Abstract

Incorporating a visuomotor skill task with resistance training does not increase strength gains in healthy young adults

By

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Resistance training causes well-documented adaptations in the nervous system and increases maximal voluntary force of healthy human skeletal muscle in the trained and also of the same muscle in untrained limb. It is also well known that practice of a visuomotor skill without a load causes neural adaptations. These findings led to the hypothesis that a combination of resistance and visuomotor training would produce accelerated and larger gains in maximal voluntary force than each method alone. The purpose of the study was to compare strength gains produced by a loaded visuomotor and a traditional resistance training program. Subjects were randomly assigned to a visuomotor or resistance training group and completed 4 sets of 6 repetitions of elbow flexion at 70-85% of maximum intensity in each of 12 sessions over 4 weeks. The visuomotor vs. the resistance group performed significantly better in the visuomotor skill task. Maximal voluntary torque increased in the trained arm similarly in the two groups but, unexpectedly, not in the untrained arm. Although there is a strong conceptual and experimental basis for the hypothesis, under the present experimental conditions a combination of a visuomotor skill with loads compared with conventional resistance training did not produce superior strength gains.

Incorporating a visuomotor skill task with resistance training does not increase strength gains in healthy young adults

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By

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Table of Contents

List of Tables

List of Figures

List of Abbreviations

Chapter 1- Introduction

Healthy adults and a variety of patient groups use strength training as an exercise modality. The primary goal of strength training is to increase muscle size and strength of the target muscles because an increase in the capacity for torque production has many benefits in sport performance, injury prevention, injury rehabilitation, and activities of daily living. Conventional resistance training consists of a repetitive and well-defined movement pattern with few variations in direction or velocity while overcoming an external load. Resistance training causes thoroughly documented adaptations in elements of the nervous system. Acute increases in peak muscle force production have been identified after a single training session (Oliveira et. al 2010). Such increases occur before changes in muscle size. A combination of adaptations such as an initial increase in electromyographic (EMG) activity (Sale 1988), increase in agonist/antagonist coactivation (Duchateau et al. 2002), changes in cortical representation (Falvo et al. 2010) and cortical excitability (Griffin and Cafarelli 2006) are associated with the initial gains in strength. An increase in contralateral strength (cross education) after unilateral training is also associated with resistance training (Moritani and Devries 1979). Cross education is considered to be driven by neurological factors due to the lack of training stimulus and similar changes in cortical activation after resistance training (Farthing et al. 2007).

Visuomotor training involves high variations in movement direction and velocity through changes of joint position through visual tracking of a target movement pattern. Compared with neural adaptations produced during the repetitive and non-variant movements of resistance training, practice of a skill task or ballistic movement produces even more robust changes in the primary motor cortex (Jensen et al. 2005, Muellbacher et al. 2001, Perez et al. 2007). Increases in cortical excitability at rest and during a tonic contraction have been observed after the practice of unloaded visuomotor training (Jensen et al. 2005). Additionally, cortical excitability as well as increases in peak force production are evident after ballistic movement training requiring quick accelerations (Muellbacher et al. 2001).

Both resistance training with simple, repetitive, and unvaried movements and visuomotor training requiring complex movements with rapid changes in direction and velocity during an unloaded condition have been shown to cause adaptations in the nervous system. These observations raise the possibility that repeated practice of a motor skill with variations in direction and velocity under a loaded condition may accentuate neural adaptations and lead to a greater motor output compared with traditional resistance training after periods of chronic practice. To date, there is only one study that used repeated bouts of a visuomotor task with a load (Keogh et al. 2010). A significant increase in elbow flexor strength was observed in the visuomotor group. However an absence of strength increase in the strength training group brings into question the validity of the study. The results are also limited due to a lack of randomization and the unique age of the subject population (70-80 yrs). A lack of knowledge exists within the literature as to the efficacy of loaded visuomotor training and the Keogh et al. study indicates further investigation of loaded visuomotor skill training is warranted.

Purpose

The purpose of this study is to compare strength gains produced by a loaded visuomotor and a traditional resistance training program

Hypothesis

It is hypothesized that completing visuomotor skill training under a loaded condition will lead to greater gains in strength in the trained and untrained arms compared to traditional resistance training.

Delimitations

The delimitations of this study were as follows:

All Participants were healthy individuals with no history of neuromuscular or musculoskeletal pathologies.

Participants were right handed and scored a minimum 15 out of possible 30 on the Edinburgh Index (Oldfield 1970).

Participants did not participate in strength training of the upper extremities more than twice per week at least three months prior to training.

Training was limited to unilateral training of the right, dominant arm.

Participants were not allowed to participate in any form of upper body resistance training including body weight exercises outside of the training during the duration of the study.

Limitations

Analysis of data was limited to the precision and accuracy of the dynamometer, goniometer, and software programs used in data collection and analysis.

Participants were assumed to be truthful in the information they provided during the selection process as well as their cessation from upper body exercise during the training period.

Chapter 2- Review of Literature

Changes within the central nervous system, specifically in the primary motor cortex of the brain are central to the hypothesis. Neural adaptations play a role during the initial strength gains during resistance training, acquisition of a visuomotor skill, and performance of ballistic movements. With this in mind, the review of literature focuses on the evidence indicating the role of the motor cortex during these training activities.

Neural Adaptations in Response to Resistance Training

An abundance of evidence exists of neurological adaptations that occur during resistance training exercise. Theses adaptations are indicated by the significant increases in muscular strength before the onset of muscular hypertrophy. The timeline for muscle hypertrophy is hotly debated, measurable changes likely do not occur until 4-5 weeks of intervention (Blazevich et al. 2006, Defreitas et al. 2010)

Changes in neural activity are seen by the initial increase in surface electroymyography (EMG) following resistance training (Sale 1988). Conversely, a decrease in surface EMG has been seen with disuse, although this could be in part caused by atrophy in the size of the muscle fibers and increase in intramuscular fat (Gabriel et al. 2006). The change in EMG activity with both training and detraining is often interpreted as evidence of an altered neuronal drive to the muscle. Increased EMG activity has also been linked with an increase in the maximal voluntary contraction (MVC) (Sale 1988). The introduction of twitch interpolation provides a 2-5% increase in force over voluntary maximal strength (Gabriel et al. 2006). This indicates an incomplete activation of motor units even during maximal contraction, leaving room for changes in neural activation to improve force output through greater recruitment of motor units.

Changes in muscle force output prior to muscular hypertrophy may further be modulated by coordination of the agonist and antagonist muscle groups. Agonist muscle contractions are accompanied by a smaller co-contraction of the antagonist muscle group. This is often referred to in the literature as agonist/antagonist coactivation. A certain level of coactivation is important for joint stability and joint health. The coactivation of the antagonist muscle decreases the net muscle force of the agonist muscle as it overcomes the antagonist force. A decrease in the activation of the antagonist muscle groups could lead to a decrease in the amount of resistance from antagonistic muscle groups and therefore lead to an increase in net agonist muscle force. The concept of resistance training reducing antagonist muscle activity during a MVC of the trained muscle is somewhat controversial due to conflicting reports. One study actually observed an increase in antagonist muscle coactivation after resistance training in older adults (de Boer et al. 2007). While there is disagreement in the concept of agonist/antagonist coactivation, it is generally accepted within the literature that resistance training improves coordination between the agonist and antagonist muscle groups (Duchateau and Enoka 2002). Upon the assessment of knee extensor strength after 8 weeks of isometric training, participants were found to have increased knee extensor strength by 32.8% (Carolan and Cafarelli 1992). This strength increase was accompanied by a decrease (14.9% to 11.5% of peak) in EMG of the antagonistic Biceps Femoris muscle without change in knee extensor EMG activity. Coactivation of the antagonist muscle group is another area in which neurological changes in muscle recruitment can affect measured strength.

The nervous system plays an important role in the early stages of strength training. It is believed that increased recruitment of motor units and changes in agonist/antagonist coactivation are responsible for increases in the maximal voluntary force produced. How and where these adaptations are modulated is controversial. Two possible locations of adaptation are within the spinal cord and the motor cortex of the brain. The next section provides evidence that neural adaptations occur within the motor cortex of the brain after chronic resistance training.

Adaptations of the Motor Cortex during Resistance Training

There are conflicting reports of whether changes occur within the primary motor cortex after traditional resistance training. Traditional resistance training may produce changes that are more subtle and harder to detect than either skill training or ballistic training. However, cortical involvement during strength training is clearly evident by the cross education effect. Cross education manifests in strength training as an increase in contralateral limb strength during unilateral strength training. Cross education is a well documented phenomenon and has been shown to increase analogous muscle group strength in healthy adults (Moritani and Devries 1979) and increase voluntary activation (Lee et al. 2009). The cross education of strength is associated with changes within the motor cortex. The use of functional magnetic resonance imaging (fMRI) to measure areas of activation within the brain showed changes in the areas of activation associated with ulnar deviation movements(Farthing et al. 2007). Alterations in the activation areas for the training movement occurred in the motor cortex of both the trained and untrained hemispheres. These changes were accompanied by an increase (47.1%) in strength of the untrained arm. The fMRI imaging indicates that the motor cortex plays a strong role in cross education. Changes occurred in the trained hemisphere provide further evidence of adaptations by the motor cortex are associated with gains in strength.

There are studies indicating that the motor cortex does not play a primary role in neural adaptations to strength training. Most notably Jensen et al. (2005) measured no increases in cortical excitability in response to resistance training in able bodied adults. This information is in conflict with evidence reported by Griffin and Cafarelli (2006), which observed increases (32%) in the maximal motor evoked potential (MEP max) in the tibialis anterior after training. Excitability has also been shown to increase through the decrease in the silent period before onset of surface EMG directly after a transcranial magnetic stimulation pulse (Kidgell et. al 2010). Furthermore, Hortobágyi et al. (2009) showed that when a virtual lesion is delivered to the intact brain during strength training using repetitive magnetic brain stimulation (rTMS), rTMS inhibited strength gains, implicating a direct role for the motor cortex. Changes within the motor cortex are also observed when measuring the movement related cortical potentials (Falvo et al. 2010). A decrease in the movement related cortical potentials after three weeks of leg extensor training indicates a re-organization of the motor representation within the motor cortex after resistance training.

