THE EFFECT OF UPPER BODY STRENGTH TRAINING ON UPPER EXTREMITY
FUNCTION IN HEALTHY OLDER ADULTS

By

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Philippians 1:3 (NLT)
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ABSTRACT

Joel D. Eggebeen

THE EFFECT OF UPPER BODY STRENGTH TRAINING ON UPPER EXTREMITY FUNCTION IN HEALTHY OLDER ADULTS

Thesis under the direction of Anthony P. Marsh, Ph.D., Associate Professor of Health and Exercise Science.

The prevention of disability in older adults is an important goal for public health. Improving or eliminating limitations in activities is critical to independence and thus the prevention of disability in the older adult population. Resistance training is a widespread and effective method to improve some aspects of lower extremity function. However, the results of studies that have assessed the effect of resistance training on upper extremity function in healthy older adults have been mixed.

The objectives of this thesis are: 1) to examine change in upper extremity strength as quantified by the isometric joint strengths of the elbow and shoulder following 6 wks of upper body resistance training, and 2) to examine change in upper extremity function as quantified by the maximal functional reaching and functional pulling strength following training. Four older adults (2 male and 2 female) completed 6 weeks of high-intensity, progressive resistance training aimed at improving the strength of the arms, chest, upper back, and shoulders. Six older adults (4 male and 2 female) served as members of a control group.

The training group significantly improved in isometric shoulder adduction strength (p=.012) and functional pulling strength (p=.011) compared to the control group. Each member of the training group increased in dynamic (1-RM) strength. None of the other measures were significantly different between the groups.

The strength training protocol used in this study was well-received, effective, and safe for older adults. The increase in functional pulling strength is a promising result and is relevant to the prevention of disability in older adults. It is evidence that upper body strength training in older adults has the potential to increase upper extremity function.
REVIEW OF LITERATURE

THE GRAYING OF AMERICA

The American population is rapidly aging. Currently, the number of older adults, persons \( \geq 65 \) years of age, increases by approximately six million people per year \(^{38}\). However, due to the baby-boomer generation, this number is expected to increase dramatically in the next few decades. By 2030, the number of Americans \( \geq 65 \) years of age will more than double to approximately 71 million, or 20\% of the total US population \(^{27}\). About 20\% of older adults suffer from some sort of chronic disability, causing difficulties in performing activities of daily living (ADLs) and instrumental activities of daily living (IADLs). As a result of the increase in chronic disability and disease with age, the cost of health care for a person age 65 or older is roughly three to five times greater than for a person younger than age 65 \(^6\). Furthermore, by 2030, the total cost of health care spending in America is projected to increase by 25\% \(^6\). Therefore, improving and preserving the health of older adults is essential to remedy the economic challenges of an aging society. A key public health goal continues to be the promotion of independence and thus the prevention of functional decline, leading to disability, in the elderly population. Exercise, including resistance training, is a widespread method for accomplishing this goal.

DISABILITY MODELS

Since the prevention of disability in older adults is an important goal for public health, it is instructive to understand the factors that lead to disability in order to identify those that may be targets for exercise or other interventions. Disability can be caused by
acute events and/or chronic processes that occur as we age. For example, a fall, an acute event, may cause an injury that leads to the inability to carry out one or more ADLs. Alternatively, a chronic condition such as osteoarthritis may initiate the declines in function that ultimately lead to disability. Several models have been developed to describe the process by which a person becomes disabled. The disablement models include the seminal work of Saad Nagi, an expansion of Nagi’s model by Verbrugge and Jette, and the contemporary International Classification of Functioning, Disability, and Health (ICF) model developed by the World Health Organization (WHO). All of these models have proven useful in determining the consequences of disease and injury at both the personal and societal level.

In his early work, Nagi described the term disablement as the “various impact (s) of chronic and acute conditions on the functioning of specific body systems, on basic human performance, and on people’s functioning in necessary, usual, expected, and personally desired roles in society.” His model, developed in the 1960’s, contains four distinct, yet related, steps. These steps include: 1) active pathology, 2) impairment, 3) functional limitations, and 4) disability.

Active pathology involves the interruption of normal cellular processes and the mobilization of the body’s defenses and coping mechanisms. It is when actual physiological changes occur in the body due to infection, degenerative diseases, injury, metabolic imbalance, or other etiology. Examples of active pathology include the cellular changes brought upon by traumatic injury, osteoarthritis, cardiomyopathy, cancer, Alzheimer’s disease, or cerebral palsy.
Impairment refers to significant anatomical or physiological losses or abnormalities at the tissue, organ, and body system level. Examples of impairments include the loss of lung function, cardiovascular deconditioning, loss of a limb, or muscle weakness. Active pathology always leads to an impairment, but not all impairments are the result of an active pathology. For example, an impairment may be residual, remaining after the active pathology stage has been eliminated. Impairments can occur in the pathology’s primary locale (weakening of the muscles surrounding an arthritic knee joint), but they can also occur in secondary locales (cardiovascular deconditioning due to inactivity).

The consequences of impairments at the individual level are functional limitations, the third step in Nagi’s disablement model. Functional limitations are restrictions in the individual’s ability to perform fundamental physical and mental actions in normal daily activities. Examples of functional limitations of this type include difficulty in walking, difficulty in carrying heavy objects, or difficulty in dressing and caring for oneself. The degree of the functional limitation is dependent not only on the underlying impairments but also on the types of activities important to the individual. For example, the loss of hand and finger dexterity could be severely limiting to a person who lives independently and loves to work in the garden, but may not be as limiting to a person who lives dependently and relies on others for self-care activities.

The final step in Nagi’s model is disability. Nagi defined disability as the “expression of a physical or a mental limitation in a social context.” Often this includes difficulty in performing ADL’s and IADL’s related to job performance, household management, personal care, hobbies, socializing with friends, or performing...
errands. According to Nagi, disability represents the gap between a person’s capabilities and the situational demands created by the social and physical environment. Furthermore, he stated that disability is influenced in three ways: 1) the characteristics of the impairments and the degree of the functional limitations, 2) the individual’s definition of the situation and response to the situation, and 3) other people’s reaction to the situation and expectation of the situation. Functional limitations and disability are similar, yet different. Functional limitations are generic, situation-free activities, whereas disability is a functional limitation in a social, situational activity.

To address the more complex nature of disability, Verbrugge and Jette expanded Nagi’s model to attain a more complete sociomedical scope. They retained the same four steps but added personal and physical environmental factors as well as lifestyle behaviors and attitudes. They added three factors which they proposed would influence the path from pathology to disability: 1) risk factors (demographics, social, lifestyle, behavioral, psychological, environmental, biological), 2) extra-individual factors (medical care and rehabilitation, medications, external supports, physical and social environment), and 3) intra-individual factors (lifestyle and behavior change, psychosocial attributes and coping, activity accommodations). These three factors either mediate or moderate the relations among the four steps of the disablement process.

In 1980, the WHO released a model of disability independent of Nagi’s work in an attempt to standardize and code health related information. In 2001, the WHO released a contemporary revision, the ICF, which attempted to provide a coherent biopsychosocial view of health states from a biological, personal, and social perspective. The ICF identifies three domains of human function: 1) body functions and structures,
2) activities, and 3) participation. Body functions and structures are defined as the physiological functions of body systems or anatomical elements, such as organs or limbs. Consequently, impairments are defined as a significant loss in body function or structure. Activity is the execution of a specific task or action. Any difficulty that a person may have in executing the activity is called a limitation. Participation is conceptualized as a person’s involvement in real life activities and any difficulty experienced in those activities is termed a restriction. Each domain can be expressed in positive or negative terms, with disability defined as a decrement at any level (impairment, limitation, or restriction). Further, each of these domains is thought to be influenced by contextual factors (environmental and personal factors) and by the person’s health condition (disorder or disease).

These three models have provided an evolving framework for understanding the process of how one becomes disabled. Important to this thesis in the prevention of disability is the step from impairment to functional limitation. The goal of intervening at the level of impairment is to delay or eliminate the progression to functional limitation. Therefore, using the contemporary ICF terminology, the goal of resistance training in older adults is to improve an impairment (weakness) in a body structure (muscle) in order to improve a limitation in an activity (upper extremity function), with the ultimate goal of eliminating a restriction in participation.

**Upper Extremity Function**

Previous work on the effects of resistance training on physical function in older adults has almost exclusively focused on the lower extremity. In what is arguably the most comprehensive review of the effects of resistance training on physical function and disability to date, Latham and colleagues concluded that progressive resistance training
improves muscle strength and some aspects of physical function involving the lower extremity (e.g., gait speed, chair rise time). However, the effect of strength training on upper extremity strength and function received no attention in the review. Muscle weakness of the lower extremity relates to deficits in key functional abilities in older adults, such as walking, the ability to get in and out of a chair, the speed of climbing steps, and balance. Clearly, a decline in one of these functional abilities can ultimately lead to disability. Interestingly, one of the disability states identified by Rejeski and coworkers involves difficulty in lifting objects, a key functional ability of the upper extremity. As described below, function of the upper extremity plays an important role in everyday tasks and yet little is known about the role of resistance training in preserving upper extremity strength and function in older adults.

