Creating a Standardized Program To Resistance Train The Muscles Of The Head And Neck

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ABSTRACT

Concussions have reached epidemic levels. There is no cure for concussions. Measures taken to reduce concussions have not been effective. The majority of research is focused on concussion causation and concussion management after the fact. The research continues but the number of concussions in athletics increases each year.

No methodical approach to producing a specific protocol to strengthen the head and neck muscles exists and no systematic study of increase in neck musculature attributed to such a protocol is documented. Thus, this study will produce a standardized methodology for the reduction of concussive and subconcussive forces, laying the foundation for further research in this area.

The research participants were healthy male and female college students, age range 18-24. There were 30 participants. Of the 30 subjects used for this study, 18 participants were randomly assigned to the experimental group and 12 participants in the control group. The participants followed a protocol consisting of 13 movements designed to sequentially train the musculature of the head, neck and upper back. The duration of the study was 8 weeks.

The strength increases were significant in the active participant group. The hypertrophy of the head and neck muscles was equally as significant and even more impressive in the male group. The females exhibited minimal muscle hypertrophy. Every active participant experienced strength increases during the eight week study; likewise each active male participant exhibited neck circumference increases. The control group experienced negligible strength or hypertrophy increases.

Dedication

I dedicate my dissertation to my wife, Claudia. Through my hardships and physical injuries, she stood by my side never wavering or contemplating failure. Claudia's strength was my strength, without her steadfast resolve this mission would have failed and completion would have been impossible. This accomplishment belongs to her as much as it does to me. I include a poem that I have drawn strength from in my most trying times of my life.

Invictus

Out of the night that covers me,
Black as the pit from pole to pole,
I thank whatever gods may be
For my unconquerable soul.

In the fell clutch of circumstance
I have not winced nor cried aloud.
Under the bludgeonings of chance
My head is bloody, but unbowed.

Beyond this place of wrath and tears
Looms but the Horror of the shade,
And yet the menace of the years
Finds and shall find me unafraid.

It matters not how strait the gate,
How charged with punishments the scroll,
I am the master of my fate,
I am the captain of my soul.

BY WILLIAM ERNEST HENLEY

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Introduction

Statement of the Problem

Concussions—and the long term effects of these head injuries—are a hot topic in America today. A Google search on February 13, 2013, of news stories related to concussions published in the previous 24 hours resulted in six pages of results. Sadly, most of these news stories related instances where an athlete suffered a concussion. Other stories talked of helmets, rules of engagement, methods of recovery, and banning football for children. However, none of them spoke about concussion prevention. Helmets are good at preventing skull fractures, but producing a concussion-proof helmet is impossible (Wilson, 2013). Also, rules cannot change the intrinsic nature of a sport. Football, for instance, is a violent sport, and rules cannot make it something it isn't. Even after rule changes initiated by the NFL in 2010 to help protect players from concussions, the rate of concussion injuries was at best static, showing no improvement (Fink, 2013).

The idea of a concussion as an injury appeared in 900 A.D. when an Arab physician, Rhazes, described a concussion as an abnormal transient physiological state without gross traumatic lesion of the brain (Rhazes, 1497). In so doing, he introduced the notion that changes from concussion injury are not permanent. But researchers today are finding evidence of long-term effects of concussion.

Recently, just before the 2013 Super Bowl, even the President of the United States commented on the problem of concussions. The President said he understood that NFL players are aware of the risks they take. "But as we start thinking about the pipeline," the President intoned, “Pop Warner to high school to college, I want to make sure we’re doing everything we can to make the sport safer” (Hartstein, 2013). Many parents put their faith in the claims of helmet companies to protect their children. However, according to Alison Brooks of the University of Wisconsin School of Medicine and Public Health, parents should be wary of such claims. Dr. Brooks said, “We were getting questions from coaches and parents about helmet companies saying their helmets can prevent concussions. There's really no evidence to support that” (Do Certain, 2012). Much current research and existing theory looks to helmet technology to protect athletes from concussion. That research, however, is finding that helmets are unable to protect athletes against concussions at a truly effective level.

In fact, research published in the *Journal of Neurosurgery* (2011) found that pre-World War II leather helmets performed better or similar to 21st-century helmets. The authors state that:

> The pre–World War II vintage leather helmets in our tests, despite their lack of technologically advanced energy-absorbent materials, frequently were associated with head impact doses and theoretical injury risks that, based on linear acceleration, angular acceleration, angular velocity, neck force, and neck moment measures, were similar to or lower than those for several 21st century varsity helmets in near- and subconcussive impacts. (Bartsch, Benzel, Miele & Prakish)

Leather helmets worked just as well or better than the helmets we have today when tested against the same kind of forces that cause concussions.

Helmets do little to protect athletes from concussions, and laws passed by politicians to address the situation don’t really protect them, either. For example, the Lystedt law—first passed in Seattle 2009—contains three essential elements:

• Athletes, parents and coaches must be educated about the dangers of concussions each year.

• If a young athlete is suspected of having a concussion, he/she must be removed from a game or practice and not be permitted to return to play.

• A licensed health-care professional must clear the young athlete to return to play in the subsequent days or weeks. (Revised Code of Washington 28A.600.190)

Once again, as evidenced by the Lystedt law (CDC, 2009), politicians also are not addressing concussions *before they occur*. The law offers no mandates on providing proper neck training in advance; only dealing with the issue after the athlete has been concussed.

Statement of Purpose

The lack of a mandate for concussion prevention leaves this field wide open for much needed research. The purpose of this study is to look at concussion prevention from a different angle. There is considerable previous research establishing a correlation “between stronger cervical spinal muscles and a higher force absorption rate of the head during concussive impacts to football players” (Black, 2007). Black (2007), however, also states that no one has yet established a national protocol for training the neck and head of athletes in collision sports. This study will examine such a protocol and its ability to increase hypertrophy and head and neck muscle strength in college age athletes.

Significance of Research

The determination of an effective protocol for strengthening head and neck muscles is of profound importance, for no such sanctioned protocol exists. The educational sanctioning bodies for athletic trainers, strength coaches, and individuals directly responsible for health care who would use such a protocol are not privy to this vital information. The National Collegiate Athletic Association, National Strength and Conditioning Association, Collegiate Strength and Conditioning Coaches Association, American College of Sports Medicine, include no questions on their examinations regarding properly strengthening the musculature of the human head and neck. None of these certifying bodies has a practical (hands-on) instructional section in any known examination. How are these health professionals being educated to prepare athletes for the rigors of their sports? How can trainers/coaches ready the athlete for the physical contact involved in competition? Without the knowledge that a standardized head and neck resistance training protocol would bring, there is no continuity among trainers in the realm of sports. These professionals do not have the necessary skill set to effectively protect athletes from harmful concussive forces.

Strength and conditioning as a profession is relatively new in comparison with other careers in the sports world. In fact, the position of strength and conditioning coach only began approximately forty years ago (Riley, 2012). Since then, the strength and conditioning field has experienced great growth and maturation (Mark Asanovich, 2011). As the position evolved and grew, the roles and responsibility of the position changed. The role was originally created to assist athletes in becoming faster and stronger (D. Riley, personal communication, July 3, 2012).

However, as the position evolved, the strength and conditioning coach became responsible for creating science-based programs for enhancing athletic performance, for providing nutritional advice, and for assisting in the rehabilitation of injured athletes. Also, many strength and conditioning programs in both collegiate and professional sports are now adding injury prevention and accountability to their regimens. This is sometimes referred to as "prehabilitation." These changes in the role of strength and conditioning trainer now necessitate the hiring of individuals with advanced college degrees.

Justification for Study

Research shows that training the muscles of the head and neck in a specific manner and as individually as possible will produce an adaptation response (Conley, Stone, Nimmons & Dudley, 1997). Other research shows that bigger and stronger muscle correlates with more energy absorption (Abbot, Aubert & Hill, 1951). Also, the head of an athlete does not react to a blow as if it were a free body. Studies with cadaveric and anthropomorphic heads show that supporting the neck reduces the incidence of head injury (Reid & Reid, 1978). The head is held firmly to the neck principally by neck musculature (Goel, Clark, Gallaes & Liu, 1988).

This correlation between large neck mass muscles and energy absorption can also be observed in nature: during their mating season, Rocky Mountain bighorn sheep clash heads with a force estimated at 2,400 pounds—and do not concuss (Big Horn, 2012). These animals are seldom hurt because their skulls and their massive neck muscles absorb the force of the blow (Rocky Mountain). The physics behind this occurrence in nature is simple: force equals mass times acceleration. According to this formula, with blows of a given force, the receiving body with more mass would experience less acceleration. The brain inside the head, therefore, would also experience less acceleration and hence less force upon it.

Therefore, any addition to the mass of the neck of an athlete, as measured by neck circumference and strength increases, will help reduce concussive injury.

Value of Study

Proactivity must be paramount with regard to the concussion epidemic. Concussions are inevitable in sports; however, as the kinetic energy involved in a concussion is lowered by increasing the size (mass) of the cylinder (neck) through direct, full range-of-motion resistance exercises and by increasing the stiffness or strength of the neck, the athlete will dissipate kinetic energy to the larger muscles of the lower body. If forces are lowered, then the athlete will concuss less, and debilitating sub-concussive forces will be lessened as well. The athlete can then play longer, with less residual damage to the brain.

Research Questions

Therefore the following research questions are posed:

1. Can a protocol be produced for the strength training of head and neck muscles? 2. Will this strength training protocol increase the neck circumference and neck strength of athletes, therefore ultimately increasing neck mass and structural stiffness?

No methodical approach to producing a specific protocol to strengthen the head and neck muscles exists, and no systematic study of increases in neck musculature attributed to such a protocol is documented. This study will attempt to do so, laying the foundation for further research in this area.

Definition of Key Terms

Capital muscles. A series of muscles that extend and flex the head at cervical vertebrae 1 and 2 with little involvement of the larger muscles of the neck.

Concussion. A stunning, damaging, or shattering effect from a hard blow. A jarring injury of the brain resulting in disturbance of cerebral function.

Concussion management. A systematic plan to properly diagnose concussions and level of concussion which can include doctors' diagnoses and diagnostic testing, concussion management also includes return to play criteria and testing, and is the after- care of post-concussion symptoms.

Contrecoup concussion. A contra-coup concussion occurs when the brain strikes the skull on the opposite side of impact; the skull movement is stopped, but the movement of the brain continues until it strikes the opposite side of the skull.

Coup concussion. Coup concussions occur when the brain strikes the skull at the site of impact.

Force. Active power in the form of strength or energy exerted or brought to bear; a cause of motion or change.

Hypertrophy. Excessive development of an organ or part. Increase in bulk (as by thickening of muscle fibers) without multiplication of parts. Exaggerated growth or complexity.

ImPACT. ImPACT (Immediate Post-Concussion Assessment and Cognitive Testing) is the first, most-widely used, and most scientifically-validated computerized concussion evaluation system. ImPACT was developed to provide useful information to assist qualified practitioners in making sound return to play decisions following concussions.

Mild Traumatic Brain Injury. A complex pathophysiologic process affecting the brain, induced by traumatic biomechanical forces secondary to direct or indirect forces to the head.

Disturbance of brain function is related to neurometabolic dysfunction, rather than structural injury, and is typically associated with normal structural neuroimaging (i.e., CT scan, MRI). Concussion may or may not involve a loss of consciousness (LOC). Concussion results in a constellation of physical, cognitive, emotional, and sleep-related symptoms. Symptoms may last from several minutes to days, weeks, months or even longer in some cases.

Post Concussive Syndrome. Symptoms such as headache, dizziness, mild mental impairment and fatigue may be present up to a few months or an indefinite period of time following a concussion.

Proactive. Acting in anticipation of future problems, needs, or changes.

Reactive. Reacting to an event after the actual episode.

Resistance training. Physical training that utilizes isometric, isotonic, or isokinetic exercise to strengthen or develop the muscles.

Return to Play (RTP). Usually associated with protocols for an athlete after a concussion or other injury.

Rotational force. Slightly oblique force which causes the head to rotate around its point of articulation at the top of the spine as it is hit.

Second impact syndrome. A condition in which the brain swells rapidly and catastrophically after a person suffers a second concussion before symptoms from an earlier concussion have subsided. This deadly second blow may occur days, weeks or minutes after an initial concussion, and even the mildest grade of concussion can lead to SIS. The condition is often fatal, and almost everyone who is not killed is severely disabled.

Sternocleidomastoid. Either of two muscles of the neck that serve to flex and rotate the head.

Sub-concussive. Below the threshold of concussion. May be as damaging as a concussion or more so.

Trapezius muscle. Either of two flat triangular muscles of the shoulder and upper back that are involved in moving the shoulders and arms.

Viscoelastic tissue. The property of materials that exhibit both viscous and elastic characteristics when undergoing deformation.

Chapter 2

Literature Review

Introduction

There is no cure for concussions or for the damage caused from a concussion—and once an athlete concusses, he or she is more likely than the average population to concuss again. Another underreported condition associated with concussions is sub-concussions. Sub-concussions are not detectable. The athlete and team physician are unaware of this injury, and the athlete continues to play. Helmets are not solving the problem. Helmets just don't reduce concussions. In fact, large helmets on Pop Warner football players only add to the weight of the player's head—which, in turn, is supported by a small, underdeveloped neck. Although the Centers for Disease Control and Prevention and the National Institute of Health are increasing awareness about concussions in young people, their efforts to prevent such injuries are ineffective. Along the same lines, although impact cognitive tests may help some, they are not proactive and can be manipulated by players, who will deliberately get a low score on the baseline test in order to pass tests when concussed during the season. These tests are almost useless in predicting concussions or return to play.

The knowledge currently possessed by most athletic trainers is insufficient for protecting their athletes against concussion. For the past twenty years, interest and participation in strength training and physical conditioning as it applies to intercollegiate athletes has increased. In the 1970s, during the initial stages of collegiate strength and conditioning coaching, the majority of strength coaches had backgrounds in one of three areas: competitive power lifting, competitive

Olympic-style weight lifting, or former football players with an interest or proficiency in strength training (Epley, 1997).

Strength coaches do not have the skill set to train the head and neck at this time. Although there are hundreds of ACL injury prevention protocols to protect a ligament that can be replaced, there are no established protocols to train and protect the athlete's neurological health due to concussion. In fact, training every part of the musculature system of the body except the head and neck sets the head and neck up for injury. Disproportionate strength among different body strength segments will predispose the athlete to injury. So why is the initial concussion allowed to occur without any proactive protective measures being taken?

What will address this epidemic effectively and immediately are stronger, larger muscles of the head and neck, along with upper back strength and hypertrophy, making the body a better dissipater of kinetic energy. All of those objectives can be accomplished through organic intervention, without resorting to additional equipment or gear that the athlete would have to wear. When looking at force as the cause of concussions, velocity and acceleration cannot be controlled. Mass is the controllable variable. Increased hypertrophy equals increased mass.

The Problem of Concussive Forces

Position statement on concussions. According to Harman et al. (2013) in *American Medical Society for Sports Medicine Position Statement: Concussion in Sports,* a concussion is defined as "a traumatically induced transient disturbance of brain function and involves a complex pathophysiologic process." In short, it is a brain injury. When an athlete, or person, receives a blow that causes a shaking of the brain inside the skull, a concussion occurs (Heller, 2012). There are short term and long term effects to concussions. Short term effects can include headache, dizziness, loss of consciousness, nausea, vomiting, balance loss, memory loss, sleep disturbance and cognitive impairment (Harman et al., 2013).