Neural adaptations to resistance training are evident almost immediately after a training stimulus is introduced. Although it is debated as to the location and function of these adaptations, there is a strong argument indicating that the motor cortex plays a role in modulating initial strength gains. Adaptations to resistance training seem to be similar to those occurring due to skill training, which appear to be highly cortical in nature.

Neural adaptations in response to skill training

It is generally accepted that the motor cortex plays a large role in skill acquisition. There are many types of skill training. The hypothesis of this study focuses on the benefits of skill training in providing variation in movement velocity and direction through non-stereotypical movement patterns. This is achieved with various feedback devices dictating changes in joint position. The device could provide any sort of sensory cue (visual, auditory, somatosensory, etc.) to the participant to alter their movement pattern. The type of skill training discussed in this review and proposed research can be classified as visuomotor tasks. Visuomotor tasks involve visually tracking an input controlled cursor displayed on a computer monitor while attempting to follow a target movement pattern. The cursor moves from left to right across the screen with vertical movement controlled by the participants' joint position. Participants attempt to match the displayed target pattern through changes in their own joint position as measured using an electronic goniometer.

It has been shown in a number of studies that skilled task training causes changes in corticospinal excitability and changes in areas of activation similar to resistance training. Most notably, Jensen et al. (2005) observed an increase in the maximum motor evoked potentials in the biceps brachii at rest and during contraction after acute and chronic visuomotor skill training. Inversely, there was a decrease in the threshold for a motor evoked potential in response to TMS. Similar adaptations in the motor evoked potentials were also evident in the tibialis anterior after acute visuomotor training. (Perez et al. 2004). Similar changes to resistance training were also found using fMRI imaging. After four weeks of practice doing a finger tapping task, the areas of activation during the skill task were significantly greater and the changes persisted over several months (Karni et al. 1995) Electroencephalographic (EEG) evidence also indicates adaptations occurring within the motor cortex of the brain. After participating in acute visuomotor training, an increase in the coherence between EEG and EMG waves was observed in the tibialis anterior (Perez et al. 2007). Furthermore, individuals within a control group who participated in voluntary movements of the ankle without a tracking task had no changes in cortical excitability (Perez et al. 2004). This would indicate that the intent to track the target or respond to feedback is an important aspect in eliciting adaptations in the motor cortex.

Individuals participating in visuomotor skill training exhibit large amounts of cortical involvement in response to acute and chronic practice of a visuomotor skill task. Cortical adaptations are not limited to visuomotor skill training as they have also been measured in ballistic movements. (Muellbacher et al. 2001, Lee et al. 2010).

Ballistic movements as a skilled task

Visuomotor skill training requires variations in limb position and velocity but not necessarily at a high rate. Another form of motor practice that evokes adaptations in the nervous system is the rapid, ballistic, execution of simple movements. The same cortical adaptations to visuomotor training are evident when using training protocols that include ballistic or high-velocity movements. These high velocity movements require a quick acceleration of the motion segment and therefore very rapid force production from the synergist muscle group. Ballistic movements have been shown to increase force production and peak acceleration in the Flexor Pollicis Brevis after ballistic finger pinching while no significant changes occurred for ramp, or slower build-ups in force, after training (Muellbacher et al. 2001). The two training groups performed identical tasks with joint kinematics only differing in acceleration between groups suggesting that acceleration may have play an important role in behavioral gains. Changes in force production and peak acceleration were accompanied by increases in the motor evoked potentials after isometric (Muellbacher et al. 2001) and dynamic ballistic resistance training (Beck et al. 2007) indicating significant involvement of the motor cortex. This is further evidenced in a smaller group that underwent additional stimulation at the brainstem and spinal levels. No changes occurred in excitability in response to brainstem stimulation (a measure of motoneuron excitability without cortical influences) or to peripheral nerves stimulation (a measure of the spinal reflex) suggesting that the adaptations occurred primarily in the motor cortex (Muellbacher et al. 2001).

Ballistic movements require a strong descending drive and it has been observed that activities with strong descending drive generate extensive bilateral cortical activity. This bilateral cortical activity may facilitate cross education and improvements in task performance were measured bilaterally after unilateral ballistic finger tapping training (Lee et al. 2010) Lee further demonstrated the importance of the contralateral cortical hemisphere in retention of learned tasks. Virtual lesions created by repetitive transcranial magnetic stimulation in the untrained cortical hemisphere decreased finger tapping performance in the trained hand. This indicates the role of the contralateral portion of the motor cortex in the retention of motor learning.

Changes in the cortical excitability, motor representation, and interhemispheric involvement in ballistic movement training are evidence that ballistic type movements are skilled tasks in terms of motor learning. The changes are similar to those that occur during other types of skill training. Muellbacher et al. (2001) observed no changes after ramp pinching exercises, indicating that the velocity of the contraction is an important variable in evoking cortical changes. There is a continuum of motor practice that evokes neural adaptations and a correlated increase in mechanical or motor output. Resistance training uses simple, non-variant movements at a slow rate and engages elements of the central nervous system. Visuomotor training normally incorporates slow but position- and time-varying movements and produces functionally important increases in motor output mediated by adaptations in the CNS. Execution of simple movements ballistically also brings about parallel adaptations in the CNS and motor output. Thus, there exists the possibility that varying position, rate of movement, task complexity, and resistance would maximize the stimulus for neural adaptations and strength gains.

Practice of Visuomotor Skill Training under Loaded Conditions

There is currently a lack of information available about loaded visuomotor skill training. To date, only one study could be found that incorporated a protocol involving the chronic practice (4 weeks) of a visuomotor skill task under a loaded condition (Keogh et al. 2010). Participants from the Keogh et al. (2010) study in the loaded visuomotor skill group were reported to have significant increase in elbow flexor strength while there was no change in a traditional resistance training group. However, there were no significant changes in strength of the untrained limbs in either the visuomotor skill training or traditional resistance training group. Additionally, a decrease in the coactivation of the trained limb in both training groups was reported. While the Keogh et al. (2010) study does report observations favorable to the hypothesis, the study did not provide any direct statistical comparisons between the traditional resistance training and visuomotor training group. Furthermore, the results are limited by selection of and the lack of random allocation of the participants within groups. It is of some interest that despite resistance training for four weeks the traditional resistance training group did not significantly improve strength and must be kept in consideration when analyzing the results. The increase in strength after undergoing loaded visuomotor training does provide evidence that further research is warranted.

Summary

Resistance training produces adaptations in elements of the central nervous system that are evident almost immediately after a training stimulus is introduced. These neural adaptations help explain the increase in muscular force output before the occurrence of muscle hypertrophy. There is debate as to the function and location of these adaptations. It appears as if the human body relies upon adaptations, at least in part, by primary motor cortex to produce initial gains in force output. Increased EMG activity and agonist/antagonist coordination are two adaptations responsible for performance gains in muscle force. Changes in the movement related cortical potentials, inhibited strength gains with the introduction of a virtual lesion during resistance training, and increases in cortical excitability provide evidence of cortical involvement facilitating initial strength gains (Hortobágyi et al. 2009, Falvo et al. 2010, Griffin and Cafarelli 2006). This occurs despite the unvaried and simple movements of resistance training.

Similar adaptations during visuomotor and ballistic training rely heavily on cortical involvement for task performance, evident by the changes in cortical representation and the increase in cortical excitability after visuomotor and ballistic type training (Jensen et al. 2005, Muellbacher et al. 2001, and

Perez et al. 2007). Visuomotor training requires complex movements with variation in speed and direction while ballistic training requires quick accelerations that are not practiced during traditional resistance training.

Neural adaptations to resistance training are associated with similar changes in the motor cortex as seen with ballistic and motor skill training, despite the inherent differences in the training types. These observations raise the possibility that by combining visuomotor skill training with a load used during traditional resistance training and incorporating quick changes in direction or ballistic type movements, neural adaptations may be accentuated. Since adaptations within the neurological system are associated with initial gains in strength, it is logical to believe that greater adaptations would lead to greater increases in strength gains. With the neural adaptations gained from the combination of training types it is hypothesized that individuals participating in visuomotor training under a loaded condition will exhibit greater strength gains. It is with this theory in mind that this study seeks to investigate the effectiveness of a loaded visuomotor motor skill task incorporating ballistic type movements at increasing elbow flexor strength compared to a traditional resistance training protocol.

Chapter 3- Methodology

The purpose of this chapter is to describe the procedures and equipment used during the experimental testing of the stated hypothesis. This chapter is divided into several subsections including participants, instrumentation, testing protocol, training protocols, and data analysis.

Participants

Participants for this study were healthy college age students between the ages of 18 and 25. Twenty-five participants were recruited and randomly assigned into one of three groups; training (ST), visuomotor training (VM), and control (CO) (ST n=10, VM n=10, CO n=5). The recruitment of participants will be done through word of mouth and advertisements in classrooms and on the campus of East Carolina University. All participants will be selected based on a set of inclusion and exclusion criteria.

Inclusion Criteria:

Participants were within the designated age group.

Participants were right hand dominant with a minimum score of 15 out of possible 30 on the Oldfield handedness test.

Participants had not engaged in upper body resistance training more than two times per week during the previous three months.

Exclusion Criteria:

Participants had a previous history of recent or serious musculoskeletal injury or neurological issue

Participants were currently taking medication that may affect neurovascular or musculoskeletal function.