Upper extremity functional tasks involve the use of the arms and hands. The ability to push, pull, lift, lower, reach, hold, turn, carry, and grasp objects are all essential tasks in the ability to successfully carry out everyday activities. Of the six set of tasks in Katz’s Activities of Daily Living scale, three tasks (bathing, dressing, eating) directly rely on the upper extremity while two other tasks (transferring, using the toilet) rely on the upper extremity to a lesser degree. Additionally, of the 31 items in the Instrumental Activities of Daily Living Scale, 16 items directly rely on the function of the upper extremity. Specifically, the ability to use a telephone, shopping, food preparation, housekeeping, and laundry all rely heavily on arm and hand function. A deficit in any of these tasks can result in the loss of independence and can cause a restriction in the participation of real life activities.
A recent study by Abizanda and colleagues examined the role of upper extremity function as a predictor of adverse events in hospitalized elderly. This prospective cohort study of 356 patients admitted to an acute geriatric unit looked at the length of hospital stay and mortality at discharge and at 1 month following discharge. They determined upper extremity function through four tasks (UEFTs): 1) picking up a glass full of water, 2) touching the ipsilateral scapula with the hand, 3) unfastening a button, and 4) cutting with a knife. The number of tasks which the patient was able to perform prior to admission was estimated and divided into two categories: a) patients who could carry out 0, 1, or 2 tasks and b) patients who could carry out 3 or 4 tasks. Likewise, the number of tasks which the patient was able to carry out on admission was calculated and divided into two categories: a) patients who could carry out 0 or 1 task and b) patients who could carry out 2, 3, or 4 tasks. From this, the loss of ability to perform the tasks on admission was determined. Furthermore, indices of global functioning were assessed on admission and recalled based on the 15 days previous to the illness which prompted admission. They found that the number of UEFTs patients were able to perform prior to and at admission were highly correlated to the indices of global functioning also taken prior to and at admission. Figure 1 shows the relationship between the number of UEFTs the patients were unable to do and the adverse events, including mortality. The solid lines represent the number of UEFTs the patients were unable to do prior to admission and the dotted lines represent the number of UEFTs the patients were unable to do on admission. Table 1 shows the odds ratios and confidence intervals of the variable disability conditions and adverse events.
Figure 1. UEFTs and Adverse Events

Table 1. Disability and Adverse Events

<table>
<thead>
<tr>
<th>Disability in UEFTs</th>
<th>Adverse Event</th>
<th>OR</th>
<th>CI 95%</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disability in 2 or more UEFTs previous to admission</td>
<td>mortality at discharge</td>
<td>7.2</td>
<td>2.8-22.5</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>mortality at 1 month</td>
<td>3.8</td>
<td>1.7-8.6</td>
<td>0.002</td>
</tr>
<tr>
<td>Disability in 3 or more UEFTs on admission</td>
<td>mortality at discharge</td>
<td>15.2</td>
<td>5.2-44.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>mortality at 1 month</td>
<td>3.3</td>
<td>1.8-6.2</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

* Table 1 modified from Abizanda et al., 2007
These data underscore the significant relationship between the number of UEFTs patients were unable to perform prior to and on admission to mortality rates at discharge and at 1 month. Patients dependent in 2 or more UEFTs prior to admission were 7.2 times more likely to die at discharge. Further, patients dependent in 3 or more UEFTs on admission were 15.2 times more likely to die at discharge. The authors concluded that upper-extremity function was extremely important as a predictor of adverse events at discharge and at 1 month following discharge for hospitalized elderly. This shows that upper-extremity function may be crucial for survival in the elderly.

The relative importance of factors that contribute to upper extremity function (e.g., muscle volume, strength, coordination) and whether it is possible to improve some or all of these factors with strength training is unknown or has received limited attention. This thesis is part of a broader study attempting to gain a better understanding of the neuromuscular factors that contribute to the ability to accomplish upper extremity tasks. Specific to this thesis is the role of strength and the impact of strength training on upper extremity function.

**Measuring Upper Extremity Function**

Upper extremity function can be evaluated through self-report questionnaires, performance based tests, or single performance tasks. Self-report questionnaires are easy to administer and can provide important information about functional status. However, they may be an inaccurate measure of upper extremity function if the participant rates his or her own functioning higher or lower than their actual ability. Moreover, self-reported function may provide insufficient information about the type of impairment and may lack sensitivity to change. Performance-based measures and single performance tasks attempt to mimic activities of daily living, thus providing a true measure of several
key functional abilities of the upper extremity. However, they require more time, effort, and resources. They also rely on a consistent effort from the participant.

Self-report measures include the Upper Extremity Functional Scale (UEFS) \cite{57} and the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire \cite{19}. The UEFS contains 20 items corresponding to usual work, household, personal care, or recreational activities \cite{8}. Examples of questions on the UEFS include: lifting a bag of groceries above your head, grooming your hair, buttoning clothes, opening doors, opening a jar, and throwing a ball. The patient would rate their degree of difficulty on each task, ranging from no difficulty to unable to perform the activity. The DASH is similar to the UEFS, and has been shown to measure the impairment, limitation, and restriction constructs from the ICF classification of disability \cite{11}. Examples of questions on the DASH include the ability to: do heavy household chores, wash your back, use a knife to cut food, and place an object on a shelf above your head.

Performance-based tests include the Physical Performance Test \cite{52} and the Continuous-Scale Physical Functional Performance test (CSPFP) \cite{8}. These tests rely on direct observation of the patient during simulated real life activities. The Physical Performance Test requires the patient to complete nine tasks of varying difficulty. Of the nine tasks, only four exclusively involve the upper extremity: 1) writing a sentence, 2) simulated eating, 3) lift a book and put it on a shelf, and 4) put on and remove a jacket. The items are scored on the speed in which the task is accomplished. The CSPFP can more easily be applied to a broader spectrum of abilities and can quantify performance across several physical domains. It has been shown to be a reliable measure of physical function not constrained by ceiling or floor effects. The CSPFP contains several tasks
related to upper extremity strength done at a submaximal level, including carrying and
transferring tasks. For example, one task is carrying and then pouring from a jug of water
into a cup. Also included are household tasks, such as sweeping, vacuuming, and making
a bed. The patient is scored on weight, time, distance, or a combination of these
dimensions. A total score is given, as well as a score for each of the five physical
domains evaluated. One of these domains is upper body strength.

A third way to evaluate upper extremity function is through single performance
tasks, such as the two-hand lift and carry and transferring items low to high. These
tasks simulate a real life activity which may be troublesome for a person with disability.
In the two-hand lift and carry, the participant walks over to a shelf, picks up a 22 kg
weight positioned at knee level with both hands, carries the weight around a cone and
puts the weight on a second shelf positioned at shoulder level. It has been shown to be
correlated with markers of disability in older adults. The transferring items low to high
task has the participants transfer a weight from a low shelf onto a higher shelf, and then
from the higher shelf back onto the lower shelf using their dominant arm. One of the
tasks used in this thesis to measure upper extremity function, the functional reaching task,
is similar to these single performance tasks.

All of these upper extremity measures assess function at a submaximal level.
Consequently, the patient’s maximal level of functional ability is unknown. The two
tasks used to measure upper extremity function in this thesis, the functional reaching task
and the functional pulling task, both attempt to measure the maximal amount of weight
that can be lifted. This provides an indication of a person’s functional reserve, that is, the
difference between their maximal ability and the requirements of submaximal tasks that one encounters on a daily basis.

**MUSCLE MASS, STRENGTH AND AGING**

Upper extremity strength plays a critical role in the ability to perform ADLs and IADLs, both of which have a direct impact on prolonging independence. A certain minimal level of upper extremity strength is needed to do everyday tasks, such as lifting a bag of groceries, opening doors, dressing and bathing, or doing laundry. In a prospective study, Rantanen and colleagues examined whether maximal isometric strength at age 75 predicted loss of independence in ADL’s over a follow-up of five years in subjects who were previously independent. In the upper extremity, hand grip strength and elbow flexion strength were measured. They found that poor maximal isometric strength at age 75 was associated with an increased risk of becoming ADL dependent. Those in the lowest strength tertile were 2.3 (hand grip strength) and 2.48 (elbow flexion strength) times more likely to become ADL dependent than those in the highest strength tertile. Although ADL dependence is often seen only below a certain minimal level of strength, the authors noted the importance of building a strength reserve to serve as a safety margin in case of sudden illness or disease.

Not only is upper extremity strength important to prolonging independence, it also has been shown to be an independent predictor of all-cause mortality in men. As part of the Baltimore Longitudinal Study of Aging (BLSA), isometric strength of the upper-extremity was measured in 993 men tested over a 25-year period. To measure strength, subjects pulled against grips in four ways: up, down, forward, and backward. Grip strength was measured using a handheld dynamometer. Both arms were tested, and total strength scores were calculated by summing all eight arm measurements and both
grip strengths. Along with muscle power, upper extremity strength was found to be an independent predictor of all-cause mortality after adjusting for body size, physical activity, and muscle mass. Additionally, the rate of change over time in muscle strength was a more significant risk factor for mortality than strength alone. Further, in a prospective cohort study, Ruiz and colleagues found that muscular strength is inversely and independently associated with death from all causes and cancer in men. In 10,265 men, muscular strength was assessed using a combination of the bench press and the leg press one-repetition maximums. After adjusting for confounders, those in the highest strength tertile had a 20% risk reduction for all-cause mortality and a 33% risk reduction for mortality by cancer when compared to those in the lowest strength tertile.

Unfortunately, muscular strength declines with age. In a cross-sectional study of muscle strength and mass in 45-78 year old men and women, Frontera and colleagues found strength of the elbow extensors and flexors to be 20-20.8% lower in elderly men and 22.2-16.7% lower in elderly females compared to the younger groups of the same gender. Further, in the BLSA, age had an independent influence on upper extremity strength even after adjusting for gender, height, weight, caloric expenditure, and muscle mass. Particularly in men, significant reductions in upper extremity strength were seen with increasing age. While the exact mechanism for the age-related loss in strength is multifactorial, an important factor appears to be sarcopenia, or the loss of muscle mass with aging. For example, Frontera and colleagues found an average difference in muscle mass of 13.4% between the oldest and youngest groups.