In fact, there are two mechanisms in which a concussion can occur: coup and contrecoup. Coup concussions occur when the brain strikes the skull at the site of impact; contrecoup concussions occur when the brain strikes the skull on the opposite side of impact (Guskiewicz et al., 2004). Contrecoup injuries occur once the skull movement is stopped, but the movement of the brain continues until it strikes the opposite side of the skull (Guskiewicz et al., 2004). As an athlete starts running and the head is accelerated, the brain will lag toward the trailing surface, causing cerebral spinal fluid to "squeeze" (p. 284) and cause maximal shearing forces at the site of impact.

Once an athlete concusses, he or she is also more likely than the average athlete to concuss again and is more likely to require a prolonged recovery time period. The severity and duration of concussion symptoms also increases from experiencing just one concussion, and recurrent concussions produce devastating effects. Studies are beginning to show that ongoing exposure to recurrent concussions contributes to long-term neurological sequelae. Other studies are beginning to show that there is an association between repeated concussions and chronic cognitive dysfunction (Harman, 2013).

Recurrent concussion study. Long term effects progress over time and can be very devastating. Since the 1920s, the repetitive brain trauma associated with boxing has been linked to progressive neurological deterioration, originally termed "dementia pugilistica." Boxers contracted the brain disorder from repetitive and cumulative strikes to the head. Epidemiological evidence suggests that the incidence of amyotrophic lateral sclerosis is increased in association with head injury. Repetitive head injury is also associated with the development of chronic traumatic encephalopathy (CTE), a tauopathy characterized neurofibrillary tangles throughout the brain in the relative absence of β-amyloid deposits (Guskiewicz et al., 2003). Also, repeat concussive episodes before the resolution of initial concussion symptoms have been associated with fatal cerebral edema via the hypothesized “second impact syndrome” (Guskiewicz et al., 2003).

A tragic story recently in the news involving a former professional football player, Junior Seau, brings this disease to light. Seau recently committed sucide, leaving behind a note which indicated that his brain should be donated for research. According to Seau's family, the former linebacker's behavior increasingly became erratic, including wild mood swings, irrational thought, forgetfulness, insomnia and depression. The family claims from autopsy reports that Seau developed CTE from repeated hits sustained during his football career. They currently are engaged in a wrongful death lawsuit against the National Football League for the league's "acts or omissions" of hiding the danger of repeated blows to the head (Associated Press, 2013).

The Problem of Sub-Concussive Forces

Current research is also pointing to another category of concussions which jeopardize the long term health of athletes involved in sports activities prone to produce jarring hits, falls, or head trauma. This category of concussions is called sub-concussions (Baugh et al., 2012). Why are sub-concussive forces so dangerous? Sub-concussive forces are the little “dings” to the head which seem so small and sometimes feel so insignificant that an athlete would not give them a second thought. Those small repeated forces accumulate over time and may be more damaging than the big “knockout” hits seen in highlight reels.

A Purdue study supports anecdotal evidence from other studies that football players not diagnosed with concussions nevertheless seem to suffer cognitive impairment (Talvage et al., 2010). In other words, some players are injured, but don't know it—unlike the chronic problem of players who know they are experiencing concussion symptoms but, for a variety of reasons, fail to report those symptoms.

How many hits does an athlete have to be involved in to reach the "tipping point" where small repeated injuries begin to erode the brain and diminish cognitive function? If there is no established protocol for detecting a sub-concussion episode, how can an athlete self-report an injury that he or she is unaware has actually happened? Such an athlete is unlikely to undergo clinical evaluation, and thus will continue to participate in sports-related activities even when changes in brain physiology (and potential brain health) are present. This continued participation is likely to increase the risk of future neurologic injury.

Research is showing that sub-concussive forces seem to attack the frontal lobe of the brain where impulse is controlled (Baugh et al., 2012). Anecdotal evidence pointing to the lack of impulse control and calling for extensive research on prevention of concussions and sub-concussions lies in the tragic actions of former professional football players such as Terry Long, who drank antifreeze until his kidneys shut down, and Chris Henry, who jumped out of a speeding vehicle to his death. Also, the fact that two former football players (Junior Seau and Dave Duerson) took their own lives by shooting themselves in the heart, both leaving notes donating their brain for research, points to the tragedy of repetitive hits to the head. Several suicides have occurred in the college and high school ranks following concussions or sub-concussive damage in the past year, further suggesting a correlation with concussions and impulse-driven action.

Brain injury prevention efforts in sports have focused on minimizing an athlete’s concussive episode risk; although the effect of repetitive sub-concussive trauma in contact sports has received increased attention recently, it has yet to be fully addressed. The world of sports needs to know that there are preventive measures athletes can take to sometimes prevent and often reduce the effects of concussions. An examination of current research points us in the right direction.

Need for Neck Strength

According to Dr. Mickey Collins, assistant director of the University of Pittsburgh Medical Center’s Sports Medicine Concussion Program, “one of the best ways to prevent concussions is through neck strength.” Dr. Collins goes on to say that “having a strong neck actually allows the forces of the blow to be taken from the head down through the neck and into the torso” (Colvin et al., 2009). And Dr. Robert Cantu, thought to be the leading concussion authority in the world, says that “a stronger neck is harder to spin [and] it is that rotation that stresses the brain and causes damage resulting in a concussion” (Nash, 2012). Dr. Cantu believes that females concuss more often than males because of a lack of neck strength (Nash, 2012). There is a need for increased neck strength in reducing concussions.

The effect of controlling rotational forces in concussion prevention has also been observed in nature, where the woodpecker’s ability to smash its head into a tree several thousand a times a day at high G-forces without injury or concussion became a matter of interest to researchers studying concussions and brain injury. Their research showed that the most important mechanism a woodpecker has, as it relates to humans, is that a woodpecker seems to never allow rotational forces to enter into its striking routine (Phillip, Fuster, Haber & Hirshman, 1979). The woodpecker uses its well-developed head and neck muscles to prevent any injurious rotational forces from damaging the woodpecker’s brain. This knowledge is useful and transferable to humans, because rotational forces are the most damaging to the human brain. The same is true for a woodpecker. Applying the research and observation of the woodpecker to the protection of man suggests that stronger and better-developed head and neck musculature can ward off dangerous rotational forces.

Female soccer players study. A 2002 study of female soccer players also points to the need to strengthen the necks of athletes. The purpose of this study was threefold: first, to track the average number of times a soccer ball comes into contact with the head of female soccer players during the course of a Division I NCAA soccer game; second, to survey 12 regional college strength coaches to ascertain if they incorporate neck strength exercises into their female soccer players’ strength programs; and finally, if warranted, to recommend the implementation of strength exercises with this population to facilitate the biomechanical heading process and reduce injury (Maneval et al., 2002).

Although the general public considers soccer to be a relatively safe activity, it is defined as a contact sport according to the American Academy of Pediatrics: “Soccer is the only game in which players literally use their heads to propel the ball” (Maneval et al., 2002). The neck muscles serve mainly to support the head in its role as a striking platform when heading the soccer ball. The musculature needs to be strong enough to provide a solid foundation for the ball to rebound off the head. The researchers found that the average number of headers per game varied between 89 and 120, a large number.

The results of this study indicated a need for the incorporation of head and neck strengthening exercises in women's soccer programs within the southeastern region of the United States. Because of the results of the study, the following guidelines are proposed:

To create the musculature needed to provide that solid foundation for heading a ball, posterior training should involve the trapezius, levator scapulae, splenius (2), and erector spinae. Anterior training of the neck would involve the rectus capitis anticus (3). Lateral training should involve the sternocleidomastoid, and scalanus group. To target each of these groups dynamically, a standard four-way neck machine would suffice.

In absence of this apparatus, four-way manual resistant exercises should be substituted. In addition, upper torso shoulder, chest, and back muscles need to be targeted as well. Exercises of choice would include shrugs and bent over rows.

Biomechanics of neck musculature study. In a study in the *Journal of Biomechanics*, the authors state, “Neck mechanics is central to head injury prevention since it is the musculoskeletal neck, which dictates the position and movement of the head” (Lavallee, Ching & Nuckley, 2013). In this study directed toward traumatic injury research in children, the authors tested 91 human subjects ranging in age from 6-23. They attempted to quantify neck strength over the period of human maturation. Measurements of head and neck anthropometry and neck strength and endurance in three bending directions (flexion, extension, and lateral) were taken.

A custom apparatus was designed and built which measured the force exerted by each subject’s neck muscles. Neck force contractions were delivered via the head, and steps were taken to eliminate force contribution from the torso. Other measurements of each test subject were taken, including neck circumference.

The results of the study showed that neck muscle strength between young males and females was similar; however, in males exhibited greater strength in adolescence and adulthood. Another finding showed that neck circumference appeared to be predictive of neck strength and endurance in children (Lavallee, Ching & Nuckley, 2013).

Human body's innate ability to protect and preserve its survival. The human body is designed to innately protect and preserve itself. Muscle covers the human skeleton and, like armor, protects, absorbs and repels attack. The nervous system alerts the body to danger, allowing for a reaction. The fight-or-flight mechanism increases heart rate, shunts blood flow to the digestive system and redirects blood to muscles in order to move and generate the muscle contraction needed to survive. The release of stress hormones initiates reactions needed in times of stress. Reflexes occur at a subconscious level and incredibly fast rate.

Human neck muscle spindles study. One such way that the body protects itself and reacts to stimulus is through muscle spindles. Muscle spindles play an important role in the control of movement and posture in mammals. In a 2003 study outlined in the *Journal of Histochemistry and Cytochemistry*, researchers studied the muscle spindles found in the deep muscles of the human neck. In this study, samples of the deep muscles of the neck (rectus capitis posterior major, rectus capitis posterior minor, obliquus capitis inferior and obliquus capitis superior) were obtained at autopsy from two females, ages 26 and 17, and three males, ages 55, 21, and unknown. The muscles tested are found deep in the suboccipital region of the neck and are quite small and short. They function in helping to maintain the stability of the cervical spine and in refining the rotatory movements of the head.

After testing and analysis, researchers discovered that the deep muscles of the neck contained a high density of muscle spindles that allow “not only great precision of movement but also adequate proprioceptive information needed both for control of head position and movements and for eye/head movement coordination” (Liu, Thornell & Pederosa-Domellof, 2003). The researchers found that the deep neck muscles of the human body protecting the cervical spine and inhibiting rotational forces contain five times more muscles spindles than some other neck muscles (Liu, Thornell & Pederso-Domellof, 2003). This study points to the human body’s ability to control rotational forces of the head and neck through muscles.

Muscle reaction to stimulus studies. Researchers have also discovered that as a force, like a stretch, is applied to a muscle, the muscle reacts by becoming stiff. In a study in the *Journal of Neurophysiology*, researchers electrically stimulated the soleus muscle in14 anesthetized cats to simulate the reaction of a muscle in a stretch-reflex response. Three different stimulus patterns—recruitment, step increases in stimulus rate, and doublets—were imposed during the course of ramp stretches applied over a wide range of velocities, and each was evaluated for its ability to prevent muscle yield. The researchers discovered that in a muscle where more motor-unit recruitment occurred (a stronger force creates more motor recruitment) was more effective in preventing muscle yield—that is, in creating muscle stiffness (Cordo & Rymer, 1982).

Another study also points to the quick reflex of head and neck musculature to stimulus and reinforces the many ways the body reacts to protect itself at the head and neck level (Simoneau, Denninger & Hain, 2008). The neck can access a rapid and highly accurate signal from the inner ear encoding the velocity of the head movement, activating muscle to counteract that load with increased neck stiffness and viscosity. The researchers proposed that this reduction in peak head velocity is caused by modulation of the strength of the vestibular-collic reflex.

In the study, the researchers measured the neck's viscoelastic properties as additional loads were added to the initial preload on the neck using a weight pulley apparatus. They did this by recording the applied force and measuring the head's angular velocity. Neck viscoelastic properties were then estimated by fitting the experimental data to a second-order mathematical model of the head biomechanics.

The results found that in the neck, forces due to intrinsic viscoelastic properties are present *immediately*; vestibular reflexes follow at 25–50 milliseconds (ms), stretch reflexes at 60+ ms, and voluntary responses begin at approximately 100 ms. In the study, peak head angular velocity, which occurred at about 50 ms for the smaller preload and significantly shorter for the larger preload, preceded the onset of stretch reflexes and voluntary responses, leaving vestibular reflexes and passive impedance as potential candidates (Simoneau, Denninger & Hain, 2008).

Normal cervical function and anatomy article. According to an article in the Hong Kong Medical Association's *CME Bulletin*, the functional and structural anatomy of the cervical spine is a complex integration which provides protection of the neural tissues, as well as allowing a great range of motion at the same time. In general, the cervical spine may be divided into 2 functional segments: the upper cranio-cervical segment, which is comprised of the occiput, C1 (atlas) and C2 (axis) vertebrae, and the lower cervical segments, which contain the C3 to C7 vertebrae.

There is approximately 35 degrees of flexion and extension between atlas (C1) and the occiput. Approximately, only five degrees of lateral flexion and 3-8 degrees of rotation are allowed. Motion between the atlas and axis is essentially rotation around the dens of 40 degrees in either direction. In lateral flexion, around 20–25 degrees is allowed and there is minimal translation between the occiput, the atlas and the axis.

The upper cervical segment is guarded against any translatory motion of a whiplash injury by strong ligaments. These ligaments include:

- the apical ligament, which protects the spinal cord within the canal;
- the alar ligament, which connects the occiput and the dens; and
- the transverse ligament, which connects the occiput to the arches of the atlas and axis.

The horizontal segment of the transverse arch stabilizes the dens of the axis[2] (Figure 2).

These ligaments are well documented in their support of the structures forming the upper cervical segment (Kong, 2008). Strong ligaments and muscles innately protect the body.

Resistance Training in Neck Musculature and Strength

Specificity of resistance training response in neck musculature study. When an athlete engages in resistance training, muscles adapt to this training. Increases in muscle cross-sectional area or individual muscle fiber size, reflecting muscle hypertrophy, are typical and well-documented responses to resistance exercise (Tesch, Thorsson & Colliander, 1991). Neck muscles are no different from muscles in other parts of the body: if the muscles of the neck are trained in as specific manner and as individually as possible, an adaptation response will take place (Conley et al., 1997). Conley et al. (1997) endeavored to quantify increases in muscle mass and hypertrophy of individual cervical muscles when subjected to specific resistance training exercises. There were three groups in this study: group one did resistance exercises without any specific resistance neck exercises, group two did a head extension exercise and other resistance exercises., and group three was the control group. MRI imaging was used to identify head and neck muscle increases.

This study showed a significant increase in group two of muscle mass in the neck region. In fact, certain muscle (splenius capitis, semisinalis capitis, and semispinalis cervicis and multifidus) increased 24-25 percent. According to the specificity of training model, these results suggest that those muscles are the primary head extenders. Other muscles in the neck region (levator scapulae, longissimus cpitis and cervicis, scalene medius and anterior muscle) increased 5-9 percent. In group one, conventional resistance exercises without a specific neck exercise did not elicit increases in muscle size (Cohen's d = 0.01) or head extension strength (Cohen's d = 0.03). The lack of generalized neck muscle hypertrophy was not due to insufficient training (Conley et al, 1997).

Muscle cross-sectional area and strength study. Increases in muscle cross-sectional area increase muscle strength. In a landmark University of Alabama study, researchers verified that muscle strength is relative to the physiological cross-sectional area of a muscle (Morris, 1948).

In this study, Morris determined the cross-sectional area of the muscles in the upper arm and upper thigh. He then determined the cross-sectional area of the individual muscles to be tested using average proportions of each muscle in the upper arm and thigh. He then took X-rays to estimate muscle attachments on the bones in order to get the leverage of the pertinent muscles. Using trigonometry to calculate leverage, he combined this with the muscle cross-sectional area and strength measurements to obtain the force produced per square centimeter.