Instrumentation

Visuomotor task performance was quantified using a purpose built electronic goniometer and software program. The goniometer measured joint position using a potentiometer powered by the voltage output from the Cambridge Electronics analog-to-digital converter board (model number 1401). The device consisted of a fixed arm containing the potentiometer and a wiper arm that rotated the axis of the potentiometer. The goniometer was secured to the lateral portion of the elbow and changes in joint position caused the wiper arm to rotate in relation to the fixed arm. The rotation of the wiper arm around the axis of the potentiometer changed the voltage output of the potentiometer. The voltage output from the goniometer was converted into a digital signal and the software displayed a red cursor on the monitor as a representation of joint position. The cursor automatically moved left to right at a constant sweep speed while the participants controlled the vertical path of the cursor. Elbow flexion moved the cursor towards the top of the screen while extension moved the cursor towards the bottom of the screen. The goal of the participant was to match as accurately as possible a target movement pattern visually displayed on the computer monitor in the form of a white line. The absolute difference between the template path and the participant's path was calculated as the error.

Strength was completed using a HUMAC/NORM model 770 testing and rehabilitation system. The dynamometer head was positioned at the maximum height and 40 degrees of rotation. The chair was positioned at 45 degrees of rotation with the back rest leaning in the maximal forward position. Further positioning of the chair and preacher rest height was adjusted to the individual participants. The dynamometer range of motion was be set at ten degrees short of anatomical zero and at 140 degrees of elbow flexion for a total of 130 degrees of motion. Torque measurements were corrected for gravitational forces due to the mass of the arm using the HUMAC software. Isometric contractions were tested at 85 degrees of elbow flexion with a duration of five seconds for contraction and rest intervals.

Testing Protocol

Each group participated in pre, mid, and post training assessment of muscle strength using an isokinetic dynamometer. Participants were seated and secured in a unilateral preacher curl position. Ten repetitions of concentric/eccentric contractions at 60 degrees per second were completed as a warm-up prior to testing. Testing was dictated by a pre-determined randomized order to designate which side will be tested first. The order of testing for each condition was also randomized for the right and left sides. Bilateral assessment of elbow flexor strength was taken isokinetically at 30 and 90 degrees per second concentric and eccentrically. The peak value of three maximal trials was recorded as the peak torque output at the specific speed and contraction type. Muscle torque was also measured isometrically.

In addition to pre, mid, and post assessments of strength, a visuomotor component will be included in the testing to compare the performance between groups. Participants were seated in the same preacher curl position. A purpose built electronic goniometer was secured to the lateral portion of the participant's arm with the axis of rotation aligned with the joint center of the elbow. Two testing templates were used to determine each participant's proficiency at completing the visuomotor skill task. The difficulty was varied between the two templates through the slope of the lines within each template. A variation in slopes changes the contraction speed and increases the difficulty of the task. One template contained no variations in slope throughout the template and had no variations in contraction speed (Fig. 1). The other template contained small variations in the slopes throughout the template (Fig 2). This meant that there were variations in the speed of the contraction within the template and therefore was a more complex visuomotor task. Participants completed each template with and without a load. The load was determined from the peak isokinetic torque collected for the elbow flexors. The highest recorded isokinetic concentric elbow flexor torque (Nm) was converted using a formula [torque (Nm)*.2248 (lbs/N)*39.7 (in/m)/forearm length (in) =F (lbs)] to determine an equivalent external load in pounds. During testing, participants completed the loaded condition for each template while holding a free weight dumbbell corresponding to 30% of the calculated force (lbs) measured for the individual arm. Test order between the right and left arms was randomized as well as the four conditions for each side (loaded and unloaded for the variable speed and non-variable speed templates).

Fig. 1

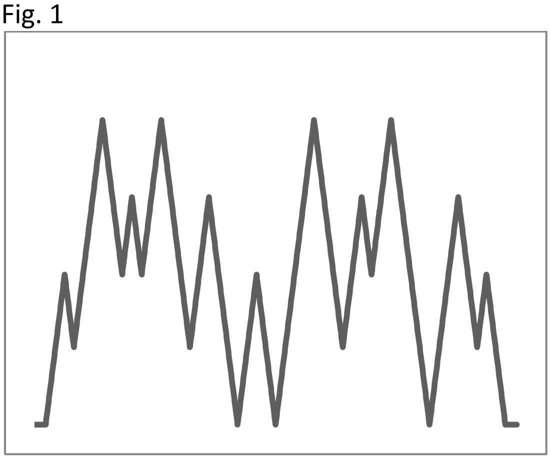
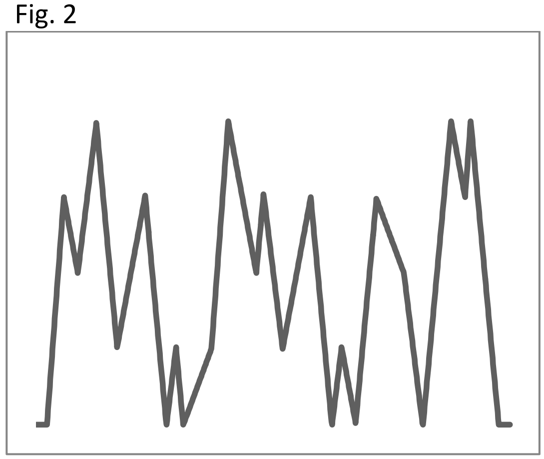


Fig. 2



Figures 1 and 2 showing the non-variable and variable speed templates

Training Protocols

The VM and ST groups participated in twelve training sessions. The twelve sessions were split with six sessions between pre and mid testing and six sessions between mid and post testing. Training took place three times per week. Both training groups completed the same warm-up protocol consisting of ten repetitions at a free weight load of twenty and forty percent of the peak isokinetic concentric elbow torque. Training intensity was increased in intervals of three training sessions. An initial load of 70% the calculated peak force was administered for the first three training sessions followed by an increase to 75% during trainings four through six. Mid-testing was completed after the sixth training session and new training values were calculated from the peak isokinetic concentric elbow flexor torques. Intensity for trainings seven through nine were 80% and for trainings nine through twelve the intensity was 85%. The strength training group completed four sets of six repetitions while the visuomotor group completed four training templates. The templates were designed to equal approximately the same total angular displacement at the elbow as the six repetitions in the strength training group. Three seconds was calculated for each repetition in order to achieve a 90 deg/s average velocity, equaling 18 seconds for a set of six repetitions. Speed was controlled by the computer software and each template is set to last ~18 seconds. Each set of six repetitions was timed on a stopwatch for the strength training group and verbal feedback to increase or decrease the speed of each rep was given at the end of each set when an individual set lasted less than 16 seconds or more than 20 seconds. Feedback was given at the end of each to avoid feedback driven changes in motor behavior that is central to the skill task training. The protocols were designed so that both the time and angular displacement of the elbow would be approximately equal during both training protocols.

To incorporate a ballistic type movement into the training protocol for the VM group, instantaneous changes from negative to positive velocities were incorporated into the templates. The templates take on a jagged instead of a rounded appearance as a result of the instantaneous changes (Fig. 3). Such changes are not physiologically achievable. However, they were included in the templates to encourage the subjects to complete very quick changes in direction with high rates of force development.

Fig. 3

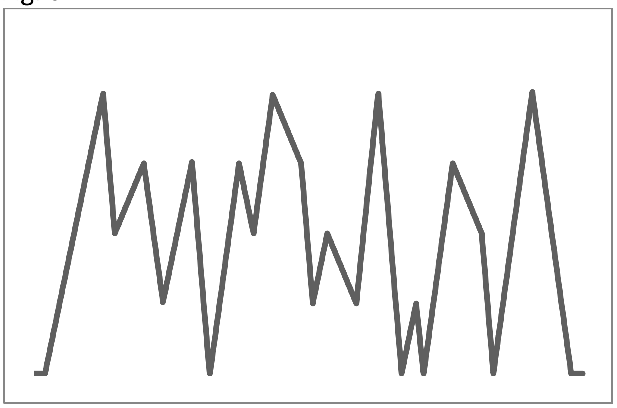


Figure 3 Instantaneous change from positive to negative velocities make the templates take on jagged appearance and encourage ballistic movements

Data Analysis

Changes in isometric and isokinetic peak torque of the elbow flexors were evaluated using SPSS software. A group by time repeated measures ANOVA was used in an attempt to identify differences in strength gains between groups. Additional repeated measures ANOVA's were used to determine if changes in pre and post test peak torque values were significantly different within groups. All testing was completed bilaterally and all conditions were compared in the untrained arm to investigate any possible differences in cross education effect.

Chapter 4- Results

Demographics

Table A

Group Statistics													
				Age (Years)		Height (m)		Mass (kg)		BMI		**Oldfield Score	
Group	N	Males	Females	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
RT	10	4	6	20.3	2.06	1.74	0.10	74.62	13.45	24.51	3.38	28.60	5.89
VM	10	4	6	19.5	1.35	1.72	0.07	66.22	12.61	22.24	2.96	27.10	7.05
CO	5	3	2	21.0	1.73	1.77	0.09	68.54	14.31	21.65	2.87	21.80	4.02
* Indicates statistical difference between pre and post measures under specific speed condition **(+ score indicates right handedness +40 max, -40 min)													

Table A lists the descriptive statistics for all subjects. There were no statistical differences between groups in any of the demographic categories. Additionally, there were no statistical differences between groups in any of the testing conditions or group means in the pre-test measurements of torque or visuomotor skill testing in the trained or untrained arm (Appendix D).

Comparison of Training Protocols

Table B

Training Velocities and Total Elbow Displacement				
	RT		VM	
	Average	St Dev	Average	St Dev
Velocity (deg/s)	83.1	6.0	72.2	8.3
Displacement (deg)	1462	73	1346	167

Table C

Training Range of Motion				
Group	RT		VM	
Bin(deg)	Average	St Dev	Average	St Dev
0-46	37.8%	5.9%	33.1%	3.6%
47-94	25.7%	3.6%	37.5%	3.7%
95-140	36.5%	2.5%	28.1%	1.1%

Joint position data was collected during the visuomotor training sessions and used to calculate average velocity, total elbow displacement, and percentage of time spent within ranges of elbow motion. In the RT group a small sample (n=3) was used to collect joint position data during one training session. The target for average contraction velocity was 90 deg/s. Joint positional data collected from the visuomotor training sessions indicated that the average training velocity in the VM group was 72.2 deg/s, while the average velocity in the RT group was 83.1 deg/s (Table B). The average elbow joint displacement for each set was 1462 degrees in the RT group and 1346 degrees in the VM group. Range of motion of the elbow was split into three equal bins and percentage of time spent in each bin was calculated in the two training groups. The RT group spent 37.8% of the training sessions between 0 and 46 degrees while the VM group spent 33.1% in that same range of motion (Table C). 25.7% and 37.5% of the time was spent in the 47 to 94 degree bin for the RT and VM group, with the remaining 36.5% and 28.1% of the time spent in the 95-140 degree bin.

