healthy participants were enrolled in this study, of which 25 were randomized into the traditional training group (age: 26 ± 8 , height: 172 ± 10 cm, weight: 73 ± 13 kg, Marx Activity Scale: 11 ± 4) and 25 were randomized to the Advanced Throwers Ten group (age: 28 ± 9 , height: 169 ± 23 cm, weight: 74 ± 16 kg, Marx Activity Scale: 11 ± 5). No pre-intervention differences existed between the groups ($P > 0.05$). Arm endurance and strength data were collected pre and post intervention using a portable load cell (BTE Evaluator, Hanover, MD). Both within and between group analyses were done in order to investigate average torque (strength) and angular impulse (endurance) changes.

Results: The traditional and Advanced Throwers Ten groups both significantly improved torque and angular impulse on both the dominant and non-dominant arms by 10–14%. There were no differences in strength or endurance following the interventions between the two training groups ($p > 0.75$).

Conclusions: Both training approaches increased strength and endurance as the muscle loads were consistent between protocols indicating that either approach will have positive effects.

Level of Evidence: Level 2

Keywords: Angular Impulse, abduction strength, Thrower's 10 exercise program

CORRESPONDING AUTHOR

Natalie L. Myers
210c Charles T. Wethington Buidling
900 South Limestone
Lexington, KY 40506-0200
phone: 859-218-0578
fax: 859-323-6003
E-mail: nataile.myers@uky.edu

¹ Department of Rehabilitation Sciences, University of Kentucky, Lexington, KY, USA

² Department of Health and Sport Sciences, Salisbury University, Salisbury, MD, USA

³ Division of Athletic Training, University of Kentucky, Lexington, KY, USA

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INTRODUCTION

The use of the overload principle as the foundation of progressive resistive training programs is well established.^{1,2} According to the overload principle, an individual must gradually increase stresses placed upon the body during exercise training in order to enhance muscular performance.² Evidence supports the use of progressive isotonic exercises utilizing the overload principle for facilitating strength gains in the upper extremity.³ Exercise guidelines have been developed that consider the type of muscle action (i.e. concentric, eccentric, isometric) as well as the volume (sets, repetitions, and load) in order to achieve desired outcomes.⁴ Most exercise programs incorporate the use of isotonic exercise, with both concentric and eccentric muscle actions. The use of isometric contractions during exercise often plays a secondary/stabilization role and is commonly incorporated into rehabilitation programs in which range of motion is limited and/or contraindicated. However, the duration of a hold or isometric portion of the muscle contraction during exercise is not well described in the strength and endurance training literature.^{2,5}

The Throwers Ten Exercise Program was originally described as a series of exercises specific to the throwing athlete designed to improve strength, power, and endurance of the shoulder complex.⁶ Wilk et al., recently published an altered version of this program, titled the Advanced Throwers Ten Exercise Program that incorporates varying levels of sustained isometric holds in an effort to combat muscular fatigue associated with upper extremity injuries in overhead athletes.⁷ For example, one set of exercises are performed with one arm remaining isometrically contracted at the end of the concentric phase while the other arm performs concentric/eccentric movement. The following set incorporates alternating concentric and eccentric movement with both arms while maintaining a sustained contraction on one arm during the lowering phase of the opposite arm. It has been suggested that incorporating sustained isometric holds will enhance muscle activation and facilitate increases in muscular strength and endurance while producing dynamic stabilization.⁷ However, to date, no research is available to support this premise. There is some supporting evidence that sustained isometric contractions can have a positive impact on muscular hypertrophy.⁸ Danneels et al randomized patients

with chronic low back pain into one of two groups, a standard training group or a dynamic-static group that incorporated a five second isometric contraction during a core exercise program. The cross-sectional area of the multifidus was measured using standardized transaxial computed tomography images pre and post. Patients in the dynamic-static group demonstrated a significant increase in hypertrophy in the multifidus musculature at the end of the 10-week training program.⁸ Although muscular strength or endurance was not the primary outcome measure, the results of this study provide some evidence that incorporating sustained isometric contractions facilitates muscle hypertrophy in a small static stabilizing muscle group.