Sarcopenia appears to affect the lower extremity more than the upper extremity. Lynch and colleagues looked at the age-associated differences in muscle quality (force...
per unit of muscle mass) between arm and leg muscle groups. They found that muscle quality was about 30% higher in the arm than in the leg across age in both genders. In men, arm and leg muscle quality declined at a similar rate with increasing age. However, in women, leg muscle quality declined approximately 20% more than arm muscle quality with increasing age. McDonagh and colleagues looked at the effect of aging on voluntary and electrically evoked muscle force in the elbow flexors and triceps surae muscles. Both muscle groups showed a reduction in maximum voluntary force and in the force of electrically evoked tetani. For the maximal voluntary contraction, the elbow flexors group decreased by 20% and the triceps surae group decreased by 41% when comparing the old to the young group. The greater loss of muscle mass in the legs compared to the arms is perhaps the reason why most of the research has been done on the lower-extremity. Nonetheless, muscle mass in the upper extremity still declines with increasing age.

In healthy younger adults, it has been shown that differences in maximum isometric joint strength of the upper limb muscles are primarily a function of muscle volume. Holzbaur and colleagues measured the maximum isometric joint strength of the shoulder, elbow, and wrist in ten healthy, younger adults. They also determined the muscle volumes of 32 upper limb muscles from magnetic resonance images of each subject. They found that the volume of the muscles surrounding a particular joint was the most important predictor of the maximum isometric strength of that joint. For example, muscle volume of the shoulder adductors explained 95% of the variation in maximum isometric joint strength of the shoulder. This study demonstrates the importance of the relationship of muscle volume to strength. However, there is a need to determine if the
relationship between muscle volume and isometric joint strength seen in younger subjects holds for older adults.

The information available on the relationship between the loss of muscle mass and the loss of strength to upper extremity function in healthy older adults is limited. There is, however, evidence that a decline in muscle mass may lead to a decline in grip strength, which can be a measure of both function and strength 24. Using 864 subjects of the BLSA, grip strength was examined in relation to age and muscle mass. In general, they found that grip strength declines at an accelerating rate after the age of 40. Grip strength was found to be strongly correlated with both age and muscle mass. However, the correlation with age was stronger 24. This suggests that while the loss of strength in older adults is partly due to a loss of muscle mass, there are still other, yet unexplained factors which may play a role.

**MEASURING MUSCULAR STRENGTH**

Muscular strength can be defined as the maximum force that a muscle, or group of muscles, can generate. It is typically measured using isokinetic, isometric, or dynamic protocols. An isokinetic strength protocol measures the maximum force generated while the muscle is contracting and either lengthening or shortening at a constant speed. Conversely, an isometric strength protocol measures the maximum force generated while the muscle is contracting, but no lengthening or shortening of the muscle-tendon complex occurs. Isokinetic and isometric strength is typically measured at an isolated joint, thus measuring the strength of a group of muscles that cause a certain joint motion. For example, elbow flexion isometric strength measures the strength of all of the elbow flexor muscles. A dynamic, or one-repetition maximum (1-RM), strength protocol is defined as the greatest resistance that can be moved through a defined range of motion using proper
technique. It is the maximum amount of weight that can be lifted one time, while keeping proper form, for a particular exercise.

In order for muscular strength to be accurately quantified, reliability of the testing protocols must be established. However, there is a lack of information available on the reliability of isometric strength testing of the upper extremity in older adults. McGarvey and colleagues measured the reliability of isometric elbow flexion and elbow extension strength in 40 healthy subjects (age range, 40-70 years). Using a torque cell dynamometer, isometric elbow flexion and elbow extension strength were measured at three time points (8:30, 12:30, 4:30) in one day. They found no significant differences for these strength measures between any time point. Symons and colleagues examined the reliability of a single-session isokinetic and isometric strength testing protocol in 19 older men. Knee extension isokinetic and isometric muscle strength was assessed on a Biodex System dynamometer in two identical testing sessions separated by 2-10 days. For isometric strength, reliability was high, with an Intraclass correlation coefficient of .90 for peak torque and .92 for average torque.

The reliability of 1-RM testing has also been established in older adults. Phillips and colleagues examined the reliability of 1-RM testing in 47 older adults on the bench press. Three 1-RM tests were conducted on nonconsecutive days, and systematic error (shift in mean) was analyzed. They found that systematic error did not exceed 3.5% within three test trials, and was eliminated between trials 2 and 3. They stated that 1-RM testing in older adults was reliable and recommended familiarization sessions prior to testing to maximize reliability. Schroeder and colleagues tested the reliability of 1-RM testing in 116 older adult men on the lat pulldown and chest press weight machines. The
test-retest difference absolute mean change was 0 for both exercises. This suggests that 1-RM testing is a reliable measure of muscle strength in older adults.

This thesis utilizes both isometric and dynamic strength testing. Especially pertinent is the isometric muscle strength of four muscle groups surrounding the elbow and shoulder. The methods utilized for this assessment are the same protocol successfully used by Holzbaur and colleagues when they assessed these same isometric muscle strengths in healthy younger adults.

**STRENGTH TRAINING IN HEALTHY OLDER ADULTS**

High-resistance weight training can lead to increases in muscular strength and size even in older adults. Fiatarone and colleagues studied the impact of heavy resistance training in older (~ 90 yrs.), frail, institutionalized men and women. After eight weeks of training, 1-RM quadriceps strength gains averaged 174% ± 31% and midthigh muscle area increased by 9% ± 4.5% 13. Although this training was done on the knee extensors, similar increases in the strength and size of the elbow flexors after training have been reported. Lexell and colleagues studied the effects of heavy-resistance training (85% of 1-RM) on elbow flexion isokinetic and dynamic strength in men and women aged 70-77 years. Also, the area of type I and II fibers in the biceps brachii muscle was examined. The elbow flexor muscles were trained using barbell curls. After 11 weeks of training, dynamic elbow flexion strength increased by 49% and isokinetic elbow flexion strength increased by 37%. The area of the biceps brachii type I and type II fibers increased by 13% and 17%, respectively 30. Further, they found that there was a remarkable similarity between men and women in response to the training 30. Brown and colleagues examined the impact of resistance training in 14 healthy older adult males. The subjects trained 3 days per week for 12 weeks. As part of the training
protocol, unilateral training of the elbow flexors was performed using a custom-built weight-lifting apparatus which brought the elbow through a full range of motion. Training progressed from 2 sets of each exercise at 50% of the initial 1-RM to 4 sets at 70-90% of 1-RM over the course of the study. Following training, dynamic elbow flexion strength increased by 48% in the trained arm. Interestingly, there was no change in isometric strength of the elbow flexors despite the increase in dynamic strength and an increase of 17.4% in the cross-sectional area of the elbow flexors.

Only twenty years ago, it was widely thought that strength training was dangerous for older adults, and it was not unusual for clinicians to advise against it. Since then, it has been shown that strength training is safe and that it is an effective means of prolonging independence in older adults. The ACSM, in its position stand on exercise and physical activity for older adults, concluded that strength training, in addition to increasing strength and muscle mass, has a positive effect on insulin action, bone density, energy metabolism, and functional status. Evans has recommended a high-intensity, progressive resistance training program for older adults in order to maximize strength gains. He recommended that the training intensity should be enough to result in muscular fatigue after 8-12 repetitions. Furthermore, he stated that each repetition should be performed slowly through a full range of motion, with proper breathing technique.

Similar to Latham’s review, in a meta-analysis of the effects of exercise interventions on functional status in healthy older adults, Gu and colleagues found that exercise (mostly resistance training) improves some aspects of physical performance related to the lower extremity (chair-rise, walk speed, walk endurance, and balance). The
effects of exercise on the upper extremity were not mentioned in the analysis. However, the authors did mention that interventions should incorporate exercise to improve both upper and lower limb functional performance outcomes\textsuperscript{16}. Five studies, all looking at the effect of resistance training on physical function measures in healthy older adults, have included some upper body resistance exercises and some measure of upper extremity function. The results of the studies have been mixed\textsuperscript{9, 10, 41, 43, 56}.

Two studies, one using the CSPFP and one using the Physical Performance Test (PPT), showed an improvement in total body and upper extremity function following resistance training. Cress and colleagues looked at the effect of exercise on physical function in independent older adults\textsuperscript{9}. Fifty-six men and women, aged 70 or older, were randomized to either 6 months of a combination strength and endurance resistance training program or a control group. Exercises involving the upper extremity were dips (Gravitron), lateral raise (dumbbells), and shoulder flexion and extension (Stairmaster Kayak). Exercise sessions were held three days a week, with the strength training intensity set at 75-80\% of estimated 1-RM. Following training, the exercise group significantly improved performance on total CSPFP score as well as in the upper body strength domain compared to the control group. The exercise group significantly increased by 13\% in the upper body strength domain, while the control group showed a slight decline\textsuperscript{9}. Using the Physical Performance Test, Nelson and colleagues looked at the effects of a home-based resistance training program on functional performance in the elderly\textsuperscript{43}. Seventy-two men and women, aged 70 or older, were randomized to either six months of home-based exercise or a control group. The overhead press, bicep curl, and tricep extension were all completed with dumbbells as part of the training. The
participants were told to complete 2 sets of 8 reps, three times per week, at an intensity of 7-8 on a 10-point Borg scale. The training group significantly improved their performance on the PPT by 6.1%, while the control group decreased by 2.8% 43.