Strength Testing

Fig. 4

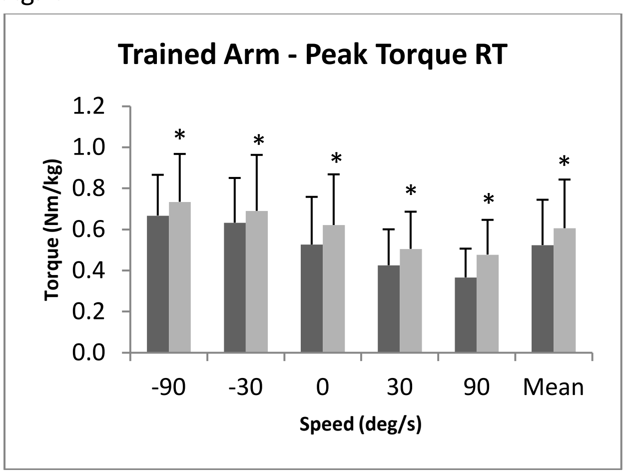


Fig. 5

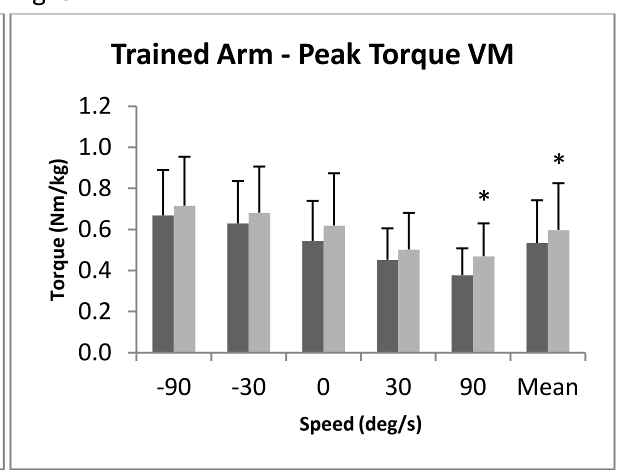


Fig. 6

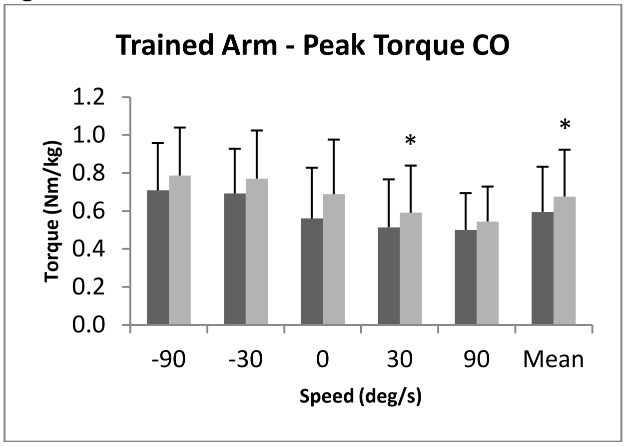


Fig. 7

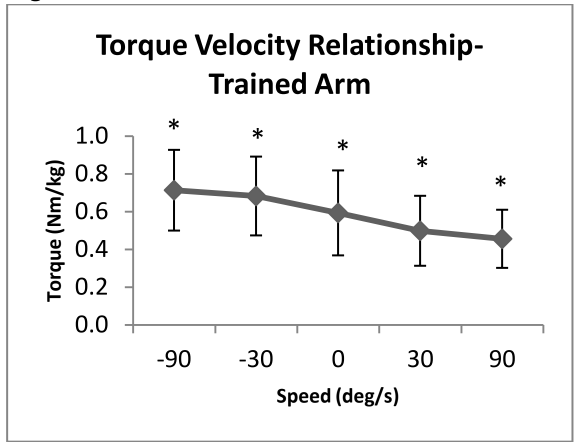


Table D

Analysis of Variance of Peak Torque - Trained Arm			
Tests of Within-Subjects Effects			
Source	Sig.	Partial Eta Squared	Observed Power
Time	0	0.597	1
Time * Group	0.776	0.023	0.085
Speed	0	0.813	1
Speed * Group	0.923	0.034	0.175
Time * Speed	0.463	0.04	0.278
Time * Speed * Group	0.84	0.045	0.226
Tests of Between-Subjects Effects			
	Sig.	Partial Eta Squared	Observed Power
Group	0.786	0.022	0.083

Figures 4, 5, and 6
These figures illustrate the changes in peak torque at each of the testing conditions and the mean across conditions.
* Indicates significant differences between the pre and post test measures.
Figure 7
Illustrates the peak torque for each testing velocity
*Indicates significant difference between all other testing conditions
Table D
List of the p values, effect size, and observed power of the statistical analysis of the changes in peak torque of the three groups in the trained arm

Trained Arm

Torque values are reported normalized to subject mass. There were no differences found in analysis of the non-normalized compared to the normalized torque. In the trained arm, for the combined groups there was a significant time effect for the changes in peak torque from pre to post

(0.55-0.63 Nm/kg, p<.001). A significant speed effect was present (p<.001, Fig. 7). A Tukey's post-hoc analysis indicated significant differences between all conditions. The RT group increased peak torque across the five contraction conditions from 0.52 to .61 Nm/kg (p=.006, Fig. 4). Significant increases in peak torque were present at all of the testing conditions for the RT group. (Ecc 90 p=.022, Ecc 30 p=.044, ISO p=.018, Con 30 p=.021, Con 90 p=.009). The VM group also increased mean torque from .53 to .60 Nm/kg (p=.006), however significant changes could only be identified under the 90 deg/s condition from pre to post (p<.001, Fig. 5). The CO group increased peak torque from .60 to .68 Nm/kg across the testing conditions (p=.019), and significantly increased torque at the 30 deg/s concentric condition (p=.001, Fig. 6). There were no significant group effects or time*group interactions. A partial Eta of .022 indicates a moderate effect size. The observed power of the analysis was .083 (Table D)

Fig. 8

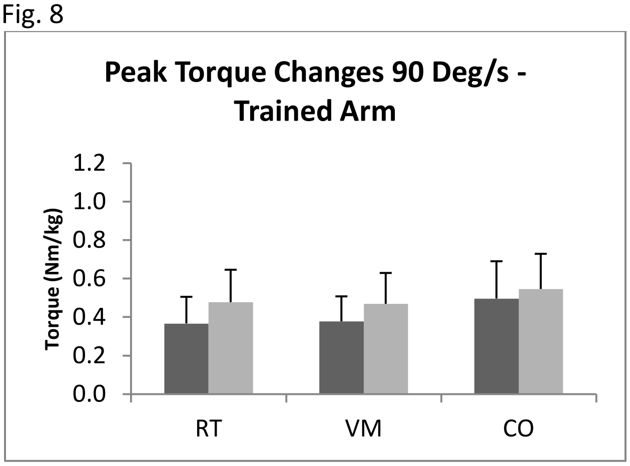


Figure 8 Illustrates the changes in peak torque at 90 deg/s for each group. There were no significant group or group*time interactions

Table E

Percent Change in Group Means - Trained Arm					
Group	Ecc 90 deg/s	Ecc 30 deg/s	Isometric	Con 30 deg/s	Con 90 deg/s
RT	10%	9%	18%	19%	30%
VM	7%	8%	14%	11%	24%
CO	11%	12%	23%	14%	10%

A separate analysis was conducted at the target training speed. A group by time ANOVA analysis of the 90 deg/s concentric condition was conducted and no group*time or time*speed interactions could be identified (Fig. 8). Effect size (.072) and observed power (.177) were both low in the group*time interaction. Observed power (.285) was low for the time*speed interaction but the largest Eta squared value (.542) of any of the speeds was present under the 90 deg/s condition. Percent change of the group mean was calculated for each condition. The largest percent change occurred at the 90 deg/s concentric condition (Table E).