Morris determined that a value of 10 kilograms of force could be assigned for every square centimeter of muscle in a man, and 7.5 kilograms per square centimeter of muscle in a woman (Morris, 1948). Thus, increased hypertrophy produces increased strength and resistance training increases hypertrophy.

The Physics Behind Increased Neck and Head Hypertrophy and Neck Strength

It goes without saying, but is important in this review, that it is stated that the neck connects the head to the rest of the body. In fact, the head of an athlete is not a free body. It does not react to a blow as if it is a free body. Research shows that an impact to a head where the neck is supported reduces the incidence of head injury. The explanation for this is that the support given by the neck does not allow for bending or rotation of the neck (Reid & Reid, 1977). Head rotational forces are considered one of the leading causes of concussion (Ommaya & Gennarelli, 1974).

A simple physics equation can explain this phenomenon. Any impact to the head is a force. The physics equation for force is $F=MA$, where F is force, M is mass, and A is acceleration. According to this formula, with blows of force F, the receiving body with more mass would experience less acceleration. The brain inside the head, therefore, would also experience less acceleration and hence less force upon it. Therefore, adding to the mass of the neck of an athlete, as measured by neck circumference and strength increases, could reduce concussion rates.

Because increased hypertrophy equals increased strength, and increased strength in the neck creates more support for the head, increased hypertrophy as measured by increased neck circumference equates to increased support for the head against impact, thereby reducing concussive force. This, in turn, calls for the creation of a specific protocol to train the muscles of the neck.

Biomechanics of the struck player study. A study found in *Neurosurgery* simulated impacts in professional football which resulted in concussions. Twenty-five different helmet impacts were reconstructed using dummies, and translational and rotational accelerations were measured in both players' heads; six-axis upper neck responses were also measured in all striking players and in five struck players. Concussed players' head motion and biomechanics were also measured. The researchers developed a model of the helmet impact to study the influence of neck strength as well as other parameters on the response of the head.

What the researchers discovered was that stronger necks reduced head acceleration (ΔV, a change in velocity) and displacement. Even small reductions in ΔV had a large effect on head injury criterion. They concluded that reduction in ΔV due to stronger necks may reduce concussion risks (Viano, Casson & Pellman, 2007).

Inferences for Further Study and Development

Studies outlined in this literature review point to the problem of concussions and sub-concussions. Studies also point to the body's innate abilities to protect itself from outside concussive forces through internal reflexes, neck strength, and increased hypertrophy. Taking in to account the studies' outline, it follows that further study should be conducted into a protocol to train the muscles in the neck that maximizes neck strength and hypertrophy.

The studies also call for accountability and proactive action. Athletic training staff work with players every day and are intuitive when crises arise; they want to protect their athletes from injury. In fact, since the female soccer study was published in 2002, nothing of any substance has changed strength training protocols in their conference; as a matter of fact, nothing has changed in the entire United States. It is a tragedy. There is no sense of urgency with coaches or doctors, and parents are not aware of the dangerous situations their children are placed in. Reactive measures, such as laws and doctor protocols for improved concussion management, have been implemented, but proactive measures are called for, especially the proactive development of a protocol to train the neck.

Chapter 3

Methodology

The purpose of this study was to train the muscles of the head, neck, and upper back using resistance training with progressive overload to determine and record organic morphological and physiological changes in the active participant groups. There were two separate research studies conducted with six months of each other. The first research study used male college students, the second used female college research subjects, and both used subjects in the age range of 18-24 years old. Therefore, the following research questions are posed:

1. Can a protocol be produced for the strength training of head and neck muscles?
2. Will this strength training protocol increase the neck circumference and neck strength of athletes, and therefore ultimately increase neck mass?

Setting and Participants

The research study was conducted in a university setting located in the southeastern United States. The subjects consisted of 22 male and 12 female college students ranging in age from 18-24 years old. This age range was selected because of the high level of circulating testosterone in the males, this allowing for the greatest possibility of hypertrophy. The female age range was selected because of the participants' high activity level and because this age range is involved in collegiate competitive sports. The exclusion criteria included students with disorders or diseases affecting the musculoskeletal system, as well as students with pre-existing cervical spine injuries or genetic abnormalities. Students were randomly split into two groups; the study group consisted of 18 students, the control group numbered 16. The study group would follow the protocol designed to obtain increased neck hypertrophy and strength. The control groups were instructed not to perform any exercises that involved direct stimulation to the neck musculature.

Materials

The pieces of equipment used for this study are prototypes. The prototypical machines allowed for the participants to safely train the musculature of the head and the neck. Neck circumference baseline measurements were taken. The United States Army Protocol for measuring the neck was used as a guide (Gordan & Brandtmiller, 1992). The males' neck circumference was measured one inch above the *prominentia laryngea* (Adam's apple) and one inch below. The females' neck circumference was measured at the center of the neck. The landmark for the female measurement was the midline of the mastoid and the base of the neck. The protocol instructions are to measure the circumference of the neck using a medical quality tape measure. A professional grade power rack was used to perform the shoulder girdle elevation in conjunction with a standard seven-foot Olympic bar. Olympic weight plates were used as resistance devices.

Procedures

Signed informed consent documents were obtained. Research subjects were allowed to familarize themselves with the equipment used in the research and the protocol. Baseline measurements of participants' neck cicumference were taken using the United States Military Standardized Protocol (USMSP), which requires one measurement for females and two for males (Gordan & Brandtmiller, 1992). Female neck circumference measurements were taken at the center measurement of the neck. Male neck circumference measurements were taken one inch above the *prominentia laryngea* (Adam's apple) and one inch below. The landmarks for the female measurements were the mastoid process and the base of the neck. A set schedule for individual training sessions was composed to allow for one-on-one training sessions with each active participant. The sessions consisted of 20 minutes of training protocol three times in a seven day span over a six-week period. Each training session performance data was recorded and logged into the data base. Neck circumference measurements were taken at the beginning of each training session. Reseachers attempted to accommodate test subjects' schedules.

Exercise Protocol

All exercise protocols were performed at a university sports performance laboratory. Male and female protocols were exactly the same. A starting weight was determined by the amount of weight a participant could safely use while performing the protocol for 12 repetitions in good form.

The test subjects performed six head and neck movements using the neck machine: front flexion, extension, right and left lateral flexion, the nod (10 degrees of front flexion resembling a person nodding "yes") and the tilt (25 degrees of flexion, with the jaw jutting outward and the head tilting gently backward). The 35-degree range of motion represents the movement of the head that does not directly activate the cervical muscles of the neck, with the exception of the atlas and axis vertebrae. Isolating the muscles of the head allowed for the hypertrophy of the capital muscles of the head.

These movements were followed by a seated bilateral shrug, also performed on the neck/shrug machine to intervate the lower trapezius muscles. A unilateral shrug was then performed on the same machine to intervate the upper trapezius. The Levator Scapula Shoulder Elevaton Shrug (LSSES) is a movement to innervate the upper trapezius and the muscles surrounding and involved in scapular retraction. The LSSES was accomplished by placing a seven-foot standard Olympic bar on the posterior of the neck, at the nape or appoximately at cervical vertebrae (CV) 7, with the subject then performing scapular retraction to allow the bar to rise vertically at the point where the trapezius shrugs vertically. This movement allowed subjects to train upper trapezius and other muscles without the limiting factor of grip strength.

One set of seated rows was performed on the isolateral row using a parallel grip, allowing for the innervation of the large muscles of the back: the latissimus dorsi and rhomboids major and minor, with contribution from the posterior deltoid. A scapular shrug was performed on the isolateral row to involve the muscles of the upper back, posterior deltoid, and the rhomboids involved in scapular retraction. The scapular shrug movement required the particpants to keep their arms straight as they used a parallel grip, retracting the scapula; it is the retraction and contraction of the upper back muscles that successfully moves the weight loaded onto the row. The retraction and pull was accomplished by using a supinated grip on the other horizontial handles. With straight arms and retraction of the scapula, participants then flexed their elbows 90 degrees (appoximately 8-12 inches) to allow for maximum innervation of the middle trapezius and fibers to the lowest fibers terminateing at thoracic vertebre 12 musculature.

The repetition range was 12 repetitions, or until a repetition could not be performed with good form, with a 15-second rest period between sets. Neck circumference measurements were taken at the beginning of each training session.

Data Analysis

Neck Strength Analysis in the Male Study

For different neck exercises in the male study, a paired t-test analysis on neck strength was performed to determine if the exercises resulted in a significant increase in neck strength. The statistical difference in neck strength was computed by subtracting participants' baseline weights from their final weights. Each test checked the normal quantile plot to ensure normality of the data. If none of the normal quantile plots indicated a departure from normality, the parametric t-test was used. The proposed P-value was set at < 000.1 for all exercise results and circumference measurements.

Upper Neck Circumference Difference Analysis

The first task was to determine if differences existed in change in neck circumference between the active group (participants involved in the study) and the control group. This analysis was accomplished by using a two-sample t-test comparing the difference in upper neck circumference (final minus baseline) for the control group versus the active group. The means and standard deviations for each group were also given.

Lower Neck Circumference Difference Analysis

The lower neck circumference study followed closely to the upper neck circumference study previously discussed. The first analysis involved a t-test to compare the difference in neck circumference for the control group and the active group. A highlighted p-value indicated the differences in neck circumference (final minus baseline) for the active participants as greater, unchanged or less than the difference for the control group.

Neck Strength Analysis in the Female Study

The Wilcoxon Signed-Rank Test was utilized to determine if the exercises resulted in a significant increase in neck and upper body strength. The increase in neck and upper body strength was computed by subtracting participants' baseline weights from their final weights. The nonparametric Wilcoxon Signed-Rank Test was chosen due to the small sample size of this six-subject study.

Chapter 4

The Creation Of A Standardized Resistance Training Protocol For Training The Muscles Of the Head and Neck In Female Athletes

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Abstract

The Centers for Disease Control and Prevention and the National Institute of Health have declared concussions a national epidemic. There is very little research being conducted about concussion reduction via proactive head and neck strengthening. If neck musculature reduces the concussive impact, then less force will be transmitted to the brain, thus decreasing the risk of concussion.

There is desperate need for a standardized head and neck resistance training protocol that should be adopted nationwide. The proposed protocol is designed to enhance the capabilities of the soft tissue that surrounds the cylindrical surface area of the human head and neck through sequenced resistance movements to train the muscles of the head and neck.

The research participants were healthy female college students, ranging in age from 18-24 years old. There were 12 participants. Of the 12 subjects used for this study, six participants were randomly assigned to the experimental group, with the other six participants becoming the control group. The participants followed a protocol consisting of 13 movements designed to sequentially train the musculature of the head, neck, and upper back. The duration of the study was eight weeks. The results of this study demonstrate that females can increase upper body strength safely and without significant muscular size gains. During this study, the female neck showed a very minimal increase in circumference, while strength level increases were substantial.

Introduction

Since the Supreme Court ruling in 1972 and the inception of Title IX, females have acquired the opportunity to participate in competitive sports at the collegiate level (Valentin, 1997). With this ruling requiring gender equality in access to collegiate sports, female sports teams comparable to those of their male counterparts are commonly found in colleges. This gender equity has resulted in female athletes also manifesting the same injuries as male athletes (Dugan, 2005). However, in "gender-comparable" sports, girls had a 70 percent higher concussion rate than boys**.** It is well known in the sports medicine world that females tear their anterior cruciate ligament (ACL) six times more often than male athletes do (Dugan, 2005). The Dugan (2005) research indicates that ACL tears in females can be reduced with sports medicine preventive programs aimed at strengthening the muscles at the knee joint. Even with these prevention programs, females will still tear their ACL in spite of the best efforts of strength coaches and athletic trainers (Dugan, 2005).

Females participate in several sports that require contact with possible collisions. Females concuss three to six times more often than males (Tierney et al., 2008).

A concussion is a traumatic brain injury that alters brain function. Effects are usually temporary, but can include problems with headache, concentration, memory, judgment, balance, and coordination. Although concussions are usually caused by a blow to the head, they can also occur when the head and upper body are violently shaken (Reid & Reid, 1981).

Concussions in females do not receive the publicity that concussions in males do. This could possibly be related to the great amount of attention that injured American football athletes are receiving from several different organizations. For example, brains of former football players are being collected by the Sports Legacy Institute (SLI) in cooperation with the Boston University School of Medicine (http://www.sportslegacy.org/cte-concussions/cte-cases-sli-legacy-donors). While there is no mention of any female SLI legacy (brain) donors on the promotional webpage, the Boston University School of Medicine has just begun to study female brains. They have registered a number of women for post-mortem brain donation, and the program has collected its first female brain. Analysis is in progress at the time of this writing (C. Baugh, personal communication, December 15, 2011).

The human neck is a vital and complex anatomical and morphological region of the body. While knee ligaments can be repaired and, if necessary, the entire knee joint can be replaced, there are no replacements for the neck, no prosthetics to take the place of the cervical spine, and certainly no organ transplants available for the human brain. Much like the ACL tear, females are at a higher risk of sustaining both neck and brain injuries. Hence, prevention of injury to these vital structures should be of paramount concern.

Research has shown that a stronger, better conditioned neck will help reduce concussions (Cantu, 1996). However, there are no preventive medicine protocols to prepare the neck for the rigors of competition. Athletic trainers and strength coaches measure the baseline strength levels of the quadriceps and hamstrings so that they will know if they are approaching pre-injury strength levels in a rehabilitating athlete. This allows them to better estimate when the athlete may safely return to competitive play. Neck injuries and brain concussions are treated very differently. There is no established “return to play” protocol that includes documentation of previous neck strength levels prior to injury. Furthermore, there are no strength training protocols established to rehabilitate the injured player (E. Storsved, personal communication, March 2011). Any athlete involved in a sport in which head and neck injuries are likely should strictly adhere to a year round neck-strengthening program. Many coaches and athletes ignore neck strengthening, use inefficient and dangerous training methods, or only exercise the neck during the off-season (Riley, 1981).

There are no standardized protocols for resistance training the muscles of the head and neck. If neck musculature reduces the concussive impact, less force will be transmitted to the brain, therefore decreasing the risk of concussion (Johnston et al., 2001). Research shows that if the muscles of the head and neck are trained in a specific manner, and as individually as possible, an adaptation response will occur (Conley, Stone, Nimmons & Dudley, 1997). Other research shows that bigger and stronger muscle correlates with more energy absorption (Abbot, Aubert, & Hill, 1951). Also, the head of an athlete does not react to a blow as if it were a free body. Studies with cadaveric and anthropomorphic heads show that supporting the neck reduces the incidence of head injury (Reid & Reid, 1978). The head is held firmly to the neck principally by neck musculature (Goel, Clark, Gallaes & Liu, 1988). These research studies (Reid, and Goel, 1981) reaffirm the necessity for a resistance protocol that addresses the musculature of the head, neck, and upper back. Such a protocol reinforces the athlete's body against impact, hence making it a better dissipater of kinetic energy.

Theoretically, low magnitude sub-concussive forces are possibly the most dangerous impacts of all. Why is there so much concern for low magnitude repetitive blows to the athlete's head? The problems with sub-concussive forces lie in their ability to elude and escape detection from professionals on the sideline, because the injured athletes are unlikely to exhibit clinical signs of head injury (such as headache or dizziness) or show impairment on a sideline assessment for concussion. Self-reporting of sub-concussive injuries by the athletes is impossible; with no concussion-like symptoms, they don't realize they are hurt. The implication is that long-term brain damage may emerge years later after an athlete discontinues participation in competitive sports (Baugh et al., 2012).