Three studies, one using a single performance task, one using the CSPFP, and one using the Assessment of Daily Activity Performance (ADAP) test, found no change in upper extremity function following resistance training. Skelton and colleagues looked at the effects of resistance training on strength, power, and selected functional abilities of older women 56. Fifty-two women, aged 75 or older, were randomized to either a 12 week total body resistance training program or a control group. Exercises designed to strengthen the shoulder abductors, adductors, flexors, and extensors and the elbow flexors and extensors were included in the training program. All exercises utilized body weight, rice bags (1-1.5 kg), or elastic tubing as resistance. Of the eight functional tasks evaluated, only one involved the upper extremity. In this task, the participant had to lift a shopping bag, with incremental weights ranging from 2-8 kg, from the floor onto a .72 m surface. The maximum amount of weight that could be lifted was used for analysis. Following training, the training group and the control group showed no significant difference in the change in the amount of weight that could be lifted 56. This was likely due to a combination of the low level of training stimulus and a ceiling effect of the functional task. Utilizing the CSPFP, Miszko and colleagues looked at the effect of strength and power training on physical function in community-dwelling older adults 41. Sixty-five men and women, between the ages of 65-90, were randomized to either a 16 week strength or power training group or a control group. Three upper body machines (seated row, chest press, tricep extension) and one dumbbell exercise (bicep curl) were
included in the progressive resistance training programs. The exercise sessions were held three days a week, and 3 sets of 6-8 repetitions were performed at 80% of 1-RM. The strength training group showed a greater increase in the upper body strength domain of the CSPFP than the control group. However, the results were not significant. de Vreede and colleagues looked at functional-task exercise versus resistance strength training and daily function in older women. Ninety-eight participants, all women older than 70 years, were randomized to a 12 week functional-task exercise or strength training group or a control group. Using dumbbells or elastic tubing, the participants worked the elbow flexors and extensors and the shoulder flexors, extensors, and rotators. Three sets of ten reps were performed on each exercise three days per week. The participants were told to increase the weight if the exercise was only rated as “somewhat hard”. Function was measured using the ADAP, which is similar in design and scoring to the CSPFP. The training group improved their total ADAP score more than the control group (p value = .06), but no difference between the groups was seen for the change in the upper body strength score of the ADAP.

These five studies all had limitations. While upper body strengthening exercises typically made up around half of the strength training program, upper extremity function was only a small part of the functional outcome measures. The information received about the upper extremity in both the PPT and the CSPFP (and ADAP) is limited because only parts of the test involve the functional ability of the upper extremity. Additionally, the bag raise functional task was thought to have a ceiling effect. Only one study used traditional weight training machines, and the upper body exercises typically only
involved the muscles surrounding the elbow and shoulder. In summary, the effect of resistance training on upper extremity function in healthy older adults remains unclear.

Measures of upper body strength were examined in all five studies previously mentioned. Compared to the control group, three studies showed a significant increase in upper body strength following strength training \(^{10,41,56}\), while two failed to show an improvement \(^{9,43}\). Skelton et al. and de Vreede et al. showed a significant increase of 22% and 8.6% in isometric elbow flexor strength following training, respectively \(^{10,56}\), while Miszko et al. showed a significant increase in chest press 1-RM following training \(^{41}\). Cress et al. and Nelson et al. both showed an improvement in upper body strength following training, but neither was significantly different than the control group \(^{9,43}\).

This can be explained primarily by an inadequate resistance training stimulus and progression, and a limited number of upper body exercises. For example, in Nelson et al., the weight used for the bicep curl progressed from 2.0 ± 2.0 to 7.4 ± 3.8 pounds over the six month training period. Additionally, only 3 upper body exercises were completed \(^{43}\).

This thesis utilizes a comprehensive upper body resistance training protocol, with an adequate training stimulus and progression.

**THE EFFECT OF UPPER BODY STRENGTH TRAINING ON UPPER EXTREMITY STRENGTH AND FUNCTION IN HEALTHY OLDER ADULTS**

Studies focusing exclusively on the effects upper body only strength training in healthy older adults are rare. However, two studies, one looking at adaptations in the elbow flexors and one looking at the finger-pinch force control of older adults, have shown promising results. Roman and colleagues studied the change in elbow flexor strength and morphology following upper body heavy-resistance training \(^{53}\). Five elderly men, with a mean age of 67.6, trained the elbow flexor muscles two times per week for
12 weeks. The training protocol consisted of four different exercises, including elbow flexion on a Cybex 340, barbell curls, dumbbell curls, and hammer curls. Four sets of eight reps were performed on the Cybex 340, all at different velocities. Three sets of eight reps were performed on each of the free-weight exercises. If the subject could complete 10 reps on each of the three sets, the weight was increased by five pounds. The isokinetic muscle strength and the volume of the elbow flexors were examined before and after training. Significant increases in strength were seen at all tested velocities, with as much as a 47.9% increase occurring at 300° per second. Further, the combined muscle volume of the biceps brachii and brachialis increased by 13.9% after the training program.

As a consequence of aging, ADL’s that require the dexterous manipulation of hand-held objects typically deteriorate. The reduced hand function of older adults may reflect, at least in part, the age-related loss of isometric finger-pinch force control. Keogh and colleagues looked at the effect of a unilateral upper limb strength training program on the finger-pinch force control of healthy older men. Eleven older men, between the ages of 70 and 80, were randomized to either a 6 week upper body strength training group or a control group. The strength training group trained twice a week, performing unilateral dumbbell bicep curls, wrist flexions, and wrist extensions. The arm selected for training was randomly determined for each subject. After a brief warm-up, the subjects completed four sets of each exercise. The first set was performed at 40-50% of 5-RM, and the remaining three sets were performed with loads that could only be lifted for 8-10 reps per set. Once the subject could complete 10 reps on each set, the weight was increased. The outcome measures of interest were changes in force variability and
targeting error (finger-pinch force control), maximum isometric finger-pinch force, and
dynamic strength on each exercise. Following training, the strength training group
significantly reduced force variability and targeting error and increased dynamic bicep
curl and wrist flexion strength in the trained limb. While there were increases in the
trained limb’s wrist extension and maximum finger-pinch strength for the strength
training group compared to the control group, these differences were not statistically
significant 26. The authors concluded that six weeks of strength training improved finger-
pinch force control of healthy older adult men, further supporting the prescription of
strength training to improve function in older adults 26.

THE EFFECT OF STRENGTH TRAINING ON UPPER EXTREMITY STRENGTH AND FUNCTION IN
CHRONIC DISEASE PATIENTS

While the effect of strength training on upper extremity function in healthy older
adults is unclear, work done with chronic disease patients has shown promising results.
Head and neck cancer survivors, coronary heart disease patients, and stroke survivors
typically have increased pain, lower motor control, and lower strength and function of the
upper extremity than healthy older adults. Strength training has proven to be a beneficial
aspect of rehabilitation 4, 7, 37, 44, 45, 59, 61.

Head and neck cancer survivors have shown an increase in upper extremity
strength and a reduction in shoulder pain and disability following upper body strength
training 37. In a study by McNeely and colleagues, 52 head and neck cancer survivors
were randomly assigned to either a 12-week upper body strength training group or a
standard therapeutic exercise control group. The strength training protocol consisted of
active and passive ROM/stretching exercises, postural exercises, and basic strengthening
exercises. The strengthening exercises focused on the following muscle groups:
rhomboids/middle trapezius; levator scapula/upper trapezius; biceps; triceps; deltoid; and pectoralis major. The participant completed 2 sets of 10 to 15 reps, starting at 25% of their 1-RM and progressing to 70% of their 1-RM by the end of the intervention.

Primary endpoints were change in patient-rated shoulder pain and disability using the SPADI, and change in 1-RM for the seated row and the chest press. Following training, the strength training group significantly reduced shoulder pain and disability (-14.1%) and significantly increased strength on the seated row (+16.3%) and the chest press (+16%) \(^{37}\).

Female cardiac patients have shown an improvement in upper extremity strength and function, and in the ability to perform household physical activity tasks following strength training \(^4,7\). Brochu and colleagues examined the effect of strength training on physical function in older disabled women with coronary heart disease \(^4\). Thirty women were randomly assigned into either a six month strength training group or a control group. The strength training protocol included five upper body exercises: 1) shoulder press, 2) bicep curl, 3) lateral pulldown, 4) bench press, and 5) tricep extension. All exercises were performed with Universal weights and dumbbells. Subjects began training at an intensity of 50% of 1-RM, completing 1 set of 10 reps of each exercise. This gradually increased to 80% of 1-RM and 2 sets of 10 reps. The CSPFP was used to measure physical function. Following training, the strength training group significantly improved in their total CSPFP score (+24%) and in the upper body strength domain (+18%). Further, a significant increase in the 1-RM on the bench press (+53%) was seen \(^4\).

Coke and colleagues studied the impact of upper body strength training on upper extremity strength and household physical activity in older women attending cardiac
rehabilitation. Thirty women were randomized into either a ten week progressive strength training group or a usual care control group. In addition to usual care, the strength training group completed a single, 12 repetition set of 5 progressive, moderate-intensity, upper body exercises including chest press, shoulder press, bicep curl, lateral row left and right, and tricep extension two days per week. Each participant began training at 40% of 1-RM for the first three weeks. At three week intervals, the weight was increased to 50% (weeks 4-6) and then 60% (weeks 7-10) of 1-RM. The primary outcome was perceived performance of household physical activity measured with the Kimble Household Activities Scale. Each participant rated their perceived ability to perform each of the 14 common HPA tasks. Upper extremity strength was quantified by the 1-RM on each exercise. Following the intervention period, both the strength training group and the control group showed improvements in upper extremity strength. However, the percent increase in strength was significantly greater in the strength training group for all exercises. The strength training group increased the mean number of household physical activity tasks performed compared to baseline (11.25 versus 8.75), whereas the control group decreased in the mean number of household physical activity tasks performed (6.86 versus 8.60). This shows that upper body strength training is an effective tool to increase muscle strength and improve the ability to perform household physical activity tasks after a cardiac event.

Stroke is the leading cause of serious, long-term disability among American adults. Since approximately 70% to 80% of people who sustain a stroke have upper extremity impairment, identifying an effective rehabilitation strategy is paramount.
Upper body strength training has been shown to improve the recovery of upper extremity function and increase upper extremity strength in stroke survivors 44, 45, 59, 61.