Untrained Arm

Fig. 9

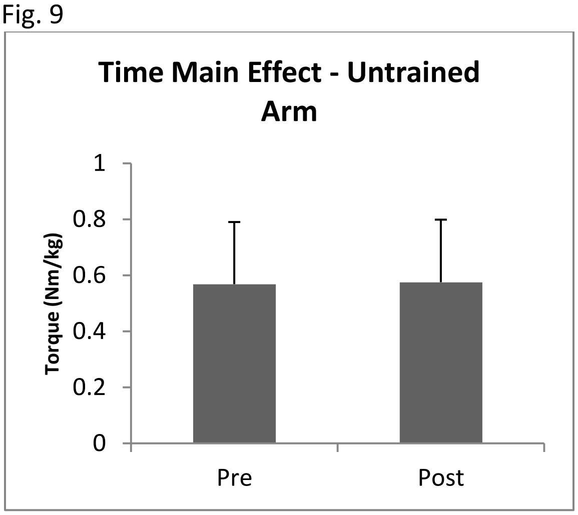


Fig. 10

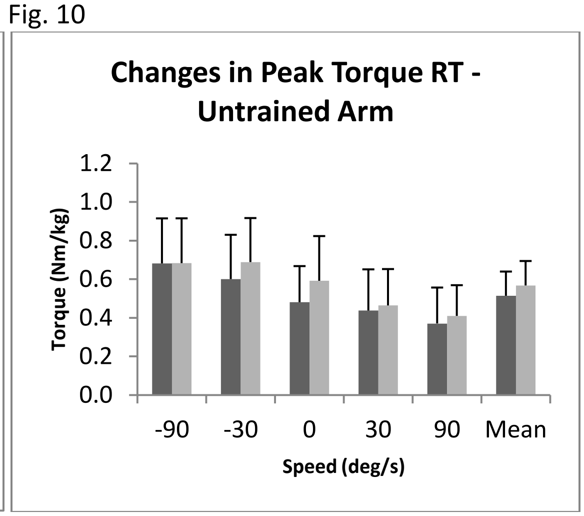


Fig. 11

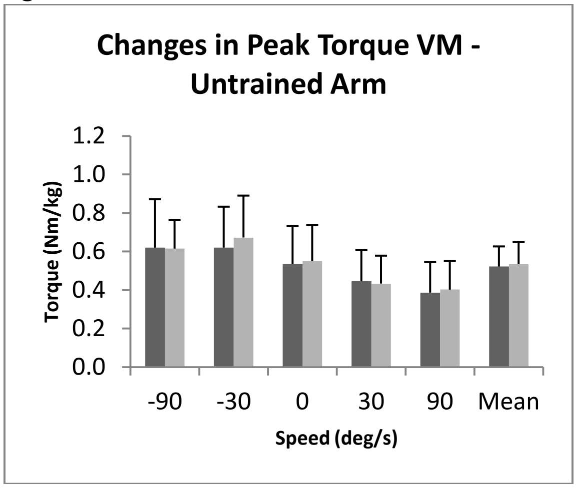


Fig. 12

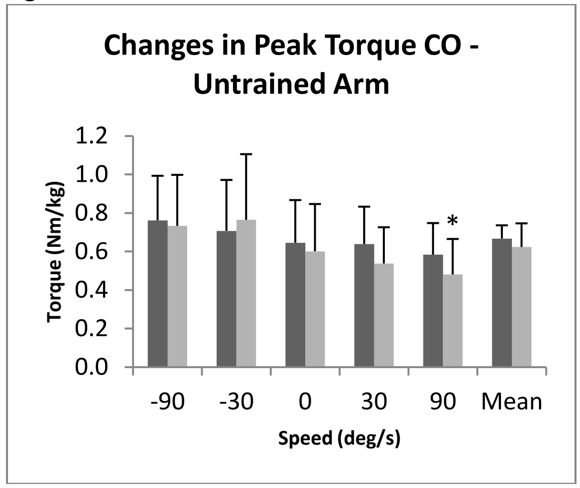


Fig. 13

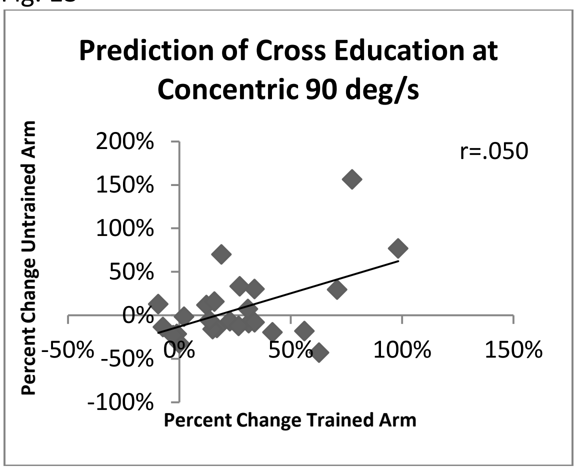


Figure 9
Illustration of the time main effect for cross education of strength to the untrained arm. Changes between pre and post were not significantly different
Figures 10, 11, and 12
These figures illustrate the changes in peak torque at each of the testing conditions and the mean across conditions.
* Indicates significant differences between the pre and post test measures.
Figure 13

Table F

Percent Change in Group Means - Untrained Arm					
Group	Ecc 90 deg/s	Ecc 30 deg/s	Isometric	Con 30 deg/s	Con 90 deg/s
RT	3%	21%	29%	12%	24%
VM	4%	12%	6%	-1%	6%
CO	-5%	6%	-10%	-15%	-20%

In the untrained arm, there was not a significant time effect (Fig. 9). The only significant difference in peak torque was identified in the untrained arm was a decrease under the 90 deg/s concentric condition in the CO group (Fig. 12). There was a significant change (.031) in peak torque in the isometric condition for the non-normalized data in the RT group. A linear regression identified a moderate (r=.50) correlation between the magnitude of percent change in the untrained arm with the magnitude of percent change in the trained arm at the 90 deg/s concentric condition for all subjects (Fig. 13). The relationships were also moderate within the isometric condition (r=.44) and interestingly the relationship was strongest at the 30 deg/s concentric condition (r=.60).

Visuomotor Skill Testing

Trained Arm

Table G

Visuomotor Error (deg) - Trained Arm									
		Loaded Non-Variable		Unloaded Non-Variable		Loaded Variable		Unloaded Variable	
Group	Time	Mean	SD	Mean	SD	Mean	SD	Mean	SD
RT	Pre	11.8	3.6	12.0	3.1	14.0	2.9	13.1	2.6
	Post	11.2	2.9	10.7	1.8	12.5	1.9	11.1	3.4
VM	Pre	18.1	5.4	16.6	2.6	18.4	4.4	15.8	4.9
	Post	*9.3	1.7	*8.9	1.6	*10.9	2.2	*9.3	1.7
CO	Pre	15.8	4.3	13.5	3.7	15.0	3.6	14.5	1.6
	Post	12.6	3.0	*9.7	2.9	*11.6	2.6	*11.3	2.3
* Indicates statistical difference between pre and post measures under specific visuomotor condition									

Due to loss of data during the collection process not all subjects could be included for a pre to post analysis for each condition. Therefore the group sizes vary for the comparisons with the group size being no lower than four in the CO group and no lower than eight in the RT or VM groups for any testing condition. A significant time effect was present in the trained arm (p<.001). Mean error across time decreased from 13.5 to 10.4 degrees. Post-hoc analysis indicated that the error was significantly greater under the loaded variable speed condition compared to the other testing conditions. The time*group interaction was not significant (p=.052). Despite the low statistical power, a partial Eta squared value of .281 indicates a large effect size. Individual analysis of the groups using separate ANOVA's showed a significant time effect for the VM group (p<.001) and the CO group (p=.006). A significant decrease in error for each of the four testing conditions was found in the VM group (Table G). Error decreased significantly under the unloaded non-variable speed (p=.003), loaded variable speed (p=.042), and the unloaded variable speed conditions in the CO group. There was no significant time effect and none of the changes in error across the four testing conditions in the RT group were statistically significant.

Untrained Arm

Table H

Visuomotor Error (deg) - Untrained Arm									
		Loaded Non-Variable		Unloaded Non-Variable		Loaded Variable		Unloaded Variable	
Group	Time	Mean	SD	Mean	SD	Mean	SD	Mean	SD
RT	Pre	14.0	5.4	12.3	4.8	15.7	4.8	12.6	3.1
	Post	11.2	2.4	12.1	4.1	12.7	2.0	*10.7	3.0
VM	Pre	15.5	5.1	14.0	2.7	15.6	4.2	13.5	4.5
	Post	*11.0	1.3	*8.7	1.1	*11.2	3.0	11.4	4.7
CO	Pre	13.3	2.1	14.4	4.3	15.8	1.7	15.5	4.6
	Post	12.2	3.2	9.7	2.9	12.8	3.4	11.3	2.3
* Indicates statistical difference between pre and post measures under specific visuomotor condition									

A cross-education effect of the skilled task was present as the untrained arm exhibited a significant decrease in mean error from 13.7 to 11.2 degrees for the combined groups (time effect p=.004). However there again was no group or group*time effect so mean error changes between groups is assumed to be equal. Error under the loaded variable speed condition was determined to be significantly different than the other testing conditions. A positive time effect was seen in the VM group (p=.029) as well as significant decreases in error under the loaded non-variable (p=.030), unloaded non-variable ($p=.001$), and loaded variable speed conditions ($p=.027$, Table H). No time effect was present and error only decreased significantly under the unloaded variable speed condition in the RT group ($p=.004$). No time effect or significant changes were found in the untrained arm for the CO group.

Chapter 5 – Discussion

Comparison of training protocols

There are inherent differences between traditional resistance training and visuomotor training. Visuomotor training involves variation in velocity and direction during completion of the visuomotor tracking task. This differs from the highly repetitive and invariant movement pattern practiced during traditional resistance training. These differences are central to the hypothesis that completing visuomotor skill training under a loaded condition will lead to greater gains in strength in the trained and untrained arms compared to traditional resistance training. Time under tension for both groups was approximately equal, while the average training velocities and total elbow joint displacements were similar.

The visuomotor task under higher loads was demanding and subjects in the VM group had difficulty moving the weight through the entire range of motion while maintaining the target velocity. This is likely to have contributed to the differences in the training velocities. Gains in strength exhibit some specificity in that the greatest gains are seen at the training speed (dos Santos et al. 2011). Changes such as in the dos Santos article occurred when testing speeds were manipulated by 60 deg/s, so a difference in training speed of 11 deg/s is not likely to affect the results of this study.

Since the subjects were using a free weight load, resistance was not constant throughout the entire range of motion. Total external load will vary as the extensor torque caused by the free weight will change based upon the distance of the load from the joint center. Since the training was completed in a seated preacher curl position, the greatest external loads occurred at joint positions in the middle of the range of motion. Analysis of the data for the training groups showed a similar distribution of time spent in the three range of motion bins.

The groups underwent similar loading throughout the training based upon their similar times spent in each range of motion bin and the identical free weight intensities. Both groups exhibited similarities in the total range of motion and the velocity of training. Additionally, by controlling the time to set completion, the time under tension was approximately equal.