The theoretical approach put forth by Wilk and colleagues⁷ of using a sustained contraction to further train shoulder musculature has reasonable physiological support.^{8,9} Currently, the authors could not find published literature that investigated whether use of a sustained muscle contraction during exercise can have a meaningful change in strength or endurance over pre-established progressive resistive exercise protocols. Therefore, the purpose of this research was to compare the effects of a sustained muscle contraction resistive training program (Advanced Throwers Ten Program) to a more traditional exercise training protocol to determine if increases in shoulder muscular strength and endurance occur in an otherwise healthy population. Thus, it was hypothesized that the Advanced Throwers Ten Program would produce greater increases in shoulder muscular strength and endurance compared to a traditional isotonic training program.

METHODS

Participants

A total of 96 healthy adult volunteers inquired about the research, contacting the primary investigator by phone or email (Figure 1, Table 1). Potential subjects were excluded from the study if one of the following criteria were met: 1) shoulder or neck pain within the prior 6 months, 2) past history of shoulder or neck fractures, and 3) past history of shoulder or neck surgeries. Eligible subjects read and signed University of Kentucky Institutional Review Board approved consent forms prior to initiating the study. All testing was performed in the Musculoskeletal

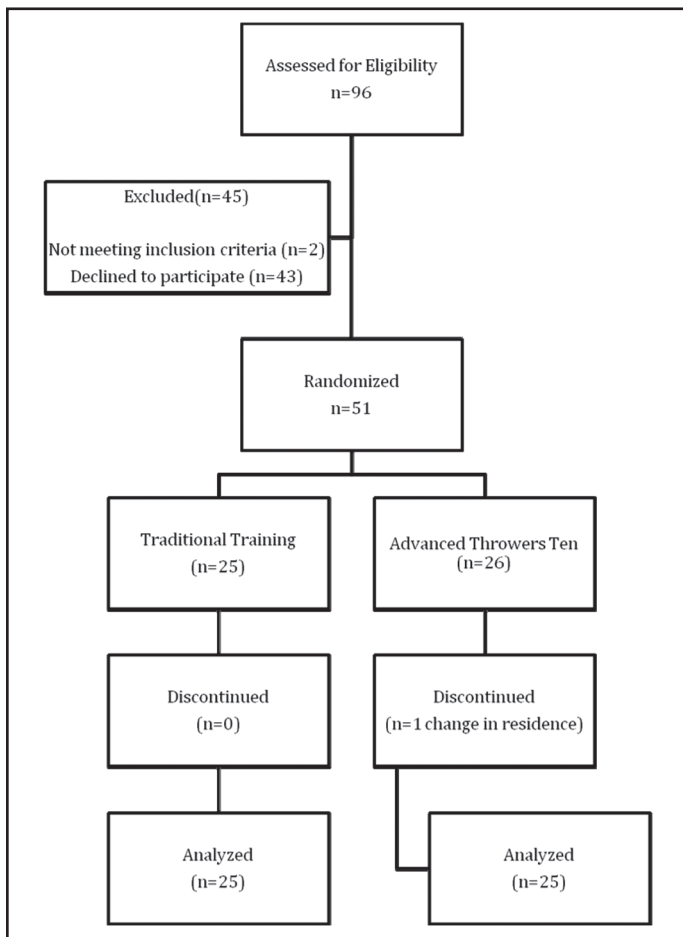


Figure 1. Consort flow diagram.

Laboratory at the University of Kentucky and Berea College Athletic Training Room from July 2013–February 2015.

Subjects filled out demographic information and the Marx upper extremity activity survey in order to evaluate the current level of upper extremity activity.¹⁰

The Marx activity survey is an activity rating scale that gives a numerical sum of scores, on a scale of 0–20, for five activities rated on a five point scale from never performed (0) to daily (4).¹⁰ This scale has been found to be reliable (ICC = 0.92), and the developers concluded that a score ≤ 6 represents low activity, 7–15 average activity, and ≥ 7 high activity. Results of the Marx activity scale and demographic information was compared using a t-test and demonstrated that the randomization process generated two similar groups (Table 1).