Pang and colleagues examined the effect of a community-based upper extremity group exercise program on motor function and performance of functional activities in chronic stroke patients 44. Sixty-three stroke patients with chronic deficits were randomly assigned into either an arm exercise group or a leg exercise group. Both the arm and leg groups underwent an exercise program for 19 weeks (1 hour sessions, 3 sessions/wk). The arm exercise sessions consisted of a brief warm-up and cool-down period, in which a series of upper extremity stretches were performed. The participants were required to rotate through 3 exercise stations designed to increase upper extremity function: 1) shoulder exercises with a Theraband, 2) range of motion, weight bearing activities, and elbow/wrist exercises with dumbbells, and 3) hand activities and functional training. The patients progressed by increasing the weight lifted and increasing the volume of training from 2 sets of 10 reps to 3 sets of 15 reps. The leg group completed a lower-extremity training program. Exercises included walking, sit-to-stand, mobility and balance tasks, partial squats, and toe rises. The primary outcome was the Wolf Motor Function Test (WMFT), used to assess upper extremity function. A secondary outcome was grip strength. A significant group by time interaction was seen (P = .017), indicating that overall, the arm group had significantly more improvement than the leg group. The arm group showed a greater improvement in the WMFT than the leg group (P = .003), and also showed a greater increase, although not significant, in grip strength (arm = 16.5 N, leg = 4.1 N). The authors concluded that an upper extremity exercise program can improve upper extremity function in persons with chronic stroke 44.
IMPLICATIONS AND STUDY OBJECTIVES

The American population is rapidly aging. Upper extremity strength and function, both shown to be important for ADL’s, IADL’s, and survival, both decline with increasing age. Despite this, upper extremity strength and function have received limited attention in healthy older adults. Further, no studies have looked at the effect of a comprehensive upper body strength training program on the strength of multiple joints in the upper extremity and upper extremity function in ostensibly healthy older adults. Therefore, this study had two main objectives: 1) to examine change in upper extremity strength as quantified by the isometric joint strengths of the elbow and shoulder following 6 wks of upper extremity resistance training, and 2) to examine change in upper extremity function as quantified by the maximal functional reaching and functional pulling strength following training. It was hypothesized that compared to the control group, the strength training group would increase isometric strength in all four isometric strength measures and would increase in functional reaching and functional pulling strength.
METHODS

OVERVIEW OF STUDY DESIGN

This randomized controlled trial took place at the Wake Forest University Department of Health and Exercise Science Clinical Research Center, the J.B. Snow Biomechanics Laboratory in Reynolds Gymnasium on the Reynolda Campus, and the MRI Building at the Wake Forest University Baptist Medical Center. Participants were recruited from a study volunteer list and screened for eligibility. Eligible participants were scheduled for three 60 minute sessions, one per day, for baseline assessment. The informed consent was obtained on the first session. After baseline assessment, the participant was randomly assigned into either a 6 week strength training group or a control group. Upon completion, participants completed a second round of three 60 minute sessions, one per day, for follow-up assessment. The measures used in this analysis were a component of a larger protocol; pertinent to this thesis were the isometric joint strength testing and the functional task testing.

PARTICIPANTS

Ten older adults, 4 female and 6 male, were recruited from the Winston-Salem, NC community. To be eligible, the participants needed to meet the following inclusion criteria: 1) adult males or females $\geq$ 65 years of age; 2) free of any medical condition that might be exacerbated by physical testing or strength training; 3) have no contraindications to undergoing MRI; and 4) have no history of neuromuscular disorder or injury that may affect the upper limb. The strength training group consisted of 2 males and 2 females and the control group consisted of 4 males and 2 females.

TESTING PROCEDURES
Isometric strength testing and functional task testing were completed on separate days to minimize fatigue and participant burden. Both tests were conducted only on the participant’s dominant side. Each test was administered by two trained personnel, who were blind to group assignment, and lasted approximately 60 minutes.

**Isometric Strength Testing**

Isometric muscle strength as quantified by the joint moment produced during a maximum voluntary contraction was measured for six muscle groups at the shoulder, elbow, and wrist using a KinCom dynamometer (Isokinetic International, Harrison, TN) located in the J.B. Snow Biomechanics laboratory in Reynolds Gymnasium on the Reynolda Campus of Wake Forest University. Prior to testing, study personnel were properly trained on test procedures, test administration, and equipment. To begin the test, the participant was strapped in and was made to feel as comfortable as possible. The muscle groups tested were the wrist flexors and extensors, elbow flexors and extensors, and shoulder adductors and abductors. The joints were tested in random order. For each trial, the participant contracted maximally for three seconds. Three trials were collected for each functional group, for a total of eighteen trials. The participant was given 60 seconds of rest between trials and more between joints. The starting positions of the wrist, elbow, and shoulder varied depending on the joint tested. When testing the wrist or elbow, the wrist was at 0 degrees, the elbow at 90 degrees, and the shoulder at 0 degrees in all directions. When testing the shoulder, the wrist was at 0 degrees, the elbow was at 0 degrees, and the shoulder was at 60 degrees of elevation with no rotation. The maximum moment generated for the elbow and shoulder joints was used for analysis.
Functional Task Testing

The functional task testing was conducted in a biomedical engineering laboratory in the MRI Building at Wake Forest University Baptist Medical Center. Two tasks, a functional reaching task and a functional pulling task, were completed in random order. A wrist brace was worn throughout both tests to minimize the effect of grip strength. Additionally, the participant was strapped across the chest into a chair to limit torso movement. The methods used for the tests were influenced by the broader interests of the larger study. During the tests, three-dimensional kinematic data was collected using a 7 camera motion capture system (Motion Analysis, Santa Rosa, CA), and electromyography (Biopac, Goleta, CA) of the biceps, triceps, and deltoïd muscles was simultaneously collected.

Functional Reaching Task: The functional reaching task was performed with the participant strapped into the chair with a table in front of him or her. Prior to beginning the task, the participant was placed in a comfortable position, with the knees at about 90 degrees. Maximum reach distance was measured on the table and marked with a piece of tape to serve as a target. To begin the task, the participant grasped a dumbbell which was resting vertically on the edge of the table directly in front of him or her. The ideal starting angle of the elbow was around 90 degrees. The task consisted of the participant lifting the dumbbell off of the table and reaching it forward, placing it near the target. At the end of the reach, the elbow was between 160 and 170 degrees. Each participant started with a one pound dumbbell, and the task was repeated with a heavier dumbbell until a maximum weight was found. This was defined as the maximum weight dumbbell that could be successfully lifted off of the table and reached towards the target, without
dragging it. The maximum weight was recorded and used for analysis. Sixty seconds of rest was given between trials. Once the maximum was found, the participant did a second trial at this weight and two trials at half-maximum for kinematic and EMG purposes.

**Functional Pulling Task:** Using a custom-built pulley system, each participant completed a level pulling task. Prior to beginning the task, the participant was strapped into the chair and placed in a comfortable position. At the starting position of the task, the participant’s elbow was between 160 and 170 degrees while grasping the handle. The task consisted of the participant pulling the handle towards his or her body, ending with the arm at the side. Each participant started with five pounds, and the task was repeated with heavier weights until a maximum weight was found. The maximum weight was recorded and used for analysis. Sixty seconds of rest was given between trials. Once the maximum was found, the participant did a second trial at this weight and two trials at half-maximum for kinematic and EMG purposes.

**TRAINING GROUP**

Participants randomly assigned into the training group completed 6 weeks of upper body strength training. All resistance training sessions were held at the Department of Health and Exercise Science Clinical Research Center. Exercise was controlled and supervised by a Master’s level exercise physiologist certified in emergency management procedures. Prior to beginning the intervention, the participant was scheduled for an orientation session. In this session, the participant was familiarized with the exercise routine and equipment, was taught proper technique, and performed an initial one-repetition maximum (1-RM) test on each weight machine. The exercise sessions took place at 2:30 P.M. on Mondays, Wednesdays, and Fridays. If a participant
missed a session, a make-up session was added. Therefore, each participant completed 18 sessions in total. The time it took to complete each exercise session varied from 50-70 minutes.

**Exercise Sessions**

For safety purposes, a resting blood pressure and a resting heart rate was taken prior to exercise. Additionally, the participant’s health status, such as any pain, sickness, muscle soreness, injury, or medication changes, was assessed before each exercise session. Each session consisted of three phases: a warm-up, resistance training, and a cool-down.

**Warm-Up:** The warm-up consisted of light aerobic activity and upper-body stretches. The participant walked two laps (about 1/6th of a mile) around the indoor track at a light intensity. Next, the participant completed six upper-body stretches, all held for 20-30 seconds. The six stretches were: cross shoulder stretch, triceps stretch, biceps stretch, forearm stretches, chest stretch, and upper back stretch. The first four were completed with the participant sitting in a chair, and the last two were completed with the participant standing next to a weight machine. For a detailed description of each stretch, see appendix A.

**Resistance Training:** The participant completed 9 upper body resistance exercises. This consisted of 6 Nautilus weight machine exercises and 3 free weight, dumbbell exercises. The 6 weight machines used were: tricep press, preacher curl, chest press, overhead press, compound row, and incline press. The 3 free weight exercises used were: lateral raise, wrist curl, and wrist extension. For a detailed description of each exercise, see appendix A. The trained staff supervised each exercise to ensure proper
lifting and breathing technique. A certain order of exercise, designed to minimize muscle

group fatigue, was determined for each participant and held constant throughout the

intervention. The weight machines were always completed before the free weight

exercises. Three sets of varying repetitions (see progression) was completed for every

exercise other than the wrist curl and wrist extension, in which only one set was

performed. A rest period of 60-90 seconds was given between each set.

**Cool-Down:** For the cool-down phase, the participant walked one lap around the

indoor track and completed the same series of stretches as done in the warm-up.

**Progression**

An aggressive progressive resistance training protocol was used. For the first

three lifting sessions, three sets of eight repetitions (reps) were performed at an initial

weight of ~60% of initial 1-RM. The weight was occasionally reduced as deemed

appropriate by the staff in order to ensure that three sets of eight reps could be completed.