Peak torque increased in the trained arm

All three groups increased strength over time. The changes in peak torque exceeded the changes in isometric peak torque reported by Jensen et al. 2005 after a similar elbow flexor training protocol. The RT protocol was effective at increasing peak torque under all of the testing conditions, while the VM group increased torque at conditions closest to the training speed. Despite bringing in subjects for a familiarization period prior to testing, it appears as if it was insufficient to curb the learning effect of completing the novel task of the isokinetic testing. Peak torque increased over time in the CO group, therefore the changes in peak torque within the training groups cannot be attributed solely to the training interventions. No differences in the changes between groups could be determined and the relatively low statistical power is an indication that a larger sample size is needed.

There was a high degree of variability in the percent changes between subjects which may have contributed to the lack of a group*time interaction. One possibility to account for variability could come from the testing protocol. Testing conditions were randomized for each testing session. Therefore, the order in which the tests were completed was different during pre and post testing. One condition may have been completed early in the order during the pre testing and later in the order during post testing. This testing design may affect peak torque due to muscle fatigue. There were no measures taken for muscle fatigue. Rest as little as 60 seconds has been shown to have no significant effects on peak torque production during isokinetic testing at varying speeds in the knee extensors (Parcell et al. 2002). Time between testing conditions was not standardized, but the intervals exceeded one minute. Measures of peak torque and variability within groups were comparable to findings from other studies involving the elbow flexors at both concentric and isometric conditions (Wittstein et al. 2010, Labarque 2002, Askew et al. 1985). Additionally, significant differences were found between all of the testing speeds and the data exhibited a standard torque velocity relationship. However, since the Parcell et al. study was conducted in the lower extremities it is possible that the muscle fatigue may exhibit differing onsets in the upper extremities and because time between conditions was not directly controlled, subject fatigue as a cause of variability cannot be ruled out.

Strength gains at the training speed

It has previously been shown that training adaptations are greatest under conditions most similar to the training type (Coyle et. al 1981, dos Santos et. al 2011). Changes in peak torque should be observed to be the greatest under conditions analogous to the training velocity. Training was completed using free weight loads and therefore velocity could not be directly controlled unlike using an isokinetic dynamometer. However, the average training velocity was closest to the 90 deg/s testing condition in both training groups. This would dictate that the greatest changes in peak torque would be seen under those testing conditions. The non-significant time*speed interaction had a large effect size and it was the largest effect size at of any of the testing velocities. This indicates that a velocity specific effect in peak torque at the training velocity may be present with an increase in sample size. Both the ST and VM group significantly improved peak concentric torque at 90 deg/s in the trained arm while the CO group did not. The greatest change in the group means under each condition occurred at this velocity. Additionally, the only statistically significant change in torque for the VM group occurred at this velocity.

Changes within the untrained arm insufficient to show cross-education effect

There were no statistical differences for any increases in normalized peak torque for any group in the untrained arm. Only the RT group increased isometric strength when not normalized to subject mass. The cross-education effect has been well established within the literature (Carroll et al. 2008) and it is possible that a combination of the relative load intensity and high variability between sexes contributed to the lack of significant findings. The most profound cross-education effects manifest at higher load intensities requiring greater descending neural drive to the musculature (Farthing 2009). Load intensities were incrementally increased from 70%- 85% of 1RM. These intensities were purposefully selected in order to ensure some relative success in the completion of the training templates, especially in the initial stages, for the VM group. However, cross education of strength has been seen at similar training intensities (Hortobágyi et al. 2011, Raue et al. 2005). There does seem to be a moderate relationship between strength increase in the trained limb and strength increase in the untrained limb.

It is possible that further investigation could reveal a cross-education effect in the RT group. The only significant change in torque in the untrained arm was seen in the RT group. In the trained arm, the most profound changes were at the concentric and isometric testing conditions. This shows a bias towards these conditions in regards to the effectiveness of the training protocols and it is logical that the same would be true in the contralateral limb. Comparisons of concentric and eccentric training have shown a specificity of adaptations to the training type (Roig et al. 2008). While subjects completed both concentric and eccentric contractions throughout the training, the load intensities were calculated based on the peak concentric values. Since the eccentric torque values were greater than concentric torque values during testing, the eccentric contractions were conducted at a lower percentage of the eccentric MVC. Therefore the concentric stimulus was greater and it is logical that the strength gains under the concentric conditions would be more robust. Percent change was greatest in the concentric and isometric conditions in the untrained limb. The RT group increased the greatest at these conditions which hints towards the possibility that the RT group would be more effective at increasing contralateral strength. However, the lack of a time main effect and group*time interaction in the untrained arm leave these claims unsubstantiated and without statistical evidence.

Visuomotor skill improved in the VM training group

Visuomotor error decreased over time. The time*group interaction was not significant and differences between groups could not be identified. However, a p-value near the threshold for statistical significance and a large effect size lend to the possibility that this is perhaps a type II error and could be a product of the small sample size. The VM group exhibited an increase in visuomotor skill by decreasing the visuomotor error over time, while those in the RT group did not when analyzing the groups separately. The improvement in visuomotor skill of the VM group would lead us to believe that the neural adaptations associated with skilled task learning did occur. A cross education effect of the skilled task was present in the groups, and appeared to be greatest in the VM group despite a lack of statistical evidence. Previous studies incorporating the type of visuomotor task specific to this study did not take any measures of contralateral skill (Jensen et al. 2005, Perez et al. 2004, Perez et al. 2006, Keogh et al. 2010). Cross education effects are present in other forms of skilled motor tasks with proprioceptive and visual elements, such as mirror tracing, and similar transfer to the contralateral limb was present in the visuomotor task (Kumar et al. 2005).

Implications for loaded visuomotor training

Strength gains from loaded visuomotor training appear to be more specific to the training velocity than traditional resistance training and seem to lack the transfer of strength to the contralateral limb. This would make the practice of loaded visuomotor training would be most effective for populations with task specific needs. Stroke patients often suffer from varying degrees of spasticity and could be a population that may benefit from loaded visuomotor training. Muscle spasticity of stroke is caused by an imbalance of excitatory and inhibitory signals (Ward 2012). Spasticity can affect gait and increase the risk of falls, or decrease in ability to perform simple activities of daily living. Loaded visuomotor training has previously been shown to be effective in reducing the power and amplitude of tremors during pointing tasks in older adults (Keogh et al. 2010). Keogh et al. further showed a decrease in coactivation of antagonist muscles after visuomotor training. This exhibits the ability of visuomotor training to increase force steadiness and elicit alterations in the neural strategy of movements. While the strength benefits from loaded visuomotor training are more velocity specific than traditional resistance training, they may be applicable to activities of daily living that aren't subject to large variations in velocity. Upper extremity reaching and lifting tasks involve sensorimotor input to control joint position and increase movement accuracy. Regulation of muscle force is required to control the load of the target object during the reaching and lifting task and this type of activity may benefit from loaded visuomotor training.

Summary

Visuomotor skill increased with repeated practice in the VM group but did not appear to change in the RT group. This is an important idea in relation to the stated hypothesis. While no direct measure of neural changes were made, one would assume that the changes in neural excitability associated with visuomotor skill task acquisition occurred in the VM group. It was hypothesized that these changes in neural excitability due to the practice of the skilled task would accentuate the similar changes in neural excitability associated with resistance training thus leading to increased strength gains. Despite the improvement in visuomotor skill task ability, there was no evidence to support the hypothesis. Both training groups increased in strength over time and no differences in the magnitude of strength gains could be identified.

It was further hypothesized that due to the neural factors associated with cross-education that a similar benefit of increased strength gains compared to traditional resistance training would also be seen in the untrained arm for the VM group. There is no evidence to support this hypothesis either due to the lack of a cross education effect in any of the groups. Changes in torque after loaded visuomotor training appeared to be more velocity specific and did not seem to transfer to the contralateral limb. Therefore loaded visuomotor training may more beneficial to populations that require more task specific training. The specificity of strength gains coupled with decreases in tremor and coactivation seen in the Keogh et al. article show promise that loaded visuomotor training may be a beneficial training modality for populations suffering from muscle spasticity such as stroke patients.

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Appendix A: Consent Form

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board Office
1L-09 Brody Medical Sciences Building• 600 Moye Boulevard • Greenville, NC 27834
Office **252-744-2914** • Fax **252-744-2284** • **www.ecu.edu/irb**

TO: Tibor Hortobagyi, PhD, Department of EXSS, ECU, Mailstop #158

FROM: UMCIRB

DATE: February 21, 2011

RE: Expedited Category Research Study

TITLE: "Effects of Strength Training with Simple and Complex Movements on Muscle Force."

UMCIRB #11-0135

This research study has undergone review and approval using expedited review on 2/18/11. This research study is eligible for review under an expedited category number 4. The Chairperson (or designee) deemed this **unfunded** study **no more than minimal risk** requiring a continuing review in **12 months**. Changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. The investigator must submit a continuing review/closure application to the UMCIRB prior to the date of study expiration. The investigator must adhere to all reporting requirements for this study.

The above referenced research study has been given approval for the period of **2/18/11** to **2/17/12**. The approval includes the following items:

- Internal Processing Form (dated 2/8/11)
- Informed consent (no version date)

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

The UMCIRB applies 45 CFR 46, Subparts A-D, to all research reviewed by the UMCIRB regardless of the funding source. 21 CFR 50 and 21 CFR 56 are applied to all research studies under the Food and Drug Administration regulation. The UMCIRB follows applicable International Conference on Harmonisation Good Clinical Practice guidelines.

IRB00000705 East Carolina U IRB #1 (Biomedical) IORG0000418
IRB00003781 East Carolina U IRB #2 (Behavioral/SS) IORG0000418
IRB00004973 East Carolina U IRB #4 (Behavioral/SS Summer) IORG0000418
Version 3-5-07

UMCIRB #11-0135
Page **1** of **1**

Informed Consent to Participate in Research
Information to consider before taking part in research that has no more than minimal risk

Title of Research Study: **Effects of strength training with simple and complex movements on muscle force**
Principal Investigator: Tibor Hortobágyi
Institution/Department or Division: Exercise and Sport Science
Address: 332 Ward Sports Medicine Building
Telephone #: 252.737.4564

Researchers at East Carolina University (ECU) study problems in society, health problems, environmental problems, behavior problems and the human condition. Our goal is to try to find ways to improve the lives of you and others. To do this, we need the help of volunteers who are willing to take part in research.