Sample size was determined from pilot data from six subjects (three in each group) undergoing the two training programs for six weeks. A univariate two-group repeated measures analysis of variance was implemented with 80% power in order to detect an interaction between the two groups using average torque as the primary outcome. With significance set at a level 0.05 it was determined that a sample size for each group was 25 subjects. (NQuery + nTerim 2.0, Statistical Solutions, Saugues, MA)

Design

This study was a two-group, pre-test/post-test randomized clinical trial. Following initial average torque (strength) and angular impulse (endurance), subjects followed a six-week exercise program performed primarily at home. The arm was measured in abduction of 90° in the scapular plane, 30° anterior to the frontal plane (scaption).

Isometric Testing

Prior to testing, intersession reliability was established and intraclass correlation coefficient (ICC),

Table 1. Participant Demographic Information reported as mean and standard deviations. Significance reported as probability from an Independent T-test

| | Traditional Training Group | Advanced Throwers Ten Group | p-Value |
|-------------------------------------|----------------------------|-----------------------------|---------|
| Age (years) | 26 ± 8.1 | 28 ± 8.6 | 0.28 |
| Height (cm) | 172 ± 10.2 | 170 ± 23.5 | 0.61 |
| Mass (kg) | 73 ± 13 | 74 ± 16 | 0.70 |
| Arm Length Right (cm) | 56 ± 4.6 | 56 ± 3.8 | 0.97 |
| Arm Length Left (cm) | 56 ± 4.6 | 56 ± 3.7 | 0.89 |
| MARX Upper Extremity Activity Score | 11 ± 3.9 | 12 ± 5 | 0.51 |

standard error of measure (SEM), and minimal detectable change (MDC) were calculated for average torque (ICC = 0.96, SEM = 3.2Nm, and MDC = 4.5 Nm), and angular impulse (ICC = 0.95, SEM = 90.2 Nm*s, and MDC = 127.7 Nm*s) using a portable load cell (BTE Evaluator, Hanover, MD). Therefore, gains greater than or equal to 5Nm and 128Nm*s in torque and angular impulse, respectively, were considered to be a meaningful change. All subjects warmed up using a series of arm motions (2 sets of 10) and shoulder stretching exercises (2 sets of 30 seconds) for approximately three minutes. The arm motions included bilateral arm scapular plane abduction (scaption) to 90°, shoulder stretches across body for the posterior shoulder, and behind the head for anterior shoulder. The testing procedures were explained, and subjects' arm length was measured bilaterally from the tip of the acromion process to the radial styloid process. This was done in order to convert the force generated during the isometric strength testing to torque, by multiplying the forces generated in Newtons by the subject's lever arm, which was measured in meters.

Isometric shoulder torque and angular impulse was measured in the position of arm abduction of 90° in the scapular plane, 30° anterior to the frontal plane (scaption) using a portable load cell (BTE Technologies Inc, Hanover, MD) for a duration of 30 seconds on both the dominant and non-dominant arms. The average torque generated over the first five seconds of the two 30-second maximal effort trials for each arm represented shoulder strength as measured using isometric torque. The average angular impulse over the entire 30 seconds of the two 30-second maximal effort trails for each arm represented shoulder endurance. An impulse represents the amount of force multiplied by the time that the force is exerted.^{11,12} This represents the integral or area under the curve of the force applied, and is referred to as angular impulse. The area under the curve represents the total work done, which is used as a measure of endurance.^{13,14} The calculation for angular impulse is detailed in the data reduction section.

All participants were tested in an upright standing position with the portable load cell connected to an inelastic plastic chain that was connected to the par-

ticipant's wrist at the radial styloid process with a black velcro strap. The strap could be adjusted and modified to fit each participant's wrist size (Figure 2). Once connected, subjects were moved into abduction of 90° in the scapular plane, 30° anterior to the frontal plane. All positions were confirmed with a standard goniometer. Each arm was tested twice with a two-minute rest between tests.⁴ Subjects were instructed to lift up against the resistance as hard as they could for 30 seconds. During testing subjects were given no verbal encouragement or visual feedback, as past literature suggests that the use of either can bias strength testing values.^{15,16} Researchers only provided feedback relating to correct posture and arm position if necessary. The testing sequence was the same for all subjects during pre- and post-testing.