Starting in session four, the weight was gradually increased as tolerated so that it reached

~70% of initial 1-RM by the end of session six. Starting in session seven (beginning of

week 3), the participant completed two sets of eight reps, and then completed as many

reps as possible, with good form, in the third set. The ideal resistance was ~75% of 1-

RM, and also enough for the participant to reach volitional fatigue at or around eight

repetitions on the third set. If the participant, with good form, was able to complete 12 or

more repetitions in one session or 10 or more repetitions in consecutive sessions in the

third set, the weight was increased as deemed appropriate by the staff. For the free

weight exercises, three sets of eight reps were performed for the lateral raise, and one set

of ten reps was performed for the wrist curl and wrist extension throughout the
intervention. The weight for these exercises was slightly increased if it was apparent that
the participant could complete all repetitions with good form at a higher weight.

1-RM Testing

Three 1-RM tests were conducted for each participant: one at baseline, one at the
end of three weeks (session 9), and one at the end of six weeks (session 18). The
maximum amount of weight that could be lifted one time, while keeping good form, was
considered the 1-RM. In each test, the 1-RM was found on all six of the weight machines.
All tests were administered by the same staff member. To perform the test, the
participant was instructed to attempt to lift the weight two times. If two reps could be
completed, more weight was added. This process continued until only one repetition
could be completed with proper technique. Ideally, the 1-RM was found after 3-6
attempts. The participant was given 60-90 seconds of rest between attempts.

CONTROL GROUP

Participants randomized into the control group were asked to continue living their
normal daily routine and were encouraged to refrain from starting a resistance training
program until they had completed follow-up testing. Each member of the control group
was called after three weeks. Any changes in health status, physical activity patterns, diet,
medications, or weight were noted.

ANALYTIC PLAN

Normality of the data was checked for all variables of interest using a one-sample
Kolmogorov-Smirnov test. As a check on the success of the strength training program,
changes in 1-RM’s and changes in the amount of work performed were examined.
Descriptive statistics were used to establish the characteristics of the training group and
of the control group. Variables of interest included age, gender, BMI, the four isometric
joint strengths, functional reaching strength, and functional pulling strength. To check for any differences between the groups at baseline, a t-test was performed on each variable. To examine changes in the four isometric joint strengths and the functional reaching strength and functional pulling strength between the groups, ANCOVA’s were performed on the change scores, adjusting for baseline values and gender. For exploratory analysis, Pearson correlations were used to assess the relationship between the isometric strength at the elbow and shoulder and the two functional strengths.
RESULTS

PARTICIPANT CHARACTERISTICS

A total of 11 participants were randomized into this study. One participant dropped out after his first exercise session due to family emergency and was not included in the analysis. The final sample included 6 males and 4 females. A total of 2 males and 2 females were in the training group, and a total of 4 males and 2 females were in the control group.

Baseline characteristics of both groups, including age, BMI, isometric joint strengths, functional reaching strength, and functional pulling strength, are presented in table 2. The two groups were similar in age and BMI. The training group tended to be stronger than the control group in all isometric joint strengths except shoulder adduction at baseline. Similarly, the training group tended to have more functional strength at baseline than the control group. However, none of these differences were significant.
Table 2. Baseline Characteristics

<table>
<thead>
<tr>
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<th>Group</th>
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<tbody>
<tr>
<td></td>
<td>Control (N=6)</td>
</tr>
<tr>
<td></td>
<td>Mean ± SD</td>
</tr>
<tr>
<td>BMI</td>
<td>24.75 ± 3.72</td>
</tr>
<tr>
<td>Age</td>
<td>75.17 ± 3.13</td>
</tr>
<tr>
<td>Reaching Strength (kg)</td>
<td>6.21 ± 2.68</td>
</tr>
<tr>
<td>Pulling Strength (kg)</td>
<td>24.24 ± 5.25</td>
</tr>
<tr>
<td>Elbow Flexion (Nm)</td>
<td>35.47 ± 17.00</td>
</tr>
<tr>
<td>Elbow Extension (Nm)</td>
<td>32.94 ± 13.75</td>
</tr>
<tr>
<td>Shoulder Abduction (Nm)</td>
<td>22.17 ± 10.84</td>
</tr>
<tr>
<td>Shoulder Adduction (Nm)</td>
<td>41.41 ± 22.53</td>
</tr>
</tbody>
</table>
INTERVENTION EFFICACY

Compliance for the training intervention was 100%. Not a single member of the training group missed an exercise session. Additionally, no adverse events were reported. Figure 2 represents the total amount of weight lifted in each exercise session, for each member of the training group. MAIPA and MILRU are females and ROBKE and GREJA are males. Each participant increased the total amount of weight lifted throughout the exercise intervention in a linear fashion. An average percent increase of 66% (range 52%-76%) was seen in the total amount of weight lifted from the beginning to the end of the intervention. Figure 3 shows the 1-RM on each weight machine for each participant at baseline, 3 weeks, and 6 weeks. A progressive increase in 1-RM was seen for each participant. The average percent increase in 1-RM from baseline to 6 weeks for each weight machine was (mean, range): Compound Row (37.4, 24-60), Overhead Press (39.6, 30.7-50), Incline Press (63.1, 28-97.4), Tricep Press (24.4, 14.3-33.3), Chest Press (30.1, 11.8-53.8), Bicep Curl (30.7, 12.5-66.7).
Figure 2. Total Weight Lifted From the Beginning to the End of the Intervention
Figure 3. 1-RM’s for Each Participant at Baseline, 3 Weeks, and 6 Weeks
**ISOMETRIC JOINT STRENGTH**

Table 3 shows the change in peak isometric strength for elbow flexion, elbow extension, shoulder abduction, and shoulder adduction of both the control group and the training group. The training group significantly increased in shoulder adduction strength compared to the control group after adjusting for baseline shoulder adduction strength and gender \([F(1,9) = 12.59, p=.012]\). None of the other changes were statistically significant, adjusting for the baseline isometric strengths and gender. For the adjusted mean change values, see appendix B. Figures 4 and 5 depict the unadjusted mean ± SD values of both groups at baseline and post testing for all four isometric joint strengths. The variability from baseline to post was much greater than expected. To illustrate this, figures 6 and 7 show each individual’s data on all four isometric joint strengths.

**Table 3. Change in Isometric Joint Strengths**

<table>
<thead>
<tr>
<th>Group</th>
<th>Control Mean ± SD</th>
<th>Training Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Post</td>
</tr>
<tr>
<td>Elbow Flexion (Nm)</td>
<td>35.47 ± 17.00</td>
<td>43.09 ± 24.96</td>
</tr>
<tr>
<td>Elbow Extension (Nm)</td>
<td>32.94 ± 13.75</td>
<td>47.23 ± 29.04</td>
</tr>
<tr>
<td>Shoulder Abduction (Nm)</td>
<td>22.17 ± 10.84</td>
<td>19.54 ± 12.04</td>
</tr>
<tr>
<td>Shoulder Adduction (Nm)</td>
<td>41.41 ± 22.53</td>
<td>45.07 ± 20.93</td>
</tr>
</tbody>
</table>

*Significant change
Figure 4. Elbow Flexion and Extension Group by Time Interactions

Elbow Flexion

Elbow Extension

Mean Peak Torque (Nm)

Time

Baseline

Post

Control

Training

Mean Peak Torque (Nm)

Baseline

Post

Control

Training

43
Figure 5. Shoulder Abduction and Adduction Group by Time Interactions

**Shoulder Abduction**

![Shoulder Abduction Graph]

**Shoulder Adduction**

![Shoulder Adduction Graph]
Figure 6. Elbow Flexion and Extension Individual Data

Elbow Flexion

Elbow Extension

Time

Baseline Post

Control Males
Control Females
Training Males
Training Females

Baseline Post

Control Males
Control Females
Training Males
Training Females

Peak Torque (Nm)
Figure 7. Shoulder Abduction and Adduction Individual Data

Shoulder Abduction

- Control Males
- Control Females
- Training Males
- Training Females

Shoulder Adduction

- Control Males
- Control Females
- Training Males
- Training Females
FUNCTIONAL STRENGTH

Changes in maximal functional reaching strength and functional pulling strength for both the control group and the training group are shown in table 4. Both groups increased similarly in functional reaching strength. The training group significantly increased in functional pulling strength compared to the control group after adjusting for baseline pulling strength and gender [F(1,6) = 31.83, p=.011]. For the adjusted mean change values, see appendix B. Figure 8 illustrates the unadjusted mean ± SD values of both groups at baseline and post testing for reaching strength and for pulling strength.

Table 4. Change in Functional Strength

<table>
<thead>
<tr>
<th>Group</th>
<th>Control Mean ± SD</th>
<th>Training Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Post</td>
</tr>
<tr>
<td>Reaching Strength (kg)</td>
<td>6.21 ± 2.68</td>
<td>7.27 ± 2.39</td>
</tr>
<tr>
<td>Pulling Strength (kg)</td>
<td>24.24 ± 5.25</td>
<td>29.17 ± 9.11</td>
</tr>
</tbody>
</table>
Figure 8. Functional Strength Group by Time Interactions

**Reaching Strength**

- **Control**
- **Training**

**Pulling Strength**

- **Control**
- **Training**
**CORRELATION ANALYSIS**

For exploratory analysis, Pearson correlations were used to assess the relationship between the isometric strength at the elbow and shoulder and the two functional strength assessments. Because the change in isometric strength was not as expected, only the post measures were used. The correlations are shown in Table 5 and significant values are marked with an asterisk. Post reaching strength was significantly correlated with post shoulder adduction strength (p<.001) and post elbow flexion strength (p=.031). Likewise, post pulling strength was also significantly correlated with post shoulder adduction strength (p<.001) and post elbow flexion strength (p=.032).