Why is this research being done?
The purpose of this research is to determine the effects of strength training on maximal voluntary force, movement accuracy, and movement variability using simple versus complex movement patterns. The decision to take part in this research is yours to make. By doing this research, we hope to learn if strength training with movements that have vs do not have variations improve voluntary strength more effectively.

Why am I being invited to take part in this research?
You are being invited to take part in this research because you are right-handed or right-legged, age 18 to 35-years-old, free of orthopedic and neurological conditions, a non-smoker, have a body mass index less than 30 $kg \cdot m^{-2}$, and do not lift weights more than once a week. If you volunteer to take part in this research, you will be one of about 30 people to do so.

Are there reasons I should not take part in this research?
I understand I should not volunteer for this study if I am a smoker, under 18 years of age, suffered a serious injury to my arms or legs, or had or have neurological condition (stroke, Parkinson's disease).

What other choices do I have if I do not take part in this research?
You can choose not to participate.

Where is the research going to take place and how long will it last?
The research procedures will be conducted in the room 332 Ward Sports Medicine Building, Biomechanics Laboratory. The study consists of 1 familiarization visit (1 h), 1 initial testing session (2 h), 6 exercise sessions (10 min each), 1 testing session midway (2 h), 6 additional exercise sessions (10 min each), and 1 final testing session (2 h). If you are in the control group, you will be asked to attend the same sessions. You will perform the testing protocols but not the training protocol instead exercising you will read magazines or listen to music for the duration as if you were in the exercise group.

What will I be asked to do?
You are being asked to do the following:

The study will require a one-month time commitment consisting of three, 2 hour, testing sessions, as well as up to 12, 15-20-minutes-long, training sessions.

At the beginning the testing session electrodes (like the ones used in a chest EKG) will be placed on the target muscle. These electrodes will measure muscle activity. In addition, a device that measures the range of movement in the target joint (elbow or knee) will be attached to my limb with Velcro bands. The testing session will assess my ability

*UMCIRB Number:*__________

*Consent Version # or Date:*__________
UMCIRB Version 2010.05.01

UMCIRB
APPROVED
FROM 2-18-11
TO 2-17-12

____
Participant's Initials

to produce maximal force on a computerized device and my ability to produce low-level forces as accurately and smoothly as possible. I will have ample opportunity to practice and become familiar with each task. To measure maximal force, you press against a pad on a computer-controlled device. To measure the ability to accurately and smoothly produce movement, you will attempt to match the movement of your limb with a template that appears on the computer monitor. You perform each task up to 3 times, with 2 minutes of rest between trials.

You will be randomly assigned to one of the following training groups:
a) Strength training at 80% of my maximal strength, using 6 to 8 repetitions in each of 3 bouts,
b) Strength training at 80% of my maximal strength, using 6 to 8 repetitions in each of 3 bouts following a template on the monitor,
c) Movement training without a load, using 6 to 8 repetitions in each of 3 bouts following a template on the monitor, or
d) No training (reading magazines, listening to music) but performing the testing protocol itself.

What possible harms or discomforts might I experience if I take part in the research?
As with any strong effort or working out in a gym and lifting weights, there is a possibility for muscle strain to occur. A thorough familiarization and warming up will minimize the risks for muscle strain and soreness. Except for a few efforts, all other efforts will be done at a below-maximal intensity, posing minimal risks for any healthy young adults

What are the possible benefits I may experience from taking part in this research?
This research might help us learn more about how incorporation of variation in movement used to work out (lift weights) may increase muscle strength more effectively than simple movements used currently in standard weight lifting exercises. As a student, you will also participate in cutting-edge technology research on muscle and nervous system function and participation in the study provides an educational experience.

Will I be paid for taking part in this research?
We pay you for the time you volunteer while being in this study. The maximum amount you will receive is $60 after the completion of the entire study (1 familiarization, 3 testing sessions, 12 training session, 16 visits total). I am entitled to compensation in proportion to the number of session completed ($60/16 = $4/visit).

What will it cost me to take part in this research?
It will not cost you any money to be part of the research.

Who will know that I took part in this research and learn personal information about me?
To do this research, ECU and the people listed below may know that you took part in this research and may see information about you that is normally kept: Tibor Hortobágyi, the main investigator, and Mr. Patrick Rider, instructor and laboratory manager.

How will you keep the information you collect about me secure? How long will you keep it?
Data files will be kept for 5 years after the study is completed. The investigators will keep your personal data in strict confidence by having your data coded. Instead of your name, you will be identified in the data records with an identity number. Your name and code number will not be identified in any subsequent report or publication. The main investigators will be the only persons who know the code associated with your name and this code as your data) will be kept in strict confidence. The computer file that matches your name with the ID number will be encrypted and the main investigators will be the only staff that knows the password to this file. The data will be used for research purposes.

What if I decide I do not want to continue in this research?
If you decide you no longer want to be in this research after it has already started, you may stop at any time. You will not be penalized or criticized for stopping. You will not lose any benefits that you should normally receive.

Who should I contact if I have questions?
The people conducting this study will be available to answer any questions concerning this research, now or in the future. You may contact the Principal Investigator at 252.737.4564 (days, between 8 am to 5 pm).

If you have questions about your rights as someone taking part in research, you may call the Office for Human Research Integrity (OHRI) at phone number 252-744-2914 (days, 8:00 am-5:00 pm). If you would like to report a complaint or concern about this research study, you may call the Director of the OHRI, at 252-744-1971

I have decided I want to take part in this research. What should I do now?
The person obtaining informed consent will ask you to read the following and if you agree, you should sign this form:

- I have read (or had read to me) all of the above information.
- I have had an opportunity to ask questions about things in this research I did not understand and have received satisfactory answers.
- I know that I can stop taking part in this study at any time.
- By signing this informed consent form, I am not giving up any of my rights.
- I have been given a copy of this consent document, and it is mine to keep.

____

Participant's Name (PRINT) **Signature** **Date**

Person Obtaining Informed Consent: I have conducted the initial informed consent process. I have orally reviewed the contents of the consent document with the person who has signed above, and answered all of the person's questions about the research.

____

Person Obtaining Consent (PRINT) **Signature** **Date**

*******************IMPORTANT INFORMATION***********************

Continuing Review/Closure Obligation

As a investigator you are required to submit a continuing review/closure form to the UMCIRB office in order to have your study renewed or closed before the date of expiration as noted on your approval letter. This information is required to outline the research activities since it was last approved. You must submit this research form even if you there has been no activity, no participant s enrolled, or you do not wish to continue the activity any longer. The regulations do not permit any research activity outside of the IRB approval period. Additionally, the regulations do not permit the UMCIRB to provide a retrospective approval during a period of lapse. Research studies that are allowed to be expired will be reported to the Vice Chancellor for Research and Graduate Studies, along with relevant other administration within the institution. The continuing review/closure form is located on our website at www.ecu.edu/irb under forms and documents. The meeting dates and submission deadlines are also posted on our web site under meeting information. Please contact the UMCIRB office at 252-744-2914 if you have any questions regarding your role or requirements with continuing review.
http://www.hhs.gov/ohrp/humansubjects/guidance/contrev0107.htm

Required Approval for Any Changes to the IRB Approved Research

As a research investigator you are required to obtain IRB approval prior to making any changes in your research study. Changes may not be initiated without IRB review and approval, except when necessary to eliminate an immediate apparent hazard to the participant. In the case when changes must be immediately undertaken to prevent a hazard to the participant and there was no opportunity to obtain prior IRB approval, the IRB must be informed of the change as soon as possible via a protocol deviation form.
http://www.hhs.gov/ohrp/humansubjects/guidance/45cfr46.htm#46.103

Reporting of Unanticipated Problems to Participants or Others

As a research investigator you are required to report unanticipated problems to participants or others involving your research as soon as possible. Serious adverse events as defined by the FDA regulations may be a subset of unanticipated problems. The reporting times as specified within the research protocol, applicable regulations and policies should be followed.
http://www.hhs.gov/ohrp/policy/AdvEvntGuid.htm

Version 02-26-07

Appendix B: Questionnaire

Questionnaire

Name ____

Phone_____________________ Email ________________________

Height _______ Weight _______ Sex: M___ F____

Date of Birth _____/_______/________

1. Do you consider yourself healthy? Yes No
2. Do you have any known neurological problems
   a. Such as Stroke, Seizure, Parkinsons, etc? Yes No
3. Are you on any medications? Yes No
   a. If yes, what meds? ___________________
4. Have you had any previous serious injuries/surgeries to the shoulder, elbow, or wrist? Yes No
   a. If yes, what injuries? ____________________
   b. When (at what age)?____________________

Which hand do you do the following task?	Left always	Left usually	Equal	Right Usually	Right Always
Spin a top					
Hold a paintbrush					
Pick up a book					
Use a spoon to eat soup					
Flip pancakes					
Pick up a piece of paper					
Draw a picture					
Insert and turn a key in a lock					
Insert a plug into a electrical outlet					
Throw a ball					
Hold a needle while sewing					
Turn on a light switch					
Use the eraser at the end of a pencil					
Saw a piece of wood with a hand saw					
Open a drawer					
Hammer a nail					
Turn a doorknob					
Use a pair of tweezers					
Writing					
Turn the dial if a combination lock					

1. **Over the past 3 months**, have you performed resistance training on your upper body? ________
    a. If yes, How often? _________ (Number of days/min per week)
2. **Currently**, how many days/min (per week) do you participate in the following activities?

    a. Resistance training _______________
    b. Cardio _________________
    c. Other ___________
    (explain:____
    ____)