Repetitive strikes to the head are believed to predispose the athlete to chronic traumatic encephalopathy, which is a progressive tauopathy that occurs as a consequence of repetitive mild traumatic brain injury (Mckee.et al,.2013). In light of the hypothesis about the undetectable, asymptomatic forces which are believed to cause the brain damage that appears later in an athlete's life, a proactive approach is required for this problem. Logic would dictate that all athletes in sports which require contact must be assumed to absorb these imperceptible forces. Furthermore, a logical remedy must also be prescribed to protect these athletes from the dangers of a problem with such surreptitiousness. Athletes must be prepared with the assumption that they will be struck. A continuity plan must be in place to combat the unseen "brain bruise." A standardized resistance program for training the muscles of the head and neck designed to prepare athletes for the rigors of their sport would combat the effects of repetitive hits to the head, thus reducing the very forces thought to cause irreversible damage to the brain.

According to McGill, Jones, Bennett and Bishop (1994), along with the additional research by Cross and Serenelli (2003); Peterson, Taylor, Murray, Gandevia and Butler (2011); Marino (2011); Rousseau and Hoshizaki (2009); Berg, Gunnell and Tesch (1994); Reid and Reid (1981); Scheip, Naglor, Ursa, Mentzer, Wilke, Lehman-Horn and Kingler (2006); Nagasaka, Brinnel, Hales, Ogawa (1998); and Kramer (2002), the application of a proper head and neck resistance training program will result in:

1. Increased passive stiffness of the head and neck. Regular resistance training has exhibited increases and alterations of the mechanical properties in passive muscle tissue.

2. Increased resistance to deformation forces. As a stronger neck becomes less compliant to outside forces, reducing deformation of the neck, therefore displacement of the head will also be reduced.

3. Lowering of concussive and sub-concussive forces. Neck strength provides neck stabilization and bracing against impact. A stronger head and neck segment aids in skull placement rigidity, thus reducing concussion occurrence.

4. Enhanced ability to move the head quickly. A conditioned neck moves more fluidly with added strength. A stronger neck can exude movement that one would call increased atheism.

5. Increased maximum oxygen uptake by strengthening the musculature that elevates the rib cage. The muscles used in heavy exertion breathing can be found between the ribs and between the neck and the upper ribs. The diaphragm, muscles between the ribs and one of the muscles in the neck, called the scalene muscle, are involved in almost every breath taken. If additional help is needed expanding the lungs, other muscles in the neck are recruited. The scalene muscles are lateral vertebral muscles that begin at the first and second ribs and pass up into the sides of the neck. There are three of these muscles. When the neck is fixed, the scalenus anterior muscle elevates the first rib to aid in breathing.

6. Increased blood flow to and from the brain to become more effective at cooling. The efficiency of selective brain cooling is increased by evaporation of sweat on the head and by ventilation through the nose. The increases in intravenous pressure gradient across the skull increase emissary flows and hence enhance the efficiency of brain cooling. Exercising the neck is known to increase blood flow to the brain. A properly conditioned neck can cool the brain more effectively.

7. Reduction of headaches due to weakened head muscles. Several studies have shown that a well-trained, stronger head and neck reduces headaches. One reason is simply that a stronger neck does not fatigue during everyday activities while holding the head upright.

8. Increased balance and athleticism by training the hotbed of proprioception. Proprioceptive inputs from the cervical musculature play an important role in head-eye coordination and postural processes. Muscle spindle density is extremely high in the deep muscles of the human neck.

9. The creation of an ongoing strength measurement to determine when an athlete can safely return to play after head and/or neck trauma. Creating a database consisting of strength levels and anthropometric measurements of the neck of every athlete, including baseline and final strength and measurements, will aid in the determination of return to play decisions for injured athletes.

Training the musculature of the cervical spine will induce physiological changes that will decrease the likelihood of concussion or other injuries to this region (Cantu, 1996). Although these injuries can never be fully prevented while the athlete continues participation in sports, strength coaches and athletic trainers must implement a sound cervical/cranial progressive resistance training protocol into their university programs. Team member athletes may be strong, fast, graceful and brilliant strategists, but if they are concussed and can’t play their desired sport, they are of no benefit to themselves or the team. There is an urgent need for a standardized resistance training protocol for both male and female athletes. This research will focus on the female athlete. Protecting the athlete and enhancing athletic performance can be accomplished by training the whole body and not forsaking the fragile yet critical components of the head and neck.

Methods

The purpose of this study was to train the muscles of the head, neck and upper back using resistance training with progressive overload to determine and record organic morphological and physiological changes in the active participant groups.

No methodical approach for producing a specific protocol to strengthen the head and neck muscles exists, and no systematic study of an increase in neck musculature attributed to such a protocol is documented. This study attempted to do so, laying the foundation for further research in this area.

The two main functions of the cervical spine are to flex and extend the head and flex and extend the cervical spine. With this in mind, functionality guided the purpose and development of the actual protocol. We hypothesize that less head and neck movement should translate in lower concussive force. In males, the larger surface area increase experienced through protocol adherence will dissipate forces over a larger structure; a larger internal cross-section muscle will better repel external forces experienced during impact. The increase in muscle strength will increase muscle stiffness, which will also benefit females.

Therefore the following research questions are posed:

1. Can a protocol be produced for the strength training of head and neck muscles?

2. Will this strength training protocol increase the neck circumference and neck strength of athletes, and therefore ultimately increase neck mass and muscle stiffness?

The proposed protocol was designed to enhance the capabilities of the soft tissue that surrounds the cylindrical surface area of the human head and neck through sequenced resistance movements to train the muscles of the head and neck. Anticipated results from protocol adherence will produce the following benefits:

a) The increase in surface area due to neck cylinder size gain (hypertrophy) lowers concussive and sub-concussive forces.

b) Strength increases effectively alter (increase) muscle stiffness, thus lowering deformation of the head and neck cylinder segment during impact.

c) The anatomical and morphological changes produced in the test subjects result in more effective kinetic energy dissipation.

d) A protocol can be produced for the safe and effective strength training of head and neck muscles.

Setting and Participants

The research study was conducted in a university setting in the southeastern United Sates. The subjects were 12 female college students ranging in age from 18-24 years old. The age range was selected because of the high activity level typical of 18-24 year old females, and the involvement of athletes in this age range in competitive sports. The exclusion criteria included students with disorders or diseases affecting the musculoskeletal system and students with preexisting cervical spine injuries or genetic abnormalities. Students were randomly split into two groups; the study group consisted of six students, and the control group consisted of six students. The study group followed the protocol designed to obtain desired results. The control group was instructed not to perform any exercises that involved direct stimulation to the neck musculature.

Materials

The pieces of equipment used for this study were prototypes. The prototypical machines allowed for the participant to safely train the musculature of the head and the neck. Neck circumference baseline measurements were taken using a medical grade tape measure. The United States Army Protocol for measuring the neck was used as a guide (Gordan & Brandtmiller, 1992). A professional grade power rack was used to perform the shoulder girdle elevation in conjunction with a standard seven-foot Olympic bar. Olympic weight plates were used as resistance devices.

Procedures

Signed informed consent documents were obtained. Research subjects were allowed time to familarize themselves with the equipment that would be used in the research and the protocol. Baseline measurements of the neck cicumference were taken using the United States Military Standardized Protocol (USMSP). The USMSP requires one measurement for females. Female circumference measurements were taken at the center measurement of the neck (Gordan & Brandtmiller, 1992). A set schedule for individual training sessions was composed to allow for one-on-one training sessions with each active participant. The sessions consisted of 20 minutes of training protocol three times in a seven day span for an eight-week period.

Exercise Protocol

All exercise protocols were performed in a sports performance laboratory. The research was conducted in a university setting in the southeastern United States. A starting weight was determined by the amount of weight a participant could safely use while performing the protocol for 12 repetitions in good form, with a 15-second rest period between sets.

The target repetition range was 12 repetitions, or until a repetition could not be performed with good form. Neck circumference measurements were taken at the beginning of each training session. Data was collected on training cards and then uploaded into a password-protected database.

The test subjects performed six head and neck movements using the head and neck machine: front flexion, extension, right and left lateral flexion, the nod (10 degrees of front flexion resembling a person nodding "yes"), and the tilt (25 degrees of flexion, with the jaw jutting outward and head gently tilting back). The 35-degree range of motion represents the movement of the head which does not directly activate the cervical neck musculature, with the exception of the atlas and axis vertbrae. Isolating the muscles of the head allows for the hypertrophy of the capital muscles of the head.

This was followed by a seated bilateral shrug, also performed on the protypical head and neck machine to innervate the lower trapezius muscles. A unilateral shrug was then performed on the same machine to innervate the upper trapezius. Next the Levator Scapula Shoulder Elevaton Shrug (LSSES) is a movement to innervate the upper trapezius and the muscles surrounding and involved in scapular retraction. The LSSES was performed by placing a seven-foot standard Olympic bar on the posterior of the neck, at the nape or appoximately at cervical vertebrae (CV) 7. The subject then performed scapular retraction, allowing the bar to rise vertically at the point where the trapezius shrugs vertically. This allowed subjects to train upper trapezius and other muscles without the limiting the factor of grip strength.

One set of seated rows was performed on the three-way row using a parallel grip, allowing for the innervation of the large muscles of the back: the latissimus dorsi and rhomboids major and minor, with contribution from the posterior deltoid. A scapular shrug was performed on the three-way row to involve the muscles of the upper back, posterior deltoid, and the rhomboids that are involved in scapular retraction. The scapular shrug movement required the particpant to keep the arms straight while using a parallel grip, then retracting the scapula and contracting the upper back muscles to successfully move the weight loaded onto the row. The retraction and pull was accomplished by using a supinated grip on the other horizontial handles. With straight arms and retraction of the scapula, participants then flexed elbows at 90 degrees, appoximately 8-12 inches, allowing for maximum innervation of the middle trapezius and fibers to the lowest fibers terminateing at thoracic vertebre 12 musculature.

Results

The female participants experienced significant strength gains. All of the females gained upper body strength. The head and neck muscles were the most impressive result of this study. One participant increased her neck strength in extension, flexion, and lateral flexion (right and left) by 40 pounds. The strength of the capital muscles was equally significant. One participant increased her capital movements by 40 pounds. Each of the strength gains represented the amount of weight the participant could lift in good form for 12 repetitions. Although statistically impossible to quantify, two phenomena were observed by the researchers during weeks 4-6: an improvement in protocol form, and a reduction of speed of movement. Together, these two observations suggested an increase in the participants’ true strength and muscle control both concentrically and eccentrically. The muscles were forced to work harder due to the reduction of speed of movement, resulting in the virtual elimination of momentum in the protocol.

For all neck and rowing exercises performed, the Wilcoxon Signed-Rank Test was utilized to determine if the exercises had resulted in a significant increase in neck and upper body strength. The increase in neck and upper body strength is computed by subtracting participants' baseline weights from their final weights. The nonparametric Wilcoxon Signed-Rank Test was chosen due to the small sample size (six subjects) of this study. However, a paired T-test was also conducted, and the results from the parametric test agreed with the results from the nonparametric test. No visible hypertrophy occurred, with final neck circumference measurements revealing only one active participant who exhibited a minimal increase (1/32 of an inch) in neck circumference. Conversely, there were no neck circumference changes in the control group.

Best Outcome Female Study Results

Movement	**Weight Increases**
Neck Extension	+45 lbs
Neck Flexion	+45 lbs
25 Degree Tilt	+45 lbs
10 Degree Nod	+45 lbs
Neutral Grip Row	+185 lbs
Bilateral Shrug	+150 lbs
Unilateral Shrug (left & right)	+75 lbs
Levator Scapulae Shrug	+140 lbs

Least Outcome Female Study Results

Movement	Weight Increases
Neck Extension	+35 lbs
Neck Flexion	+35 lbs
25 Degree Tilt	+35 lbs
10 Degree Nod	+35 lbs
Neutral Grip Row	+140 lbs
Bilateral Shrug	+80 lbs
Unilateral Shrug (left & right)	+40 lbs
Levator Scapulae Shrug	+80 lbs

Likewise for the female study, the strength training did not have a significant impact on neck circumference. Only one female subject experienced a 1/32-inch increase in neck circumference. The rest of the participants had no significant change in neck circumference. This includes active and control group subjects.

Test Mean

Hypothesized Value	0
Actual Estimate	0.00522
DF	5
Std Dev	0.01278

	t Test	Signed-Rank
Test Statistic	1.0000	0.5000
Prob > t	0.1816	0.5000

For each neck exercise, a Wilcoxon Signed-Rank Test was used to determine if the exercises resulted in a significant increase in neck strength. The increase in neck strength was computed by subtracting participants' baseline weights from their final weights. The nonparametric Wilcoxon Signed-Rank Test was chosen due to the small sample size (six subjects per group) of the study. However, the paired t-test was also calculated, and the results from the parametric test agreed with the results from the nonparametric test.

Head Nod

The highlighted p-value for the Wilcoxon Signed-Rank Test analysis indicates that Head Nod strength significantly increased from the baseline measure to the final measure. The box plot graphically illustrates the differences from baseline to final.

Test Mean	
Hypothesized Value	0
Actual Estimate	33.3333
DF	5
Std Dev	4.08248

	t Test	**Signed-Rank**
Test Statistic	20.0000	10.5000
Prob > t	<.0001*	0.0156*

Lateral Flexion Left

The highlighted p-value for the Wilcoxon Signed-Rank Test analysis indicates that lateral flexion (left) strength significantly increased from the baseline measure to the final measure. The box plot graphically illustrates the differences from baseline to final.

Test Mean	
Hypothesized Value	0
Actual Estimate	33.3333
DF	5
Std Dev	4.08248

	t Test	**Signed-Rank**
Test Statistic	20.0000	10.5000
Prob > t	<.0001*	0.0156*

Lateral Flexion Right

The highlighted p-value for the Wilcoxon Signed-Rank Test analysis indicates that lateral flexion (right) strength significantly increased from the baseline measure to the final measure. The box plot graphically illustrates the differences from baseline to final.

Test Mean	
Hypothesized Value	0
Actual Estimate	33.3333

DF	5
Std Dev	4.08248

	t Test	**Signed-Rank**
Test Statistic	20.0000	10.5000
Prob > t	<.0001*	0.0156*

Neck Extension

The highlighted p-value for the Wilcoxon Signed-Rank Test analysis indicates that neck extension strength significantly increased from the baseline measure to the final measure. The box plot graphically illustrates the differences from baseline to final.

Test Mean

Hypothesized Value	0
Actual Estimate	33.3333
DF	5
Std Dev	4.08248

	t Test	**Signed-Rank**
Test Statistic	20.0000	10.5000
Prob > t	<.0001*	0.0156*

Neck Flexion

The highlighted p-value for the Wilcoxon Signed-Rank Test analysis indicates that neck flexion strength significantly increased from the baseline measure to the final measure. The box plot graphically illustrates the differences from baseline to final.

Test Mean	
Hypothesized Value	0
Actual Estimate	33.3333
DF	5
Std Dev	4.08248

	t Test	**Signed-Rank**
Test Statistic	20.0000	10.5000
Prob > t	<.0001*	0.0156*

Head Tilt

The highlighted p-value for the Wilcoxon Signed-Rank Test analysis indicates that neck tilt strength significantly increased from the baseline measure to the final measure. The box plot graphically illustrates the differences from baseline to final.

Test Mean	
Hypothesized Value	0
Actual Estimate	33.3333
DF	5

Std Dev	4.08248

	t Test	**Signed-Rank**
Test Statistic	20.0000	10.5000
Prob > t	<.0001*	0.0156*

Neutral Grip Row

The highlighted p-value for the Wilcoxon Signed-Rank Test analysis indicates that neutral grip row strength significantly increased from the baseline measure to the final measure. The box plot graphically illustrates the differences from baseline to final.

Test Mean

Hypothesized Value	0
Actual Estimate	110.833
DF	5
Std Dev	19.3434

	t Test	**Signed-Rank**
Test Statistic	14.0350	10.5000
Prob > t	<.0001*	0.0156*

Unilateral Shrug

The highlighted p-value for the Wilcoxon Signed-Rank Test analysis indicates that unilateral shrug strength significantly increased from the baseline measure to the final measure. The box plot graphically illustrates the differences from baseline to final.