Randomization and Blinding

All participants were randomly assigned into one of two treatment groups; the traditional training group (group 1) or the Advanced Throwers Ten group (group 2). An independent investigator on the research team utilized Excel (Microsoft, Redwood, WA) to generate random numbers to create group assignment sequence. The random numbers corresponding to the treatment groups were placed in a



Figure 2. Testing position using portable load cell.

sealed opaque envelope until the initial testing session was complete blinding the investigator from group membership during initial pre-test measurements. After the initial testing session the sealed envelope was opened and the subject was placed in one of the two treatment groups. Therefore the investigators were not blinded to treatment groups at post-testing due to logistics of testing.

Intervention

The exercise chosen for both groups were shoulder scaption, described as the arm abducted to 90° and in the plane of the scapula, 30° anterior to the frontal plane. This exercise was selected for this study as it is part of the both the advanced and traditional throwers ten program, and electromyographic evidence supports that the deltoid and rotator cuff muscles are activated in this position making it a common exercise prescribed in rehabilitation and prevention programs.¹⁷⁻¹⁹

Scaption exercises were performed with the subject in a standing position elevating the arm to 90°. The participants used specific resistance loads based on the peak force generated during the pre-testing session. Participants starting weight was calculated using 15% of their maximum force during the initial testing session. Researchers then progressed each individual linearly by 25% each week during the six-week intervention.²⁰ Participants were provided resistive weights if they did not have equipment available.

Detailed descriptions of each training program can be found in Table 2. Each participant was instructed to complete the exercises four times per week. Participants were asked to refrain from any upper extremity weight-training or workouts over the course of the study and this was reiterated to each participant at all follow-ups. Researchers contacted participants each week by phone to assure the exercises were performed in the correct manner and being progressed appropriately. Participants were given an exercise log and asked to record repetitions, resistive loads, exercise compliance, and their perceived difficulty when they completed the exercises. Both groups had above a 95% compliance rate throughout the duration of the study. The BORG scale was used to gauge perceived exertion. The scale ranges from 0-10,

beginning a level of “no feeling of exertion” and continues to level of “near maximum, very, very hard.” A score of zero denotes no perceived exertion and a score of 10 denotes near maximum perceived exertion, with varying levels in between.²¹ The BORG scale was used in this study to gauge the individuals perceived level of exertion each day they performed the training program, with respect to gradual load increases. It was also used as a tool to monitor if a subjects load progression should be increased or decreased. If participants reported scores of 2–3 and no soreness in the first two days of exercise they were progressed to the next recommended load. If subjects continuously reported scores between 9-10 they remained at that load for another week.

Data Reduction

The raw data from the BTE software was exported and placed with subject specific data into an excel document. A template was created that allowed the researchers to calculate average torque and angular impulse for each trial. The average torque for the two trials for each arm were averaged together and recorded and represents strength. Angular Impulse, or area under the curve, indicated the total effort applied for the 30-second effort and represents endurance. Every 1.56 seconds (6 hz) data was gathered from the load cell in the form of pounds. Pounds were converted to Newtons and each participant's arm length was recorded in meters allowing for the force generated to be converted into torque (Nm). The resultant of the torque value and the duration of the effort (30 second time window) is represented by Nm*s. The total area under the curve was calculated using the trapezoidal method, which calculates individual impulses over the total time duration. The summations of each of the adjacent trapezoids were summed in order to calculate total area under the curve.¹¹ Therefore, an increase in the area under the curve from pre to post test represented gains in muscular endurance.