3. **<u>Prior to college</u>**, how often (days/min per week) did you do the following:
    a. Resistance train ______________
    b. Cardio ______________
    c. Other ______________
4. **<u>In total</u>**, how long (years) have you engaged in the following:
    a. Resistance training ___________________
    b. Cardio ___________________
    c. Other _______________
5. **<u>Prior to the last three months</u>**, have you:
    a. Participated in organized sport ______________
        i. Describe ____

Appendix C: Data Collection Sheet

Name____ Date_____/______/________

DOB______/______/________ Sex: Male / Female

HT________________ m

WT________________ kg

Forearm Length: Right ______________inches Left __________inches

Group: Strength Training / Visuomotor

Testing Protocol – [Pre-test]

STRENGTH TESTING

Test order (side): Right side ____________ Left Side _____________

Randomization Order: ___-___-___-___-___-___-___-___-___-___

Right Biceps

Randomization		Test Order		Force/Velocity	Test 1 [post] Max Torque (N*m)			
					Con	Rep	Ecc	Rep
1	2			$30°s^{-1}$				
3	4			$90°s^{-1}$				
5				Isometric (75° Flexion)				

- **Max torque ($90°s^{-1}$)________ *8.85 in-lbs ÷_________(arm length)= __________lbs max**
- **Lbs max _________ *30% = ____________ load for VM test**

Right Triceps

Randomization		Test Order		Force/Velocity	Test 1 [post] Max Torque (N*m)			
					Con	Rep	Ecc	Rep
6	7			$30°s^{-1}$				
8	9			$90°s^{-1}$				
10				Isometric (75° Flexion)				

Randomization Order: ___-___-___-___-___-___-___-___-___-___

Left Biceps

Randomization		Test Order		Force/Velocity	Test 1 [post] Max Torque (N*m)			
					Con	Rep	Ecc	Rep
1	2			$30^\circ s^{-1}$				
3	4			$90^\circ s^{-1}$				
5				Isometric (75° Flexion)				

- **Max torque ($90^\circ s^{-1}$)_________ *8.85 in-lbs ÷_________(arm length)= ___________lbs max**
- **Lbs max __________ *30% = _____________ load for VM test**

Left Triceps

Randomization		Test Order		Force/Velocity	Test 1 [post] Max Torque (N*m)			
					Con	Rep	Ecc	Rep
6	7			$30^\circ s^{-1}$				
8	9			$90^\circ s^{-1}$				
10				Isometric (75° Flexion)				

VISUOMOTOR TESTING

Test order (side): Right side ____________ Left Side _____________

Randomization Order: ___-___-___-___

Right Side

Random Number	Test Order	Template	Protocol	Load
1		Easy	Unloaded	N/A
2		Easy	Loaded	____________lbs
3		Hard	Unloaded	N/A
4		Hard	Loaded	____________lbs

Randomization Order: ___-___-___-___

Left Side

Random Number	Test Order	Template	Protocol	Load
1		Easy	Unloaded	N/A
2		Easy	Loaded	____________lbs
3		Hard	Unloaded	N/A

4		Hard	Loaded	___________lbs

Testing Protocol – [Mid-test]

STRENGTH TESTING

Test order (side): Right side ____________ Left Side _____________

Randomization Order: ___-___-___-___-___-___-___-___-___-___

Right Biceps

Randomization		Test Order		Force/Velocity	Test 1 [post] Max Torque (N*m)			
					Con	Rep	Ecc	Rep
1	2			$30°s^{-1}$				
3	4			$90°s^{-1}$				
5				Isometric (75° Flexion)				

- **Max torque ($90°s^{-1}$)________ *8.85 in-lbs ÷_________(arm length)= __________lbs max**
- **Lbs max _________ *30% = _____________ load for VM test**

Right Triceps

Randomization		Test Order		Force/Velocity	Test 1 [post] Max Torque (N*m)			
					Con	Rep	Ecc	Rep
6	7			$30°s^{-1}$				
8	9			$90°s^{-1}$				
10				Isometric (75° Flexion)				

Randomization Order: ___-___-___-___-___-___-___-___-___-___

Left Biceps

Randomization		Test Order		Force/Velocity	Test 1 [post] Max Torque (N*m)			
					Con	Rep	Ecc	Rep
1	2			$30°s^{-1}$				
3	4			$90°s^{-1}$				
5				Isometric (75° Flexion)				

- **Max torque ($90°s^{-1}$)________ *8.85 in-lbs ÷_________(arm length)= __________lbs max**
- **Lbs max _________ *30% = _____________ load for VM test**

Left Triceps

Randomization		Test Order		Force/Velocity	Test 1 [post] Max Torque (N*m)			
					Con	Rep	Ecc	Rep
6	7			$30°s^{-1}$				
8	9			$90°s^{-1}$				

10		Isometric (75° Flexion)				

VISUOMOTOR TESTING

Test order (side): Right side ____________ Left Side _____________

Randomization Order: ___-___-___-___
Right Side

Random Number	Test Order	Template	Protocol	Load
1		Easy	Unloaded	N/A
2		Easy	Loaded	____________lbs
3		Hard	Unloaded	N/A
4		Hard	Loaded	____________lbs

Randomization Order: ___-___-___-___
Left Side

Random Number	Test Order	Template	Protocol	Load
1		Easy	Unloaded	N/A
2		Easy	Loaded	____________lbs
3		Hard	Unloaded	N/A
4		Hard	Loaded	____________lbs

Notes:

Testing Protocol – [Post-test]

STRENGTH TESTING

Test order (side): Right side ____________ Left Side _____________

Randomization Order: ___-___-___-___-___-___-___-___-___-___

Right Biceps

Randomization		Test Order		Force/Velocity	Test 1 [post] Max Torque (N*m)			
					Con	Rep	Ecc	Rep
1	2			$30°s^{-1}$				
3	4			$90°s^{-1}$				
5				Isometric (75° Flexion)				

- **Max torque ($90°s^{-1}$)_________ *8.85 in-lbs ÷_________(arm length)= ___________lbs max**
- **Lbs max __________ *30% = _____________ load for VM test**

Right Triceps

Randomization		Test Order		Force/Velocity	Test 1 [post] Max Torque (N*m)			
					Con	Rep	Ecc	Rep
6	7			$30°s^{-1}$				
8	9			$90°s^{-1}$				
10				Isometric (75° Flexion)				

Randomization Order: ___-___-___-___-___-___-___-___-___-___

Left Biceps

Randomization		Test Order		Force/Velocity	Test 1 [post] Max Torque (N*m)			
					Con	Rep	Ecc	Rep
1	2			$30°s^{-1}$				
3	4			$90°s^{-1}$				
5				Isometric (75° Flexion)				

- **Max torque ($90°s^{-1}$)_________ *8.85 in-lbs ÷_________(arm length)= ___________lbs max**
- **Lbs max __________ *30% = _____________ load for VM test**

Left Triceps

Randomization		Test Order		Force/Velocity	Test 1 [post] Max Torque (N*m)			
					Con	Rep	Ecc	Rep
6	7			$30°s^{-1}$				
8	9			$90°s^{-1}$				
10				Isometric (75° Flexion)				

VISUOMOTOR TESTING

Test order (side): Right side ____________ Left Side _____________

Randomization Order: ___-___-___-___

Right Side

Random Number	Test Order	Template	Protocol	Load
1		Easy	Unloaded	N/A
2		Easy	Loaded	____________lbs
3		Hard	Unloaded	N/A
4		Hard	Loaded	____________lbs

Randomization Order: ___-___-___-___

Left Side

Random Number	Test Order	Template	Protocol	Load
1		Easy	Unloaded	N/A
2		Easy	Loaded	____________lbs
3		Hard	Unloaded	N/A
4		Hard	Loaded	____________lbs

Notes:

Notes:

Appendix D: Analysis of Baseline Measures

Pre-Test Assessments of Peak Torque - Trained Arm										
	Ecc 90 deg/s		Ecc 30 deg/s		Isometric		Con 30 deg/s		Con 90 deg/s	
Group	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
RT	0.67	0.20	0.63	0.22	0.53	0.23	0.43	0.18	0.37	0.14
VM	0.67	0.22	0.63	0.21	0.54	0.20	0.45	0.15	0.38	0.13
CO	0.71	0.25	0.69	0.23	0.56	0.27	0.52	0.25	0.50	0.19
Analysis of variance between groups										
p-value	0.94		0.839		0.987		0.78		0.254	

Pre-Test Assessments of Peak Torque - Untrained Arm										
	Ecc 90 deg/s		Ecc 30 deg/s		Isometric		Con 30 deg/s		Con 90 deg/s	
Group	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
RT	0.68	0.23	0.60	0.23	0.48	0.19	0.44	0.21	0.37	0.19
VM	0.62	0.25	0.62	0.21	0.54	0.20	0.45	0.16	0.39	0.16
CO	0.76	0.23	0.71	0.26	0.65	0.22	0.64	0.19	0.58	0.16
Analysis of variance between groups										
p-value	0.553		0.689		0.332		0.144		0.075	

Pre-Test Visuomotor Error (deg) - Trained Arm								
	Loaded Non-Variable		Unloaded Non-Variable		Loaded Variable		Unloaded Variable	
Group	Mean	SD	Mean	SD	Mean	SD	Mean	SD
RT	14	5.4	12.3	4.8	15.7	4.8	12.6	3.1
VM	15.5	5.1	14	2.7	15.6	4.2	13.5	4.5
CO	13.3	2.1	14.4	4.3	15.8	1.7	15.5	4.6
Analysis of variance between groups								
p-value	0.228		0.427		0.711		0.909	

Pre-Test Visuomotor Error (deg) - Untrained Arm								
	Loaded Non-Variable		Unloaded Non-Variable		Loaded Variable		Unloaded Variable	
Group	Mean	SD	Mean	SD	Mean	SD	Mean	SD
RT	11.8	3.6	12	3.1	14	2.9	13.1	2.6
VM	18.1	5.4	16.6	2.6	18.4	4.4	15.8	4.9
CO	15.8	4.3	13.5	3.7	15	3.6	14.5	1.6
Analysis of variance between groups								
p-value	0.201		0.424		0.907		0.169	