Test Mean

Hypothesized Value	0
Actual Estimate	45.8333
DF	5
Std Dev	11.583

	t Test	**Signed-Rank**
Test Statistic	9.6925	10.5000
Prob > t	<.0001*	0.0156*

Bilateral Shrug

The highlighted p-value for the Wilcoxon Signed-Rank Test analysis indicates that bilateral shrug strength significantly increased from the baseline measure to the final measure. The box plot graphically illustrates the differences from baseline to final.

Test Mean

Hypothesized Value	0
Actual Estimate	91.6667
DF	5
Std Dev	23.1661

	t Test	**Signed-Rank**
Test Statistic	9.6925	10.5000
Prob > t	<.0001*	0.0156*

Underhand Scapula Retraction Pull

The highlighted p-value for the Wilcoxon Signed-Rank Test analysis indicates that underhand scapula retraction pull strength significantly increased from the baseline measure to the final measure. The box plot graphically illustrates the differences from baseline to final.

Test Mean

Hypothesized Value	0
Actual Estimate	108.333
DF	5
Std Dev	23.8048

	t Test	Signed-Rank
Test Statistic	11.1474	10.5000
Prob > t	<.0001*	0.0156*

Levator Scapula Shrug

The highlighted p-value for the Wilcoxon Signed-Rank Test analysis indicates that levator scapulae strength significantly increased from the baseline measure to the final measure. The box plot graphically illustrates the differences from baseline to final.

Test Mean

Hypothesized Value	0
Actual Estimate	108.333
DF	5
Std Dev	23.8048

	t Test	Signed-Rank
Test Statistic	11.1474	10.5000
Prob > t	<.0001*	0.0156*

Scapula Retraction

The highlighted p-value for the Wilcoxon Signed-Rank Test analysis indicates that scapula retraction strength significantly increased from the baseline measure to the final measure. The box plot graphically illustrates the differences from baseline to final.

Test Mean

Hypothesized Value	0
Actual Estimate	110.833

DF	5
Std Dev	19.3434

	t Test	Signed-Rank
Test Statistic	14.0350	10.5000
Prob > t	<.0001*	0.0156*

Discussion

The results of this study demonstrate that females can increase upper body strength safely and without significant muscular size gains. During this study, the female neck showed a very minimal increase in circumference while strength level increases were substantial. The females did not exhibit the hypertrophy of their male counterparts, in comparison with a previous study conducted by this author with male participants. The strength gains obtained by the female participants will add stiffness to the head and neck musculature. To the researchers' knowledge, the capital muscles had never been isolated and aggressively trained in the allotted 35 degrees of movement at cervical levels 1 axis and 2 atlas. This researcher hypothesizes that the strength and stiffness increase will lower both concussive and sub-concussive forces. Year-round adherence to the proposed protocol will result in reduction of head displacement due to capital (head) and neck strength increases.

It is intuitive that a stronger athlete will be better-protected and less susceptible to injury. A properly trained and conditioned head and neck segment will increase performance as well as protection. Kinetic energy is more effectively dissipated by the properly trained and prepared muscles of the head, neck, and upper back, including the shoulder girdle. During weeks 4-6, the researchers observed strength increases coupled with participants' improved performance of movements in protocol form, and reduced speed of participants' movement both concentrically and eccentrically, thus indicating greater strength and muscle control.

Reduced deflection leads to reduced deformation of the affected area. If the body is to be prepared for competition, strengthening and protection of the head neck should certainly be of the highest priority. As an interesting side note, recruiting females for this research study was extremely difficult because of the prevalence of unwarranted fears of developing an enormous neck. By the fifth week of the study, the participants' peers noticed no increase in neck size, but marked increases in fitness due to the participants' efforts; by the sixth week, the researchers had a waiting list of 15 females who wanted to be involved in the study—a true paradigm shift and a step in right direction toward removing myths about females and developing large muscles.

It should be noted, that despite high effort levels exerted by the active research subjects coupled with significant strength increases; there were no adverse effects were observed or reported during the research study.

Conclusions

A standardized head and neck resistance training protocol is desperately needed and should be adopted nationwide. As concussion rates continue to increase, a preponderance of evidence is mounting which shows that stronger, larger head and neck muscles lower the susceptibility of an athlete to concussion. The scale of the sub-concussive damage a given athlete has sustained will not be known until years after the athlete leaves competitive sports. Once that tipping point has been reached, it will be too late for preventative measures to be implemented with those athletes because the damage will have been done. Instead of managing concussions better, we should prepare our athletes better. Not having a concussion would be much better for an athlete than managing one. Proactivity is the key to combating this debilitating epidemic, educating coaching staffs, athletic trainers, strength coaches and team physicians to not only be aware of concussions but to illuminate the proper methods of safe, effective, and prudent strength training principles. At the completion of the study, our collected data revealed tremendous strength increases that should translate into more resilient athletes who can tolerate the forces, both concussive and sub-concussive, of their particular sports.

Neck Machine

(Figure 1)

Power Rack

(Figure 2)

Iso-lateral Row

(Figure 3)

Permission granted to use likeness.

90 Degree Scap/Retrac Row

(Figure 4)

Permission granted to use likeness.

Retraction of the Scapula

(Figure 5)

Permission granted to use likeness.

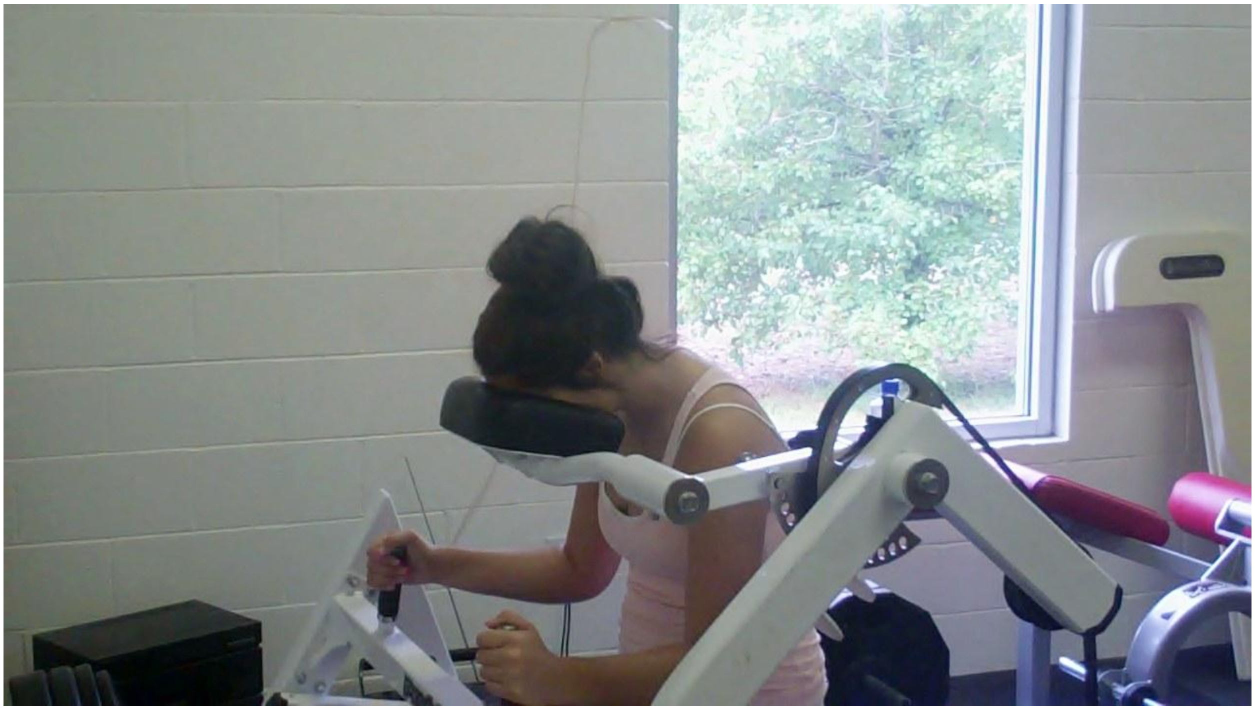
Extension

(Figure 6)

Permission granted to use likeness.

Flexion

(Figure 7)



Permission granted to use likeness.

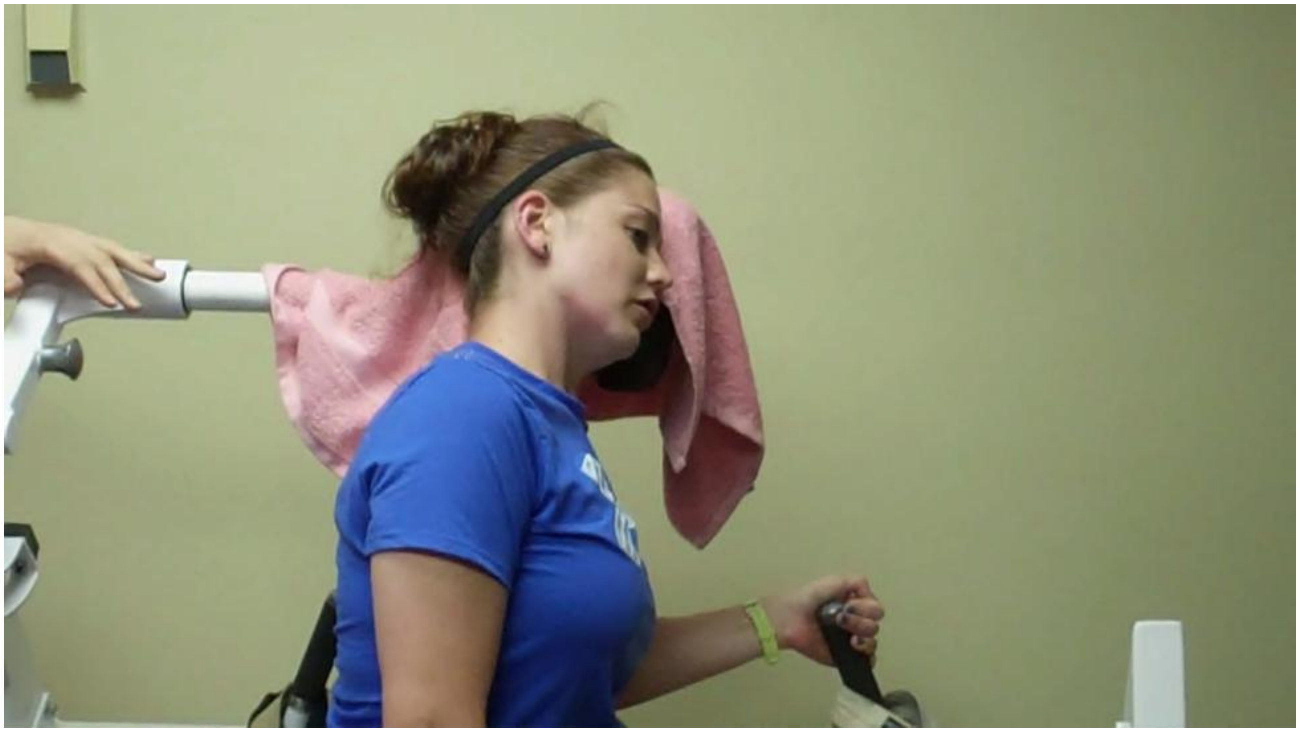
Lateral Flexion (Right)

(Figure 8)

Permission granted to use likeness.

Lateral Flexion (Left)

(Figure 9)



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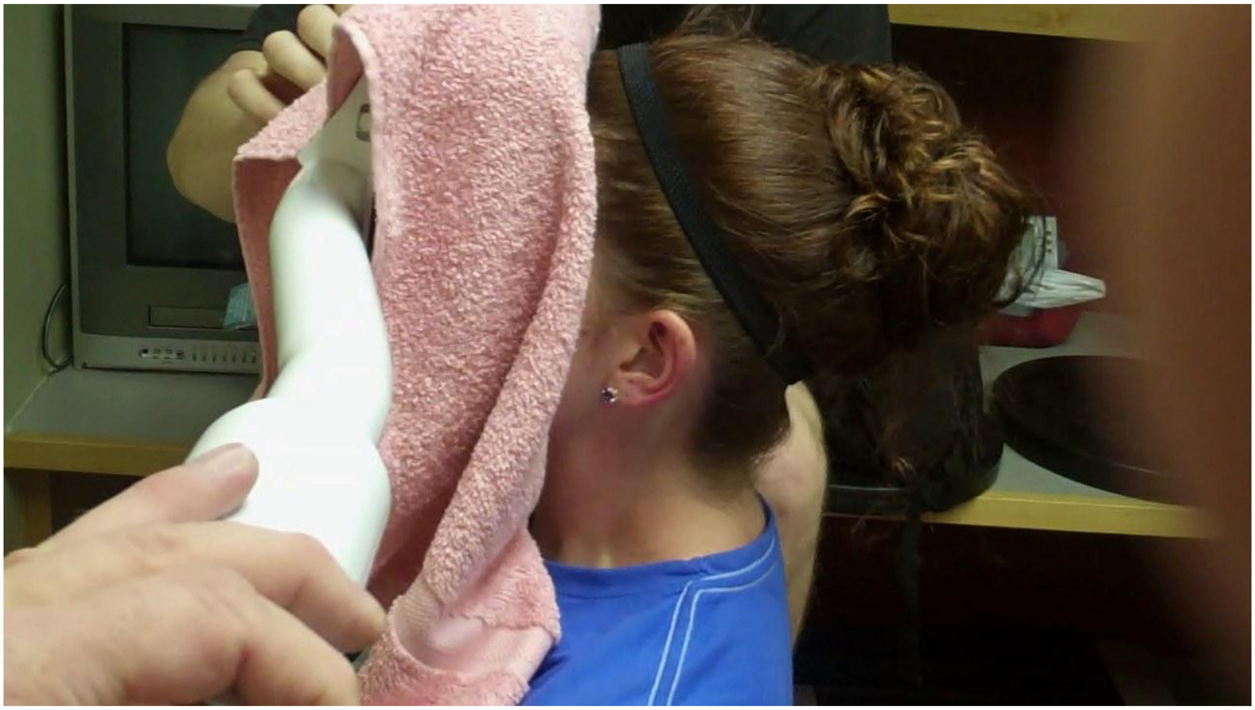
10 Degree Head Nod

(Figure 10)



Permission granted to use likeness.

25 Degree Tilt

(Figure 11)

Permission granted to use likeness.