Statistical Analysis

To determine between group differences, torque and angular impulse percent change scores were analyzed using separate Mann-Whitney U tests for both the dominant and non-dominant arms. Percent change was calculated for torque and angu-

Table 2. Six-week Exercise Intervention Protocol for both Training Groups

| Traditional Training Group | | |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-------------|
| Exercise Protocol | Set | Repetitions |
| Bilateral isotonic scaption to 90° | 3 | 15 |
| Rest | | 1 minute |
| Bilateral isotonic scaption to 90° | 3 | 15 |
| Total volume | | 90 |
| Advanced Throwers Ten Group | | |
| Bilateral isotonic scaption to 90° | 1 | 10 |
| Isotonic scaption with the right arm with sustained hold on the left arm at 90° scaption* | 1 | 10 |
| Isotonic scaption with the left arm with sustained hold on the right arm at 90° scaption* | 1 | 10 |
| Scaption with alternating left and right arm lifts to 90° | 1 | 20 |
| Rest | | 1 minute |
| Bilateral isotonic scaption to 90° | 1 | 10 |
| Isotonic scaption with the right arm with sustained hold on the left arm at 90° scaption* | 1 | 10 |
| Isotonic scaption with the left arm with sustained hold on the right arm at 90° scaption* | 1 | 10 |
| Scaption with alternating left and right arm lifts to 90° | 1 | 20 |
| Total volume | | 100 |
| *The sustained hold was dependent on the length of time it took the participant to complete the 10 repetitions of the isotonic movement on the opposite side. | | |

lar impulse using the following equation for each participant.

$$(\text{posttest value} - \text{pretest value}) / \text{pretest value} * 100.$$

The Mann-Whitney U test compares the mean rank scores of the two groups to determine differences between the groups. In order to analyze within group changes for raw torque and angular impulse data four separate Wilcoxon Signed Rank Tests for both the dominant and non-dominant arms were utilized. These non-parametric tests were used because the

data were not normally distributed as determined by a Shapiro-Wilk Test ($p < 0.001$). All data were analyzed using Statistical Package SPSS version 21 [IBM Corp. Armonk, NY, USA]. A α level of $p \leq 0.05$ was considered significant for all statistical analyses.

RESULTS

Torque and angular impulse improved in the majority of all measures across time (Table 3). Torque and angular impulse on both the dominant and non-dominant arms improved in both the traditional

and advanced throwers ten groups between 10–14% suggesting that both approaches can have positive implications (Table 4). There were no significant differences in torque generated by the dominant arm ($p = 0.92$) or the non-dominant arm ($p = 0.85$) following the interventions between the training groups. Likewise, there were no significant differences in angular impulse generated by the dominant arm ($p = 0.79$) or the non-dominant arm ($p = 0.75$) between the training groups (Table 4).

DISCUSSION

The advanced throwers ten was designed to enhance strength, endurance, and dynamic stability for return to interval sport training.⁷ However, it is currently unknown if improvements in strength and endurance occur following the advanced throwers

ten program. Therefore, the current study investigated the effect of a six-week exercise program consisting of two different training programs. It was hypothesized that incorporating sustained isometric holds into a commonly prescribed shoulder scaption exercise would have significantly greater gains in muscle strength and endurance when compared to a traditional isotonic scaption exercise. There were no between-group differences; however, the traditional group increased strength and endurance by 13% and 12%, respectively. Similarly the advanced throwers ten group improved strength and endurance by 11% and 12%, respectively.

The evidence to support incorporating sustained contractions into basic strength training regimes should not be underestimated. There is evidence

| Table 3. Median and interquartile range (IQR) for all dependent measures within pre- and post-test data for both group | | | |
|-------------------------------------------------------------------------------------------------------------------------------|----------------------------|-----------------------------|-------------|
| Group | Pre-test | Post-test | p-Value |
| Torque Dominant Arm | | | |
| Traditional | 29.16 (21.7-40.8 Nm) | 30.81 (28.1-47.0 Nm) | $p = 0.001$ |
| Advanced Throwers Ten | 41.07 (22.0-46.1 Nm) | 40.62 (26.0-55.4 Nm) | $p = 0.006$ |
| Torque Non Dominant Arm | | | |
| Traditional | 29.22 (22.2-41.2 Nm) | 30.86 (28.7-46.2 Nm) | $p = 0.005$ |
| Advanced Throwers Ten | 34.42 (24.0-45.3 Nm) | 42.99 (28.7-52.1 Nm) | $p = 0.003$ |
| Angular Impulse Dominant Arm | | | |
| Traditional | 667.41 (516.7-1007.6 Nm*s) | 750.44 (610-1123.0 Nm*s) | $p = 0.001$ |
| Advanced Throwers Ten | 989.32 (568.5-1228.9 Nm*s) | 1066.64 (707.9-1393.1 Nm*s) | $p = 0.002$ |
| Angular Impulse Non Dominant Arm | | | |
| Traditional | 721.09 (508.4-999.1 Nm*s) | 762.17 (620.7-1078.8 Nm*s) | $p < 0.001$ |
| Advanced Throwers Ten | 925.62 (578.8-1204.5 Nm*s) | 931.89 (735.4-1254.5 Nm*s) | $p = 0.005$ |