**Table 5. Pearson Correlations Among Isometric and Functional Strength**

<table>
<thead>
<tr>
<th>Post Reaching Strength (lbs)</th>
<th>Post Elbow Flexion (Nm)</th>
<th>Post Elbow Extension (Nm)</th>
<th>Post Shoulder Abduction (Nm)</th>
<th>Post Shoulder Adduction (Nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post Reaching Strength (lbs)</td>
<td>.677*</td>
<td>.421</td>
<td>.457</td>
<td>.926*</td>
</tr>
<tr>
<td>Post Pulling Strength (lbs)</td>
<td>.796*</td>
<td>.280</td>
<td>.384</td>
<td>.977*</td>
</tr>
</tbody>
</table>
DISCUSSION

The prevention of disability in older adults is an important goal for public health. Improving or eliminating limitations in activities is critical to independence and thus the prevention of disability in the older adult population. Resistance training is a widespread and effective method to improve some aspects of lower extremity function. However, the results of studies that have assessed the effect of resistance training on upper extremity function in healthy older adults have been mixed. Two studies have shown an improvement in function following 6 months of strength training, while three studies failed to show an improvement.

This study had two main objectives: 1) to examine change in upper extremity strength, as quantified by the isometric joint strengths of the elbow and shoulder following 6 weeks of upper body resistance training, and 2) to examine change in upper extremity function, as quantified by the maximal functional reaching and functional pulling strength following training. It was hypothesized that compared to the control group, the strength training group would increase isometric strength in all four isometric strength measures and would increase in functional reaching and functional pulling strength.

INTERVENTION EFFICACY

The strength training intervention was well-received by all participants. No adverse events were reported, supporting previous studies showing that a high-intensity progressive resistance training protocol is safe for older adults. The compliance rate was
100%. Not a single subject of the training group missed an exercise session. Three previous studies have reported a compliance rate of 74%, 80.5%, and 82% \(^9,^{10,43}\).

**Training Protocol**

Previous studies that have used an upper body strength training protocol have had some limitations. For example, de Vreede et al. only used elastic tubing and light weights as the primary resistance \(^{10}\). Further, Nelson et al. only utilized the overhead press, biceps curl, and triceps press exercises \(^{43}\). Even in studies with an upper body only strength training protocol, the number of upper body exercises was small \(^{26,53}\). Roman et al. used four exercises, all for the elbow flexors, and Keogh et al. only used the bicep curl, wrist flexion, and wrist extension exercises. We used a comprehensive, high-intensity progressive strength training protocol aimed at improving the strength of the arms, upper back, chest, and shoulders. The combination of the number of exercises performed and the progression of intensity in our study is greater than any other previous study looking at the effect of strength training on upper extremity function.

**Dynamic (1-RM) Strength**

Previous studies have reported modest improvements in dynamic (1-RM) strength of the upper extremity following resistance training \(^{17,41,43}\). Nelson et al. and Miszko et al. reported an increase in chest press 1-RM of 15.7% and 14.4% after 6 months and 4 months of training, respectively. After 8 weeks of training, Henwood & Taaffe reported an increase of 12.5%, 2%, and 25% for the chest press, supported row, and biceps curl, respectively. After 6 weeks of training, we observed an increase of 30.1%, 37.4%, 30.7%, 39.6%, 63.1%, and 24.4% for the 1-RM strength of chest press, compound row, biceps curl, overhead press, incline press, and triceps press, respectively. Clearly, our training
Protocol was very effective compared to previous data. We made certain that volitional fatigue was reached at the end of the third set, therefore ensuring maximum progressive overload. Based on our results, it appears that this method is more effective than the subjective RPE ratings used by Nelson et al. and the strict adherence to percent 1-RM used by Miszko et al. and Henwood & Taaffe to prescribe intensity.

**ISOMETRIC JOINT STRENGTH**

One objective of this study was to determine the change in maximal isometric strength of the elbow and shoulder following training. We hypothesized that compared to the control group, the training group would increase strength in all four isometric strength measures. Previous research has only looked at the change in isometric elbow flexion strength following training. de Vreede et al. and Cress et al. showed an increase of 8.6% and 10.7%, respectively, while Skelton et al. showed a larger increase of 22% following training. In these studies, the control group had no change or a slight decrease in elbow flexion strength.

Our results show that shoulder adduction strength increased significantly in the training group compared to the control group. None of the other isometric strength measures were significantly different between the two groups. When contrasted to the increase in dynamic strength exhibited by the training group, the changes in isometric strength were somewhat unexpected. The increase in shoulder adduction strength is promising, but the fact that the other measures of isometric strength did not change despite increases in dynamic strength is puzzling. However, our findings are consistent with the previous research of Brown and colleagues, who found that after 12 weeks of training, dynamic elbow flexion strength increased by 48% while the isometric strength of the elbow flexors did not change. Further, Frontera and colleagues found that despite...
a 107% increase in dynamic knee extension strength, isometric knee extension strength did not increase. Brown and colleagues noted that this observed specificity points to the important role of nervous system adaptations in the response to strength training, in particular the role of learning and coordination. Interestingly, Lexell and colleagues found that after 11 weeks of training the elbow flexors using barbell curls, dynamic elbow flexion strength increased by 49% while isokinetic elbow flexion strength also increased by 37%. These results show that the transfer of strength from dynamic to isokinetic may be greater than the transfer of strength from dynamic to isometric. Barry and colleagues propose that the neural adaptations exhibited by older adults in response to strength training are akin to motor learning. As a result, they suggest that it would be expected that the neural adaptations might transfer less readily beyond the specific training task to other movement contexts. This could explain why in our study, the increases in dynamic strength did not transfer to an increase in all four measures of isometric strength.

The variability in isometric strength from baseline testing to post testing was much greater than expected, as illustrated by the large standard deviations of the change values. The variation within trials, however, was low. The average coefficient of variation within trials for all measures of isometric strength were (baseline %, post %): elbow flexion (19.1, 7.6), elbow extension (7.7, 13.9), shoulder abduction (8.4, 9.5), and shoulder adduction (9.5, 6.4). We conducted additional analysis, utilizing the average of the three trials rather than the peak, but this had no effect on the conclusions. Regardless of group, some participants doubled or tripled their baseline value, while some participants decreased their baseline value by half.
Four factors that might have led to the variability of the isometric strength measures are learning or familiarization with the testing procedure, voluntary effort of the participant, the difficulty of the movements, and genetic differences. It would be reasonable for the participants to increase strength slightly simply due to being more familiar with the testing apparatus and procedure. However, it is unlikely that this would account for the large increases or reductions in strength we observed. A consistent maximal effort from the participant during the strength testing is critical in obtaining reliable results. This may present a challenge when testing older adults. Schroeder and colleagues suggest that apprehension about performing maximal strength exercises may limit performance during the initial evaluation session. Such psychological factors may contribute to submaximal performance at baseline followed by improvements in subsequent testing sessions. Further, a reduction in strength could be explained by a reduction in effort from baseline to post testing. Another reason for the variability may be the difficulty of the movements. Particularly for elbow extension, shoulder abduction, and shoulder adduction, maximal exertion is a novel task for most people. Simply learning how to coordinate the movement may have accounted for some of the increase in strength. Further, in training subjects, the response to the strength training stimulus may have been influenced by genetic factors, such as the ACE genotype, which may have increased the variability on the isometric tests.

To further investigate this variability issue, we conducted a reliability study using the two principal investigators as subjects. Both completed two sessions of the isometric joint strength testing, with a day in between the testing sessions. The percent change from the first to the second session for peak isometric strength of both subjects was:
elbow flexion (10.5, 4), elbow extension (-4.82, -11), shoulder abduction (51.1, 296), and shoulder adduction (-11.6,-11.3). However, the variation within trials was again low. Twenty-three out of the 32 (72%) coefficient of variation values remained below 10%. Although neither subject was an older adult, this underscores the potential for variations in isometric strength of the upper extremity between testing sessions, particularly for the shoulder. One suggestion for future research is the implementation of at least two baseline assessments of isometric joint strength when testing older adults.

**UPPER EXTREMITY FUNCTION**

The primary objective of this study was to determine the effect of upper body strength training on upper extremity function. We utilized two maximal effort functional tasks, a functional reaching task and a functional pulling task, to assess upper extremity function. We hypothesized that compared to the control group, the training group would increase functional strength in both tasks. In previous research, the effect of strength training on upper extremity function has been mixed⁹,¹⁰,⁴¹,⁴³,⁵⁶. However, most of the research has only included upper extremity function as a small part of a total physical functioning assessment. In the one study that did include a single performance task of the upper extremity, Skelton and colleagues reported no difference between the training group and the control group in an incremental bag raise task. However, there was a ceiling effect for this task. The median score for the training group at post testing was 8 kg, which was the maximal amount of weight that was available⁵⁶. In contrast, we attempted to assess function at a maximal level. This provides an indication of one’s functional reserve, the difference between one’s maximal ability and the requirements of submaximal tasks that one encounters on a daily basis. Rantanen and colleagues suggest that the functional reserve can be seen as a safety margin that helps prevent disability
from developing, for example, following inactivity and deconditioning associated with surgery or an acute illness. Those with a greater strength reserve may lose more strength without reaching the threshold for disability.

Our results show that functional pulling strength increased significantly in the training group compared to the control group. There was no difference between the groups in functional reaching strength. The increase in functional pulling strength is a promising and important result. However, the failure to increase in functional reaching strength, despite showing an increase in dynamic strength and isometric shoulder adduction strength, is disappointing. This is consistent with previous research which shows that increases in strength do not always lead to increases in function. Of the five studies looking at the effect of resistance training on some measure of upper extremity function in healthy older adults, the two studies that showed an improvement in function did not show an increase in strength. Conversely, all three studies that failed to show an improvement in function showed an increase in strength.

Based on our results and in accordance with the argument above, that is, that the neural adaptations in older adults caused by resistance training might transfer less readily beyond the specific training task to other movement contexts, it appears that increases in functional strength may only occur if it is similar to the training task. In our study, we observed a strong correlation (r = .941) between post functional pulling strength and final compound row 1-RM. Interestingly, the training group increased by 37.4% in compound row 1-RM and by 32.3% in functional pulling strength. In contrast, the functional reaching task was not as comparable to any of the strength training exercises. This may
be the reason that we saw an increase in functional pulling strength but failed to see an increase in functional reaching strength.