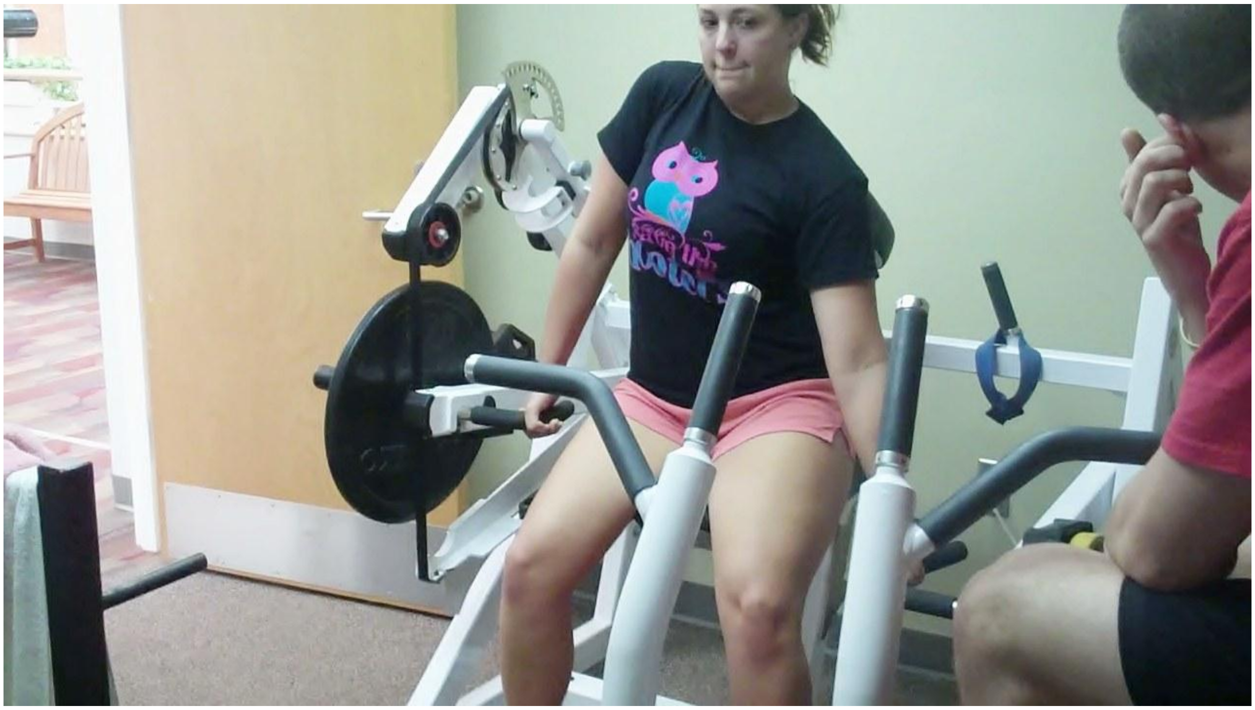
Unilateral Shrug (Left)

(Figure 12)

Permission granted to use likeness.

Unilateral Shrug (Right)

(Figure 13)



Permission granted to use likeness.

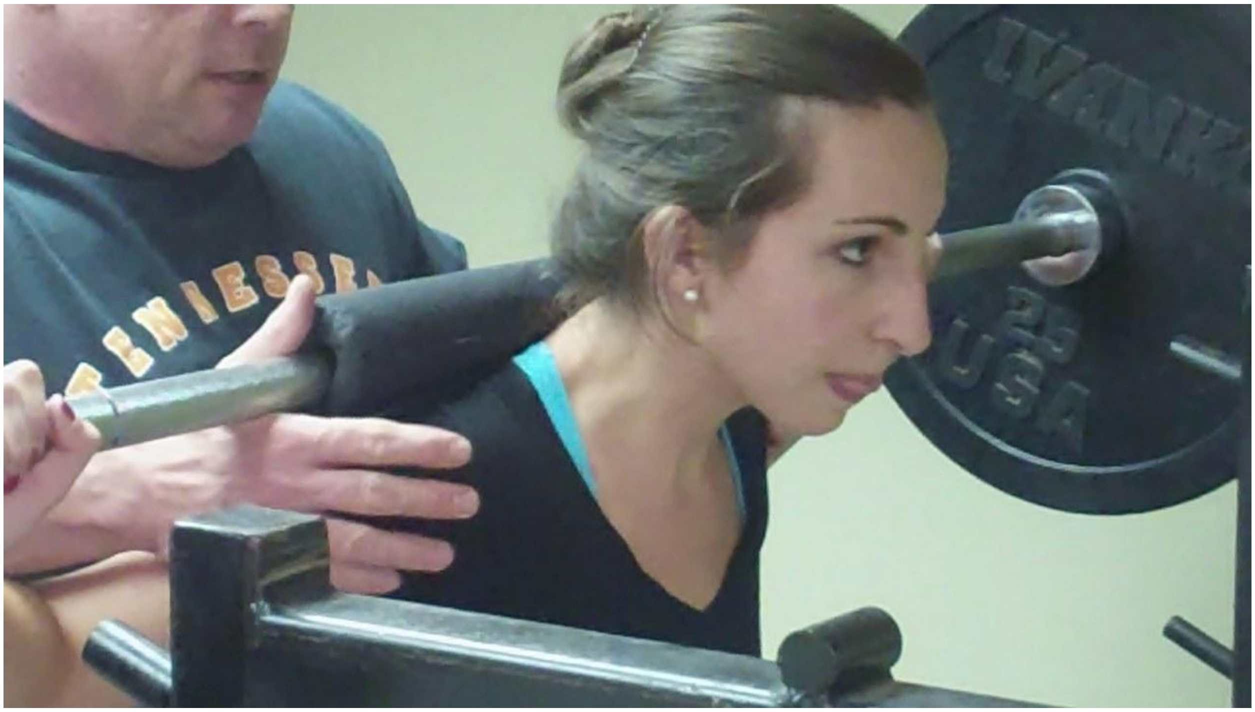
Seated Bi-lateral Shrug

(Figure 14)

Permission granted to use likeness.

Levator Scapula Raise

(Figure 15)



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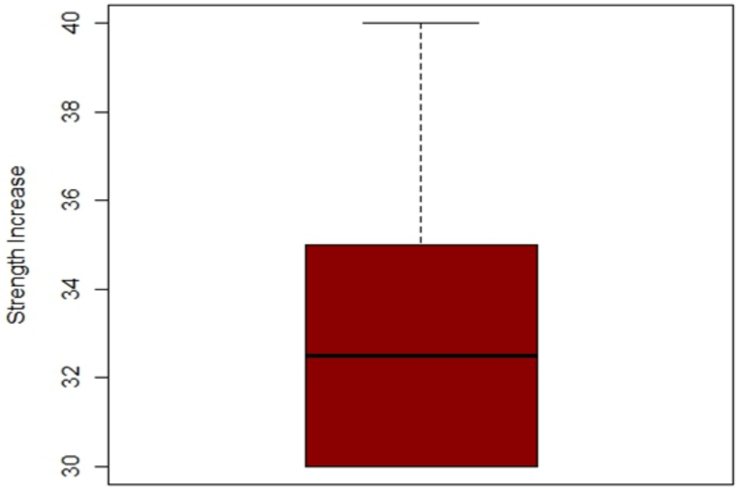
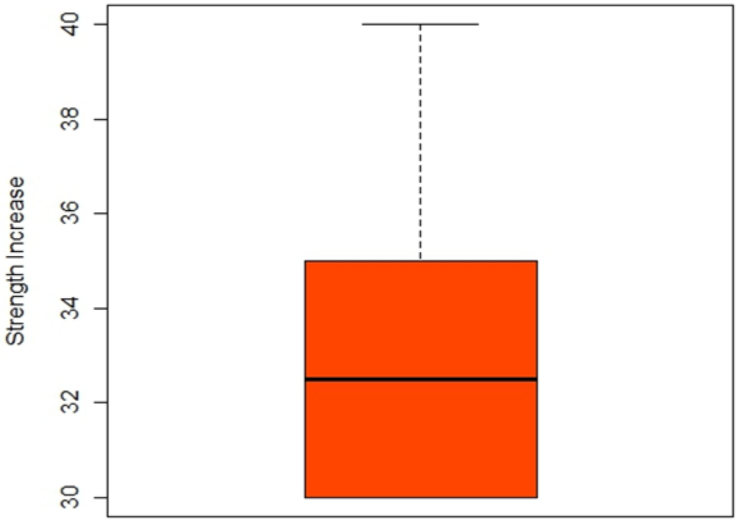
Head Nod

(Figure 16)



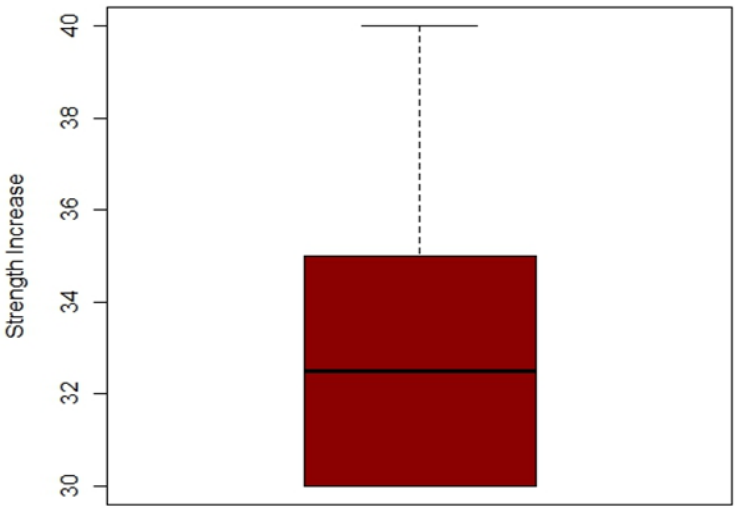
Lateral Flexion (Left)

(Figure 17)



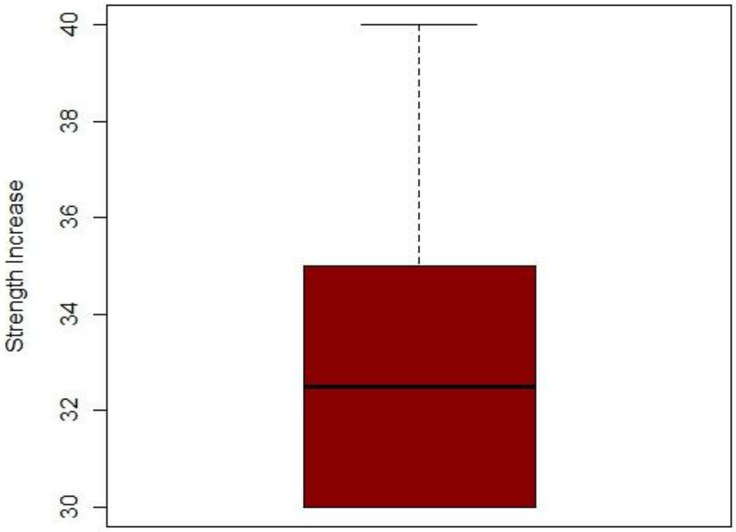
Lateral Flexion (Right)

(Figure 18)



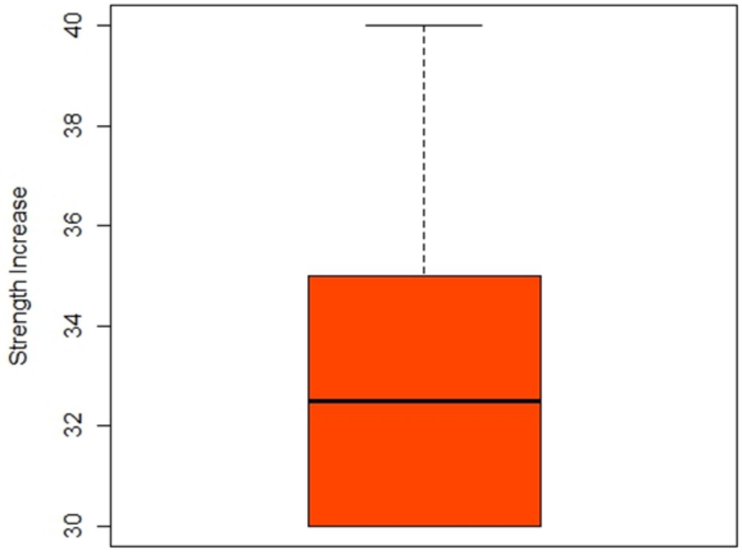
Neck Extension

(Figure 19)



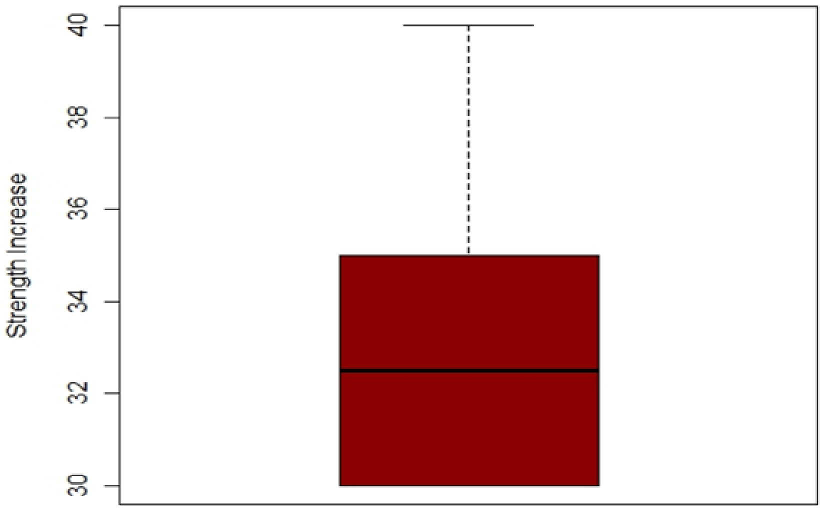
Neck Flexion

(Figure 20)



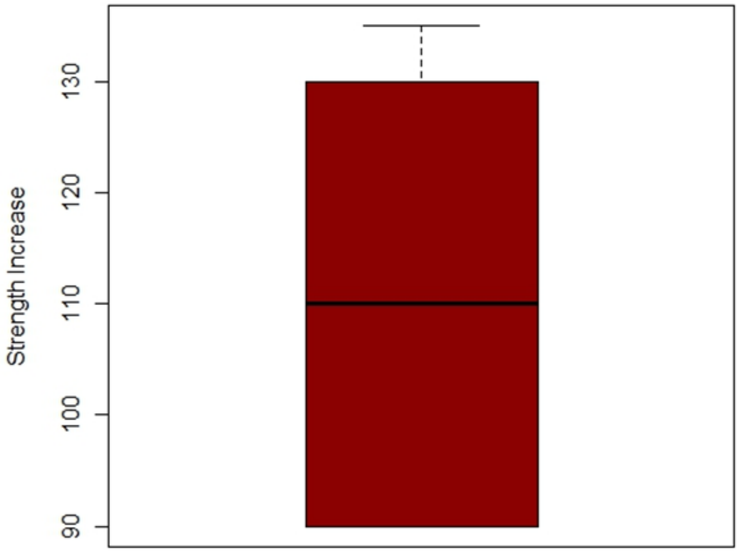
Neck Tilt

(Figure 21)



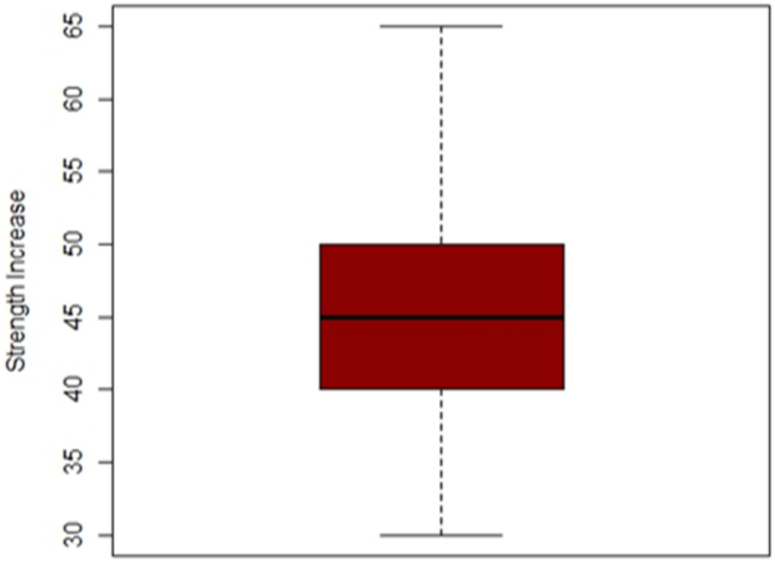
Neutral Grip Row

(Figure 22)