| Table 4. Median % Change and interquartile range (IQR) for all dependent measures between groups | | | |
|---------------------------------------------------------------------------------------------------------|----------------------|-----------------------|------------|
| | Traditional | Advanced Throwers Ten | p-Value |
| Torque Dominant Arm | 12.26 (-1.8 – 22.6%) | 10.53 (0.5 – 29.7%) | $p = 0.92$ |
| Torque Non Dominant Arm | 13.04 (-3.3 – 23.7%) | 11.89 (1.3 – 30.9%) | $p = 0.85$ |
| Angular Impulse Dominant Arm | 14.82 (-0.7 – 31.7%) | 11.67 (4.0 – 21.5%) | $p = 0.79$ |
| Angular Impulse Non Dominant Arm | 10.08 (4.4 – 33.9%) | 11.33 (-2.7 – 26.0%) | $p = 0.75$ |
| Note: All values represent an increase in median % change | | | |

that in a small stabilizing muscle group that percent changes as high as 7% occur when assessing muscular hypertrophy in the lumbar multifidus following a 10-week training program incorporating sustained holds.⁸ Although the researchers did not measure strength directly, hypertrophic changes in both the upper and lower extremity have been shown to correlate with increases in muscle strength.^{22,23} Strength and hypertrophic changes have also been shown to accompany one another following resistance-training protocols.^{24,25} Furthermore, sustained isometric holds increase motor unit recruitment^{9,26} which may also help explain hypertrophic changes in muscle. Therefore incorporating sustained holds during exercise may provide physiological changes to the targeted muscle group(s).

Strength gains of 12% in the current study are similar to one strength training study despite methodological differences in strength measures. In trained athletes strength has been shown to improve between 12–15% over a 12-week period.²⁷ Although, this study did not focus on trained athletes, individuals were considered moderately active on the MARX activity scale.¹⁰ Traditionally, strength gains are observed in programs focusing on low repetitions and high resistance as initially suggested by the classic work of DeLorme.²⁸ However, the current study investigated strength gains utilizing a high number of repetitions with low resistance, which targets muscle endurance.²⁸ Despite, DeLorme's suggestions on strength and endurance intensity and volume training parameters, documented upper extremity strength gains have been shown to be as large as 25% following dynamic shoulder activity with prescribed exercise parameters consisting of three sets of 15 repetitions (traditionally thought to train muscular endurance).²⁹ Therefore, it is reasonable to suspect that an individual can acquire improvements in strength even when implementing a training protocol that is dosed using parameters more traditionally associated with endurance training. The results of this study demonstrate that while a training program may emphasize an endurance protocol, there are additional benefits of improving muscular strength as well.

Measuring endurance in addition to strength was an important component of the current study. Strength measures a muscle's ability to perform maximally

over a small time period.³⁰ Endurance measures the ability of a muscle to sustain a contraction at maximal or submaximal effort over time.³⁰ Another way to interpret endurance would be the ability a muscle has to sustain work. Work is the force multiplied by the distance moved. An impulse is similar to work, as it is the force generated by a muscle multiplied by the time the force is applied.^{11,12} A sustained maximal contraction of shoulder abduction for 30 seconds would represent a measure of shoulder endurance. For this study, angular impulse was measured by using the torque generated during abduction multiplied by time, 30 seconds. This measure represents the total work performed during the entire 30 seconds of maximal abduction. Angular impulse or total work represents the muscles' ability to sustain a contraction during the entire time that force is being generated.^{13,14} This measure would evaluate the ability of an individual to abduct maximally for prolonged time. This measure is likely to be more representative of a functional demand in which someone would have sustained a contraction for 30–60 seconds such as installing drywall with a drill while building a house. Maximal strength alone only describes the single highest value obtained momentarily.