Our finding that upper body strength training improved functional pulling strength is relevant to the prevention of disability in older adults. Strength training increased the functional reserve for submaximal pulling tasks. Pulling is an important task for performing activities of daily living and maintaining independence for older adults. Examples of tasks that require pulling strength include: opening doors, grabbing items from shelves, daily housework such as sweeping and vacuuming, using the upper body to assist with stair climbing, and lifting heavy items from the ground. The fact that our training group increased in functional pulling strength is evidence that upper body strength training can improve upper extremity function.

**Correlation Analysis**

Because this study was a pilot study, we performed an exploratory analysis of the data. We examined the correlation between the maximal isometric joint strengths and the two maximal functional tasks. Because the change values were so variable, we looked at the correlation between only the post measures.

Shoulder adduction strength and elbow flexion strength were significantly associated with both functional reaching strength and functional pulling strength. It is not surprising that they were strongly associated with functional pulling strength, as pulling requires the concentric action of the latissimus dorsi muscle, a shoulder adductor, and the biceps brachii muscle, an elbow flexor. More surprising was the strong association with functional reaching strength because this task does not require the concentric action of any of the shoulder adductors or elbow flexors. Although not available for this thesis,
EMG was recorded during each of the functional tasks. This may help to explain these associations.

An application of this finding may be the increased use of shoulder adduction as a measure of upper extremity strength. Currently, most studies only look at elbow flexion if they include a measure of upper body strength. Adding a measure of shoulder adduction strength to elbow flexion strength may provide a better indicator of overall strength and function of the upper extremity.

**STUDY LIMITATIONS**

It is important to note the limitations of this study. We had a small sample and almost all participants were white males or females living in the Winston-Salem, NC community. This limits the power to find significant results and also the generalizability of the study. Further, most participants were relatively functionally able at baseline.

The KinCom dynamometer had not been used for isometric joint strength testing of the upper extremity in our lab before this study. The reliability of testing the upper extremity using the KinCom is unknown. Further, when performing our own reliability study, a mechanical issue was noted which may have affected the validity of the isometric elbow extension strength. We found a method to increase the force produced by using the arm strap for leverage.

Both measures of upper extremity function, the functional reaching task and the functional pulling task, are new. No previous research has been done utilizing either of the tasks. Therefore, the reliability and validity of the tasks are not known. Also, the first three participants to perform the functional pulling task, all members of the control group, maxed out the amount of weight available, so their data could not be used for analysis.
**FUTURE DIRECTIONS**

There is a need for further research to be done to find the best possible methods to assess upper extremity function. The number of functional tasks for the upper extremity needs to be expanded to match the wide array of tasks available for the lower extremity. Future research is necessary to prove the validity and reliability of our two functional tasks. Similarly, reliability studies of isometric joint strength testing on the KinCom dynamometer are needed. Future studies should attempt to include a larger, more diverse, and less functionally able sample. More research is needed on the transfer of dynamic strength to isometric strength and functional strength. Also, further research is needed to determine which joint strengths (elbow flexion, shoulder adduction) are most important for upper extremity function. This could help guide the design of overall strength training protocols for older adults.

**IMPLICATIONS AND CONCLUSIONS**

In this study we examined the effect of upper body strength training on upper extremity strength and function in healthy older adults. We found that strength training improved functional pulling strength and isometric shoulder adduction strength. Further, each member of our training group improved in dynamic strength. The lack of improvement in all measures of isometric strength and functional strength supports the notion that the neural adaptations in older adults caused by resistance training might transfer less readily beyond the specific training task to other movement contexts. The strength training protocol used in this study was well-received, effective, and safe for older adults. The increase in functional pulling strength is a promising result and is relevant to the prevention of disability in older adults. It is evidence that upper body strength training in older adults has the potential to increase upper extremity function.
APPENDIX A

Warm up: Approx. 5-10 min.

Walk two laps around the small track or ride an exercise bike for a few minutes. This should be done at a light intensity.

Stretches:

The first four stretches should be done sitting in a chair. The last two should be performed next to a wall or exercise machine.

1. Cross Shoulder stretch
   - Cross one arm horizontally over your chest, grasping it with either your opposite hand or forearm just above the elbow joint.
   - Hold for 20-30 seconds and switch arms.

2. Tricep stretch
   - Extend one hand over your head and down the center of your back with fingers pointed downwards. Use the other hand to grasp the elbow and pull gently downward while exhaling.
   - Hold for 20-30 seconds and switch arms.

3. Bicep stretch
   - Take your arms out to the sides, slightly behind you. Starting with your thumbs up, rotate your thumbs down and back until they are pointing backward.
   - Hold for 20-30 seconds.

4. Forearm stretches
   - Extend one arm out in front of you. Grasp the undersides of your fingers with your other hand and push up and towards you. This should stretch the bottom of the forearm.
   - Hold for 20-30 seconds.
   - With the same hand, grasp the top of the fingers and push down and towards you. This should stretch the top of the forearm.
   - Hold for 20-30 seconds.
   - Repeat for your other arm.

5. Chest stretch
   - Extend one arm out to the side and either place your hand against a wall or grab onto the frame of an exercise machine. Twist your upper body into the stretch, so that you can feel tension in your chest.
   - Hold for 20-30 seconds and switch arms.
6. Upper back stretch
   - Extend both arms in front of you and grab onto the frame of an exercise machine. Bend down and sink back into the stretch, so that you can feel tension in your upper back.
   - Hold for 20-30 seconds.

**Resistance Training:** Approx. 40-50 min.

Your goal is to complete 3 sets of 8-10 repetitions for each exercise. Complete as many repetitions as you can on the third set so the intervention staff can determine if the weight should be increased. Aim to complete each phase of the exercise in ~2-3 seconds.

1. Triceps Press
   - To adjust the resistance, place the pin into the weight stack next to the amount of weight that you would like to lift.
   - The seat should be adjusted so that your elbows are slightly above your shoulders.
   - Secure the seat belt.
   - Press the handles downward until your elbows are almost fully extended.
   - Return slowly to starting position.

2. Vertical Chest Press
   - To adjust the resistance, place the pin into the weight stack next to the amount of weight that you would like to lift.
   - The seat should be adjusted so that your shoulders are even with the handles.
   - Place feet on footpad and press forward to position the handles.
   - Grasp the horizontal handles and release the footpad.
   - Press handles forward until your elbows are almost fully extended.
   - Return slowly to starting position.

3. Bicep (Preacher) Curl
   - To adjust the resistance, place the pin into the weight stack next to the amount of weight that you would like to lift.
   - Sit on the machine and rest your arms on the pad so that your elbows are in line with the red dot on the side of the machine.
   - Grip the bar and curl it upward as far as possible.
   - Pause, and slowly return to starting position.

4. Overhead press
   - To adjust the resistance, place the pin into the weight stack next to the amount of weight that you would like to lift.
   - The seat should be adjusted so that the handles are positioned just below your shoulders.
   - Grasp the horizontal handles with your palms facing out and push the weight above your head, exhaling while you push up. Extend your arms above your head but don’t lock out your elbows.
- Slowly bring the weight back down to the starting position, controlling the movement the whole time and inhaling as you lower the weight.

5. Compound row
- To adjust the resistance, place the pin into the weight stack next to the amount of weight that you would like to lift.
- To begin this exercise, sit on the machine and place your chest flat up against the pad.
- The pad should be adjusted so that you need to reach slightly in order to grasp the handles.
- While grasping the handles your arms should be parallel to the floor and your elbows should be slightly bent.
- Grasp the top of the handles and pull towards you as far as you can while squeezing your shoulder blades together. Exhale as you pull towards you.
- Extend your arms back to the starting position, controlling the movement the whole time and inhaling as you return to the starting position.

6. Incline press
- To adjust the resistance, place the pin into the weight stack next to the amount of weight that you would like to lift.
- To begin this exercise, sit on the machine facing out with your back flat on the pad and feet flat on the floor.
- The seat should be adjusted so that the handles are positioned just below your shoulders.
- Grasp the horizontal handles with your palms facing out and push the weight out away from your body, exhaling while you push out. Extend your arms, but don’t lock out your elbows.
- Slowly bring the weight back down to the starting position, controlling the movement the whole time and inhaling as you lower the weight.

7. Lateral Raise
- Grip dumbbells and start with your arms at your sides.
- Keeping your elbows slightly bent, raise your arms out to the side until your arms are parallel to the floor. Pause, then return to the starting position.

8. Wrist Curl
- Seated on a bench, grip the dumbbell in one hand with that arm resting on your thigh.
- With your palm facing up, curl your wrist upwards, keeping your arm resting on your thigh.
- Switch hands and repeat exercise.

9. Wrist Extension
- Seated on a bench, grip the dumbbell in one hand with that arm resting on your thigh.
- With your palm facing down, extend your wrist upwards, keeping your arm resting on your thigh.
- Switch hands and repeat exercise.

**Cool Down:** Approx. 5-10 min.

Repeat warm-up exercises.
APPENDIX B

Estimated Marginal Means of the Change Values

<table>
<thead>
<tr>
<th></th>
<th>Group</th>
<th></th>
<th></th>
<th></th>
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<tbody>
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<td></td>
<td>Control</td>
<td>Training</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Change</td>
<td>Std. Error</td>
<td>Change</td>
<td>Std. Error</td>
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<td>Functional Pulling (kg)</td>
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<td>1.57</td>
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<td>Elbow Flexion (Nm)</td>
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<td>4.43</td>
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<td>4.85</td>
<td>29.52*</td>
<td>5.96</td>
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</tbody>
</table>

All measures adjusted for baseline values and gender
REFERENCE LIST


45. Patten, C., J. Dozono, S. Schmidt, M. Jue, and P. Lum. Combined functional task practice and dynamic high intensity resistance training promotes recovery of


SCHOLASTIC VITA

Joel David Eggebeen

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Undergraduate Study

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Certifications

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