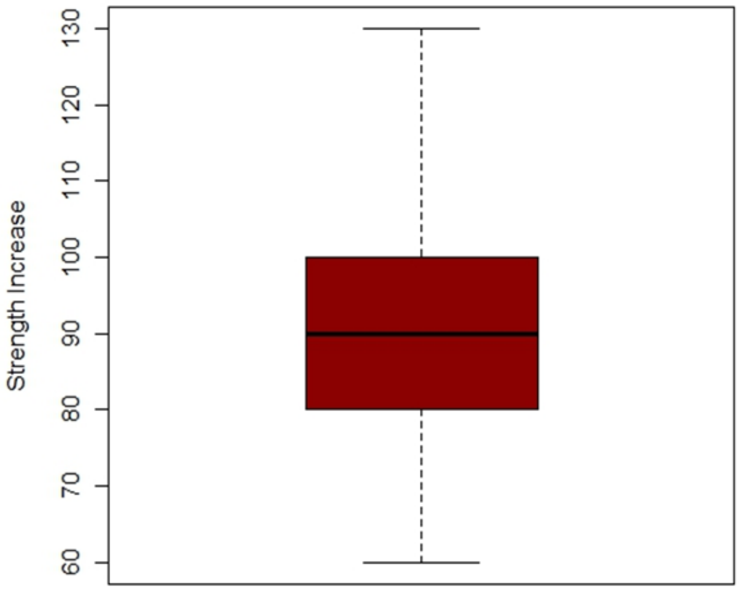
Unilateral Shrug

(Figure 23)



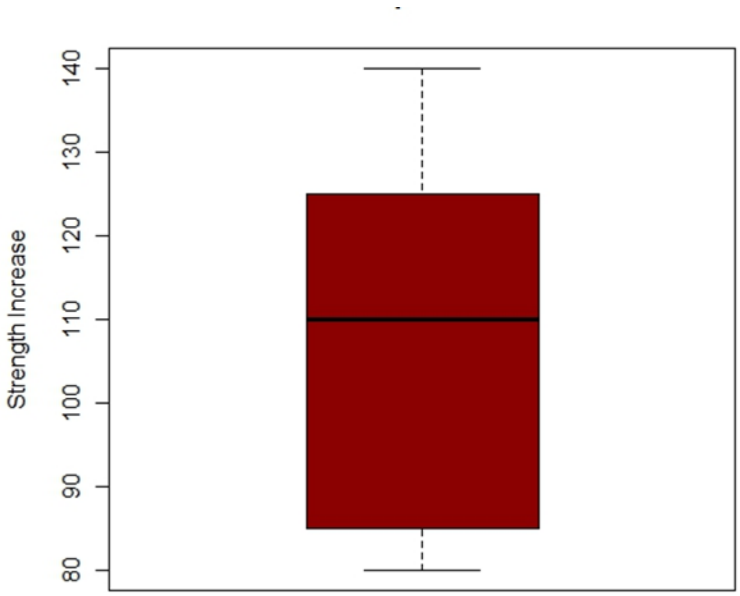
Bilateral Shrug

(Figure 24)



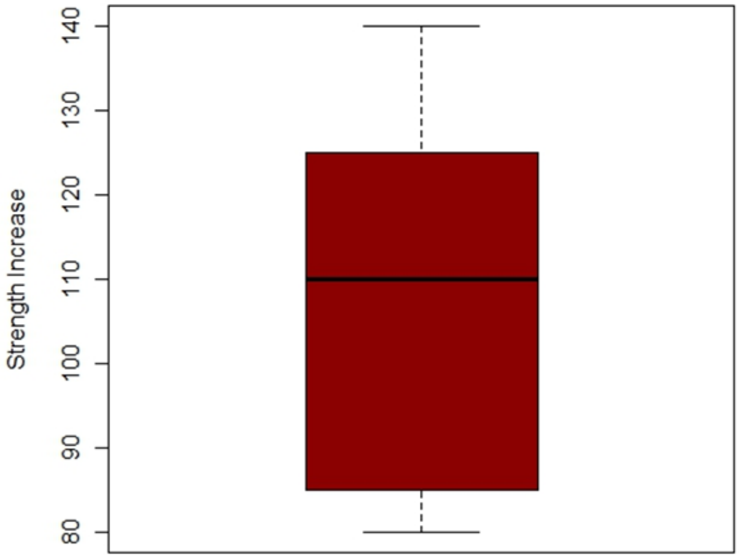
Underhand Scapula Retraction Pull

(Figure 25)



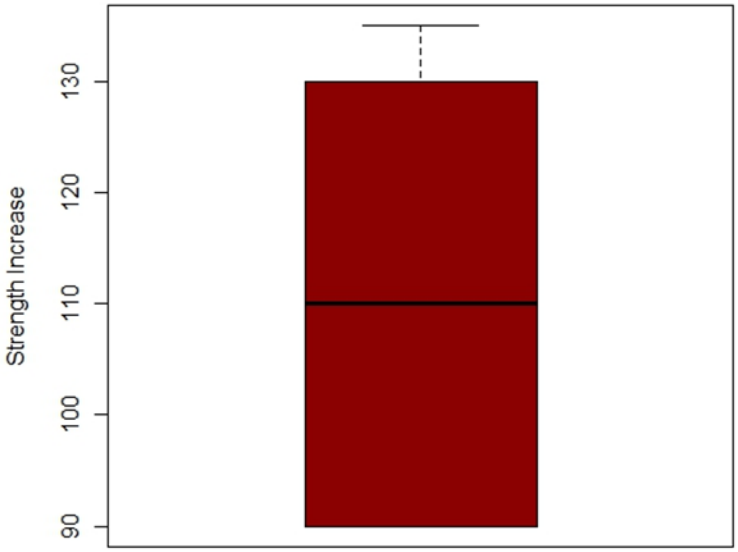
Levator Scapula

(Figure 26)



Scapula Retraction

(Figure 27)



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Chapter 5

Protecting Athletes with Stronger Muscles of the Head and Neck

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Abstract

Concussions have become a national epidemic. Millions of dollars have been spent to fund studies over the last 15 years. The majority of this research is focused on concussion causation and concussion management after the fact. The research continues, but the number of concussions in athletics increases each year.

No methodical approach to producing a specific protocol for strengthening the head and neck muscles exists, and no systematic study of increase in neck musculature attributed to such a protocol is documented. This study will produce a standardized methodology for the reduction of concussive and sub-concussive forces, laying the foundation for further research in this area.

The research participants were healthy male college students, ranging in age from 18-24 years old. There were 18 participants. Of the 18 subjects used for this study, 12 participants were randomly assigned to the experimental group and six participants were assigned to the control group. The participants followed a protocol consisting of 13 movements designed to sequentially train the musculature of the head, neck, and upper back. The duration of the study was eight weeks.

The strength increases of participants in the active group were significant. The hypertrophy of the head and neck muscles for participants in the active group was equally as significant and even more impressive. Every active participant experienced strength increases during the eight week study; likewise, each active participant exhibited neck circumference increases. Participants in the control group experienced negligible strength or hypertrophy increases.

Introduction

American Football is not safe in its current state. This same conclusion came to two Presidents of the United States 108 years apart: Theodore “Teddy” Roosevelt and Barack Obama. On October 9, 1905, representatives from Yale, Harvard and Princeton were summoned to the White House. President Roosevelt told the university officials that if football could not put an end to on-field brutality, then he would abolish the game with an executive order (Edwards, 1982). Just before the 2013 Super Bowl, President Obama commented on the problem of concussions. The President said he understood that NFL players are aware of the risks they take. “But as we start thinking about the pipeline,” the President intoned, “Pop Warner to high school to college, I want to make sure we’re doing everything we can to make the sport safer” (Hartstein, 2013).

In the century between President Roosevelt and President Obama, many of football’s rules were enacted or changed with player safety in mind. The helmets have evolved from leather to carbon fiber and Kevlar. The protective body pads have also become modernized. Much current research and existing theory looks to helmet technology to protect athletes from concussion, and many parents put their faith in the claims of helmet companies to protect their children. However, according to Alison Brooks of the University of Wisconsin School of Medicine and Public Health, parents should be wary of such claims. Dr. Brooks said, “We were getting questions from coaches and parents about helmet companies saying their helmets can prevent concussions. There's really no evidence to support that.” Much current research and existing theory looks to helmet technology to protect athletes from concussion. That research, however, is finding that helmets are unable to protect athletes against concussions at a truly effective level (Do Certain, 2012).

In fact, research published in the *Journal of Neurosurgery* in 2011 found that pre-World War II leather helmets performed better or similar to 21st-century helmets. The authors state that:

> The pre–World War II vintage leather helmets in our tests, despite their lack of technologically advanced energy-absorbent materials, frequently were associated with head impact doses and theoretical injury risks that, based on linear acceleration, angular acceleration, angular velocity, neck force, and neck moment measures, were similar to or lower than those for several 21st-century varsity helmets in near- and sub-concussive impacts. (Bartsch, Benzel, Miele & Prankish, 2011)

Leather helmets worked just as well or better than the helmets we have today when tested against the same kind of forces that cause concussions.

While helmets have limited capabilities to protect athletes from concussions, laws passed by politicians to address the situation don’t really protect athletes either. For example, the Lystedt law—first passed in Seattle—contains three essential elements:

> • Athletes, parents and coaches must be educated about the dangers of concussions each year.
>
> • If a young athlete is suspected of having a concussion, he/she must be removed from a game or practice and not be permitted to return to play.
>
> • A licensed health-care professional must clear the young athlete to return to play in the subsequent days or weeks. (WA State Gen. Laws chapter 28A.600)

Once again, as evidenced by the Lystedt law, politicians also are not addressing concussions *before they occur*. The law offers no mandates on providing proper neck training in advance, only dealing with the issue after the athlete has been concussed (CDC, 2009).

Concussions have become a national epidemic. Millions of dollars have been spent to fund studies over the last 15 years. The majority of this research is focused on concussion causation and concussion management after the fact. The research continues, but the number of concussions in athletics increases each year. To date, concussion prevention has amounted to better helmet technology, better legislation, improved skills training, and stricter on-field penalty enforcement. Concussion prevention, by definition, refers to the measures taken to ward off potential concussive forces prior to the actual episode. There seems to be a misunderstanding or a possible disconnect when the word “prevention” is used in conjunction with the word “management” in the medical and athletic training realm. A great deal of concussion research has been conducted to examine the best methods of managing and averting possible concussive events. I refer to this as passive prevention. Passive prevention can be described as intervention directed at removing possible contingencies that could lead to concussion with little proactivity. While multiple areas of concussion prevention have been researched, there remains an absence of research examining effective training programs for muscles that protect the cervical spine (Leggett et al., 1991).

Interestingly, monitoring research studies, online sources of information, and daily press releases concerning concussions reveals no information relating to concussion prevention. Instead, such stories will involve helmets, rules of engagement, methods of recovery and banning football for children. However, none of them speak to proactive prevention. Helmets are effective for the prevention skull fractures, but producing a concussion-proof helmet is impossible (Wilson, 2013). Also, rules cannot change the intrinsic nature of a sport. Football, for instance, is a violent sport, and rules cannot make it something it isn’t. Even after rule changes initiated by the NFL in 2010 to help protect players from concussions, the rate of concussion has been, at best, static and showing no improvement (Fink, 2013).

The Centers for Disease Control and Prevention, along with the National Institute of Health, announced in 2008 that concussions have become a national epidemic (CDC, 2008). Concussion is a frequent occurrence in contact sports: annually, from 1.6 to 3.8 million sports-related concussions occur in the United States. Most sport-related head injuries are minor; although the majority of athletes who suffer a concussion recover within a few days or weeks, a small number of individuals develop long-lasting or progressive symptoms (McKeeet.al 2009).

Justification for Study

Research shows that if the muscles of the head and neck are trained in a specific manner and as individually as possible, an adaptation response will occur (Conley, Stone, Nimmons & Dudley, 1997). Other research shows that bigger and stronger muscle correlates with more energy absorption (Abbot, Aubert, & Hill, 1951). Also, the head of an athlete does not react to a blow as if it were a free body. Studies with cadaveric and anthropomorphic heads show that supporting the neck reduces the incidence of head injury (Reid & Reid, 1978). The head is held firmly to the neck principally by neck musculature (Goel, Clark, Gallaes & Liu, 1988). This correlation between large neck mass muscles and energy absorption can also be observed in nature: during their mating season, Rocky Mountain bighorn sheep clash heads with a force estimated at 2,400 pounds—and do not concuss (Big Horn, 2012). These animals are seldom hurt because their skulls and their massive neck muscles absorb the force of the blow (Rocky Mountain).

The physics equation behind this occurrence in nature is simple: $F=MA$, where F is force, M is mass and A is acceleration. According to this equation, with blows of force F, the receiving body that has more mass would experience less acceleration. If the neck mass were greater, then the brain, therefore, would also experience less acceleration and hence less force upon it. Unlike the musculoskeletal system, the brain cannot be conditioned to accept trauma. In fact, the reverse is true: once injured, the brain may be more susceptible to future injury (Gerberich et al.1983). Therefore, adding to the mass of the neck of an athlete (as measured by neck circumference and strength increases) will help reduce concussive injury. It is also understood that insufficient muscle strength in the cervical spine could predispose an athlete to concussion because he or she cannot create the interior muscle force necessary to counter the external force which causes head acceleration , neck deformation, and head displacement (Tierney et al., 2004) (Black, 2007).

Preeminent concussion experts Dr. Robert Cantu , M.D., and Dr. Michael Collins, Ph.D., concur that "one of the best ways to prevent concussions is through neck strength." Dr. Collins goes on to argue: "Having a strong neck actually allows the forces of the blow to be taken from the head down through the neck and into the torso" (Collins, 2012). Also, Dr. Robert Cantu, regarded as the leading concussion authority in the world, asserts: "A stronger neck is harder to spin; it is that rotation that stresses the brain and causes damage resulting in a concussion." He believes females concuss more often than males because of a lack of neck strength (Cantu, 2012). Thus, there is a need for increased neck strength in reducing concussions.

When an athlete engages in a progressive resistance training program, muscles adapt to the overload training. Increases in muscle cross-sectional area or individual muscle fiber size, reflecting muscle hypertrophy, are typical and well-documented responses to resistance exercise. Neck muscles are no different from muscles in other parts of the body. The muscles of the neck are trained in as specific manner and as individually as possible, in order to achieve an adaptation response (Conley, 1997). By training the head, neck and trapezius muscles, strength coaches enhance both the protection and performance of their athletes. A stronger neck increases the strength of an athlete, who then can function at a higher level of work capacity.

Statement of Purpose

The absence of a training protocol leaves the field of concussion prevention wide open for much needed research. The purpose of this study is to look at concussion prevention from a different angle. There is considerable previous research establishing a correlation “between stronger cervical spinal muscles and a higher force absorption rate of the head during concussive impacts to football players” (Black, 2007). As Black observes, no such protocol has yet been established for training the neck and head of athletes in collision sports. However, despite the recognition of a need for an increase in neck strength in order to reduce the potential for concussion, there is no standardized protocol for proactively preparing the athlete for the physical rigors of the sport. This study will examine such a protocol and its ability to increase hypertrophy and head and neck muscle strength in college age athletes.

Value of Study

Proactivity must be paramount with regards to the concussion epidemic. Concussions are going to occur in sports; however, as the kinetic energy is lowered by increasing the size (mass) of the cylinder (neck) through direct, full range-of-motion resistance exercises and by increasing the stiffness or strength of the neck, the athlete will dissipate kinetic energy to the larger muscles of the lower body. If concussive forces are lowered, then the athlete will concuss less, and debilitating subconcussive forces will be less as well. The athlete can then play longer, with less residual damage to the brain.