There is variability seen in percent change scores when investigating muscular total work or endurance across the current body of literature. Glenohumeral rotation total work as assessed using an isokinetic dynamometer has been shown to increase by 40% following a strength-training program.²⁹ This increase was nearly four times greater than those seen in the current study, and is more than likely contributed to differences in training volume during the protocol. The protocols in this study had a total daily training volume ranging between 90-100 repetitions while the volume in Niederbracht's study was 225 repetitions. However, the current study demonstrated similar endurance gains to Campos et al, as individuals' improved muscular endurance by 10% when participating in a lower extremity-training regime with exercise parameters consisting of 3 sets of 11 repetitions.⁵

When designing this clinical trial the researchers controlled for the total volume of training by establishing the total time on muscle tension for the anterior and middle deltoid. This was done through a pilot study conducted before the start of this research that

utilized EMG activity during exercises that would be implemented during the intervention. This allowed researchers to ensure that each training program would produce similar total work values to prevent one group from working more than the other and having greater potential for gains in strength and/or endurance. The results of this study support that the total amount of work completed by each training program was similar. Consequently, this may be one reason why the researchers did not discover any between group differences.

Regardless of non-significant group differences, both groups had some participants that achieved improvements beyond measurement error in muscular strength and endurance across a six-week intervention. The authors acknowledge that meaningful improvements were not seen in the overall pre- to post- intervention scores within each of the groups (Table 3); rather, certain individuals exceeded the numerical value that represented a clinically relevant change in muscular strength and endurance while others did not. Fifteen participants demonstrated meaningful changes in either strength or endurance on the dominant and non-dominant arms. Of those 15 participants, nine increased in both strength and endurance, five participants within the traditional throwers group and four within the Advanced Throwers Ten group. These nine participants ranged in sex, age (19–52), weight (52–89 kg), height (66–183 cm), and MARX activity score (1–20), indicating that both these training regimes may be used on a diverse healthy population, which improves the external validity of this study.

This study is not without limitations as the Advanced Throwers Ten was initially proposed as a new approach to rehabilitate overhead throwing athletes, yet all of the participants enrolled were healthy adults with no previous history of shoulder or neck injury; therefore generalization to an injured population should not be attempted. The scaption exercise described by Wilk et al⁷ is performed with the patient sitting on a swiss ball, but the exercise used in this study did not incorporate the use of a stability ball as not all participants had access to such equipment. The exercise programs prescribed in this study were home-based. Given that the exercise program was home-based, the authors relied on the

participants' honesty regarding exercise compliance and avoidance of additional upper extremity weight-training. However, all participants completed a weekly exercise compliance log and were reminded to avoid upper extremity weight-training at each follow-up appointment. Furthermore, although all participants were instructed to perform the exercises continuously (i.e. no rest between repetitions), it is possible that some participants performed the repetitions slower than others, thus performing a greater volume of work. Future studies should incorporate the use of a metronome during exercise to avoid this possibility. Incorporating a supervised training session under a personal trainer has been shown to elicit greater gains in strength compared to unsupervised training in moderately training men; however, both modes of training have shown to improve strength by more than 20%.³¹ Lastly, the starting weight of 15% of the peak force generated may not have stimulated enough muscular demands to illicit early changes in strength and endurance. Future studies should consider increasing the starting weight to be equivalent to 20–25% of peak initial force. Because both exercise programs produced strength gains, future research should be conducted to investigate a combination of exercises from the two programs with respect to overhead athletes.

CONCLUSION

The current study is one of the first studies to investigate the use of sustained isometric exercises in comparison with traditional isotonic training exercises in the shoulder. Given the results, either set of exercises can be used to improve shoulder strength and endurance. Both sets of exercises are time efficient in that they only take five minutes to perform. The advanced throwers ten exercise investigated in this study provides variation to a commonly prescribed scaption exercise that may reduce boredom while training. In addition, incorporating sustained isometric holds during exercise may be beneficial for overhead athletes that must maintain elevation over an extended period of time as such exercises may reduce the likelihood of fatigue.

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