Research Questions

Therefore the following research questions are posed:

1. Can a protocol be produced for the strength training of head and neck muscles?
2. Will this strength training protocol increase the neck circumference and neck strength of athletes and therefore ultimately increase neck mass?

No methodical approach to producing a specific protocol to strengthen the head and neck muscles exists, and no systematic study of increase in neck musculature attributed to such a protocol is documented. Thus, this study will produce a standardized methodology for the reduction of concussive and subconcussive forces, laying the foundation for further research in this area.

Methods

The purpose of this study was to train the muscles of the head, neck and upper back using resistance training with progressive overload to determine and record organic morphological and physiological changes in the active participant groups.

No methodical approach to producing a specific protocol to strengthen the head and neck muscles exists, and no systematic study of an increase in neck musculature attributed to such a protocol is documented. This study will attempt to do so, laying the foundation for further research in this area.

The two main functions of the cervical spine are to flex and extend the head and flex and extend the cervical spine. With this in mind, functionality guided the purpose and development of the actual protocol. We hypothesized that less head and neck movement should translate into lower concussive force. In males the larger surface area increase experienced through protocol adherence will dissipate forces over a larger structure; a larger internal cross-section muscle will better repel external forces experienced during impact. The increase in muscle strength will also increase muscle stiffness therefore making the neck less compliant to deformation forces.

The proposed protocol was designed to enhance the capabilities of the soft tissue that surrounds the cylindrical surface area of the human head and neck through sequenced resistance movements to train the muscles of the head and neck. Anticipated results from protocol adherence will produce the following benefits:

a) The increase in surface area due to neck cylinder size gain (hypertrophy) lowers concussive and sub-concussive forces.

b) Strength increases effectively alter (increase) muscle stiffness, thus lowering deformation of head and neck cylinder segment during impact.

c) The anatomical and morphological changes produced in the test subjects result in more effective kinetic energy dissipation.

d) A protocol can be produced for the safe and effective strength training of head and neck muscles.

Setting and Participants

The research study was conducted in a university setting in the southeastern United Sates. The subjects were 18 male college students ranging in age from 18-24 years old. The age range was selected because of the high level of circulating testosterone, activity level, and involvement in competitive sports. The exclusion criteria included students with disorders or diseases affecting the musculoskeletal system and students with preexisting cervical spine injuries or genetic abnormalities. Students were randomly split into two groups; the study group consisted of 12 students, and the control group consisted of six students. The study group followed the protocol designed to obtain desired results. The control group was instructed not to perform any exercises that involved direct stimulation to the neck musculature.

Materials

The pieces of equipment used for this study were prototypes. The prototypical machines allowed participants to safely train the musculature of the head and the neck. Neck circumference baseline measurements were taken using a medical grade tape measure. The United States Army Protocol for measuring the neck was used as a guide (Gordan & Brandtmiller, 1992). A professional grade power rack was used to perform the shoulder girdle elevation in conjunction with a standard seven-foot Olympic bar. Olympic weight plates were used as resistance devices.

Procedures

Signed informed consent documents were obtained. Research subjects were allowed time to familiarize themselves with the equipment that would be used in the research and the protocol. Baseline measurements of the neck circumference were taken using the United States Military Standardized Protocol (USMSP). The USMSP requires two measurements for males. Male circumference measurements were taken one inch above the *prominentia laryngea* (Adam's apple) and the second measurement was taken one inch below the Adams's Apple located on the male neck (Gordan & Brandtmiller, 1992). A set schedule for individual training sessions was composed to allow for one-on-one training sessions with each active participant. The sessions consisted of 20 minutes of training protocol three times in a seven day span for an eight-week period.

Exercise Protocol

All exercise protocols were performed in a sports performance laboratory. The research was conducted in a university setting in the southeastern United States. A starting weight was determined by the amount of weight a participant could safely use while performing the protocol for 12 repetitions in good form, with a 15-second rest period between sets.

The target repetition range was 12 repetitions, or until a repetition could not be performed with good form. Neck circumference measurements were taken at the beginning of each training session. Data was collected on training cards, and then uploaded into a password-protected data base. The test participants were trained individually, and each repetition was coached to ensure validity and precise protocol movement.

The test subjects performed six head and neck movements using the head and neck machine: front flexion, extension, right and left lateral flexion, the nod (10 degrees of front flexion resembling a person nodding "yes"), and the tilt (25 degrees of flexion, with the jaw jutting outward and head gently tilting back). The 35-degree range of motion represents the movement of the head that does not directly activate the cervical neck musculature, with the exception of the atlas and axis vertebrae. Isolating the muscles of the head allows for the hypertrophy of the capital muscles of the head.

This was followed by a seated bilateral shrug, also performed on the protypical head and neck machine to innervate the lower trapezius muscles. A unilateral shrug was then performed on the same machine to innervate the upper trapezius. Next, the Levator Scapula Shoulder Elevation Shrug (LSSES) is a movement to innervate the upper trapezius and the muscles surrounding and involved in scapular retraction. The LSSES was performed by placing a seven-foot standard Olympic bar on the posterior of the neck, at the nape or approximately at cervical vertebrae (CV) 7. The subject then performed scapular retraction, allowing the bar to rise vertically at the point where the trapezius shrugs vertically. This allows subject to train upper trapezius and other muscles without the limiting the factor of grip strength.

One set of seated rows was performed on the isolateral row using a parallel grip, allowing for the innervation of the large muscles of the back: the latissimus dorsi and rhomboids major and minor, with contribution from the posterior deltoid. A scapular shrug was performed on the isolateral row to involve the muscles of the upper back, posterior deltoid and the rhomboids that are involved in scapular retraction. The scapular shrug movement required the participants to keep their arms straight as they used a parallel grip, then retracting the scapula. It is the retraction of the scapula and contraction of the upper back muscles that successfully moves the weight loaded onto the row. The retraction and pull was accomplished by using a supinated grip on the other horizontal handles. With straight arms and retraction of the scapula, participants then flexed elbows at 90 degrees, approximately 8-12 inches, allowing for maximum innervation of the middle trapezius and fibers to the lowest fibers that terminate at thoracic vertebrae 12 musculature.

Results

The strength increases were significant in the active participant group. The hypertrophy of the head and neck muscles was equally as significant and even more impressive. Every active participant experienced strength increases during the eight week study; likewise, each active participant exhibited neck circumference increases. The control group experienced negligible strength or hypertrophy increases. Active participants increased strength in capital muscle movements, indicating that the muscles that actually attach and move the human skull and attach to the cervical spine were indeed becoming stronger. The final strength increases were not one-repetition maximum lifts. Each of the strength gains represented the amount of weight the participant could lift in good form for 12 repetitions. Although statistically impossible to quantify, two key phenomena were observed by the researchers: an improvement in protocol form and a reduction of speed of movement. Together, these two observations suggested an increase in the participants' true strength and muscle control both concentrically and eccentrically. The muscles were forced to work harder due to the reduction of speed of movement, resulting in the virtual elimination of momentum in the prescribed protocol exercises.

Data Analysis

Best Outcome Male Study Results

Movement	**Weight Increases**
Neck Extension	+67.5 lbs.
Neck Flexion	+49.5 lbs.
Lateral Flexion Right	+67.5lbs.
Lateral Flexion Left	+67.5lbs.
25 Degree Tilt	+67.5 lbs.
10 Degree Nod	+49.5 lbs.
Neutral Grip Row	+180 lbs.
Bilateral Shrug	+180 lbs.
Unilateral Shrug (left & right)	+80 lbs.
Levator Scapulae Shrug	+261lbs
Underhand Scapula Retraction Pull	+170lbs
Neck Circumference Increase	Neck Circumference Decrease
4 inch Circumference Increase Upper Neck	Zero Neck Circumference Decrease
3 3/4 inch Circumference Increase Lower Neck	Zero Neck Circumference Decrease

Least Outcome Male Study Results

Movement	**Weight Increases**
Neck Extension	+47.5 lbs.
Neck Flexion	+44 lbs.
Lateral Flexion (Right)	+45 lbs.
Lateral Flexion (Left)	+45 lbs
25 Degree Tilt	+47.5 lbs.
10 Degree Nod	+44 lbs.
Neutral Grip Row	+125 lbs.
Bilateral Shrug	+60 lbs.
Unilateral Shrug (left & right)	+30 lbs.
Levator Scapulae Shrug	+205 lbs.
Underhand Scapula Retraction Pull	+60lbs
Neck Circumference Increase	Neck Circumference Decrease
1.5 inch Circumference Increase Upper Neck	Zero Neck Circumference Decrease
2.5 inch Circumference Increase Lower Neck	Zero Neck Circumference Decrease

Discussion

The significant increases in head and neck hypertrophy that were exhibited by active participants can be attributed to the sequence in which the movements were performed and the participants' adherence to protocol form. What this protocol allows for is an ability to train the muscles of the head and neck separately, aided by a focus on resistance within the 35 degrees of motion known to predominantly involve the capital muscles of the head. The upper cervical spine is the site of the most concentrated area of mechanoreceptors. Whereas cutaneous mechanoreceptors provide information derived from external stimuli, another major class of receptors provides information about mechanical forces arising from the body itself, the musculoskeletal system in particular. Mechanoreceptors are the joint position receptors. These contribute to body's kinesthetic awareness in space and balance. Similarly, the sub-occipital muscles also have very dense number muscle spindle cells and Golgi tendon organs. Muscle spindles measure the rate of change in muscle length and monitoring joint position as it relates to the muscle. The Golgi tendon organ measures muscle tension. Thus, the head has the ability to react very quickly to stimuli because of feedback the brain receives from the abundance of receptor sites located in the head and neck region.

Strength increases occurred across the board within the 35 degrees of motion of the head, as well as notable size and strength gains in the superficial neck muscles. Among active participants, hypertrophy was consistent throughout the eight week study. These results illustrate that over a period of time, with sufficient overload, an adherence to this protocol will induce a progressive change in morphological and physiological function of the head and neck muscles.

Participants were randomly assigned to the active and control groups. The use of random selection added validity and potential applicability across a wide variety of populations. Another advantage of the random selection process was that the active group included a diverse collection of body types in terms of genetic predisposition, featuring ectomorphs, mesomorphs, and endomorphs. For example, the participant with the least perceived genetic predisposition had a 2.5-inch increase in neck circumference. This suggests that the protocol has the potential to be effective for all body types across a gamut of sports.

The effectiveness of the protocol could be attributed to the strict adherence to the predetermined form of each movement. Each repetition was coached through full range of motion. The adherence to protocol form was extremely stringent. If proper form was broken, then that particular repetition was not recorded. Each participant was trained separately in a distraction-free environment that allowed for concentration and focus on the task at hand. This created a purposeful, goal-driven environment.

It should be noted, that despite high effort levels exerted by the active research subjects coupled with significant strength increases and substantial neck circumference hypertrophy; there were no adverse effects were observed or reported during the research study.

Conclusions

Simple physics tells us that a larger area will disperse more energy over that larger surface area. Viewing the human neck as a cylinder, when that cylinder's circumference increases there is concomitant increase in its ability to dissipate larger forces from impact and translate that energy into heat. When the human is startled, many protective contingencies go into motion. The head lowers, reducing the length of the neck and cervical spine. Cervical vertebrae C1 and C2 are put into a posture that offers a stiffer head and neck segment, reducing rotational acceleration and overall head and neck movement, which reduces concussive forces. This research study confirms that the human male neck can exhibit considerable circumference increases while adhering to proper strength training principles encompassed in a well-devised resistance protocol. As the mass of the human neck and head increases, a greater force is required to displace the head and neck.

The human body is already endowed with the needed standard operating equipment to protect itself. These protective devices are additionally increased and enhanced through a properly-performed resistance training program. An increase in muscle tissue surrounding the human neck reduces deformation of the neck when force is applied. Strength increases also occur in soft tissue such as movement-restricting ligaments, tendons and collagen. Training programs for cervical neck musculature, such as the protocol described here, help to compliment and improve the body’s natural defense mechanisms. In order to proactively affect concussion rates, a standardized head and neck resistance training protocol must be initiated throughout the sports world.

Upper Neck Circumference Difference Analysis

The first task was to determine if differences exist in change in neck circumference between the active group (participants involved in the study) and the control group. This analysis was done using a two-sample t-test comparing the difference in upper neck circumference (final minus baseline) for the control group versus the active group. The means and standard deviations for each group are also given.

The highlighted p-value indicates that the change in upper neck circumference (final minus baseline) for the active participants was significantly greater compared to the change in neck circumference for the control group.

The differences in upper neck circumference are also displayed graphically in the box plots. Box plots are a graphical display of the data that give the minimum, 25th percentile, median, 75th percentile, and maximum, allowing for comparison of the distributions for each of the groups. Differences in upper neck circumference appear greater for the active group compared to the control group.

Means and Standard Deviations

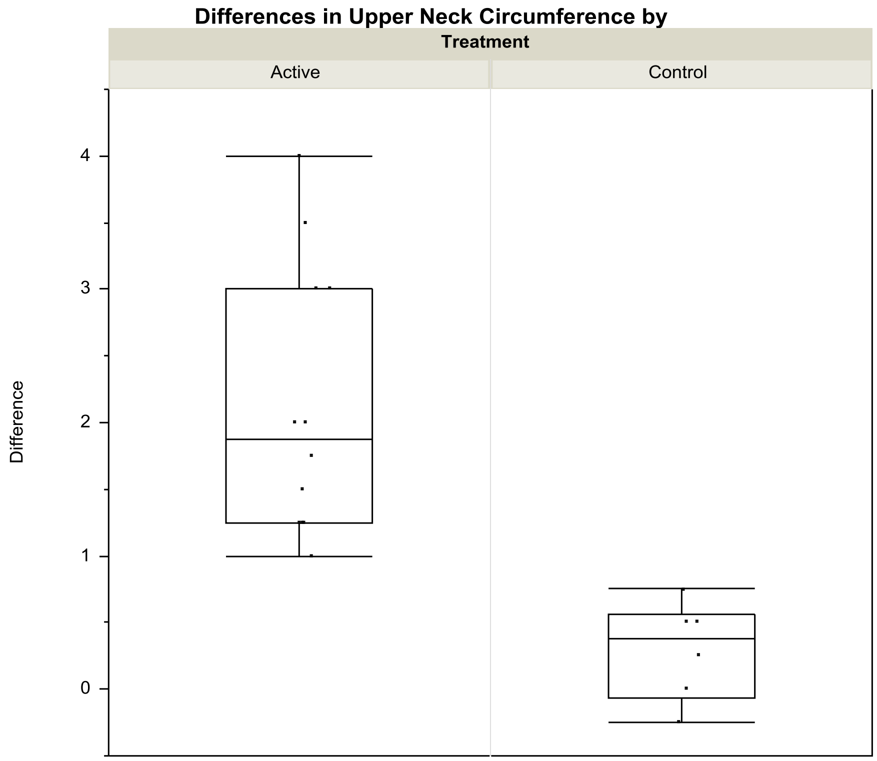
Level	**Number**	**Mean**	**Std Dev**
Active	12	2.12500	1.00284
Control	6	0.29167	0.36799

t Test

Control-Active

Assuming unequal variances

Difference	-1.8333	t Ratio	-5.62107
Std Err Dif	0.3262	DF	15.28385
Upper CL Dif	-1.1393	Prob < t	<.0001*
Lower CL Dif	-2.5274		
Confidence	0.95		



We were also interested in whether or not the differences in upper neck circumference from the baseline measures to final measures were significant for the active participants. A paired t-test was used to test whether neck circumference significantly increased from the baseline measure to final measure. The mean and standard deviation are given for the difference in upper neck circumference (final minus baseline). The highlighted p-value for the paired t-test analysis indicates that neck circumference significantly increased from the baseline measure to the final measure for the participants who were actively involved in the study. The box plots graphically illustrate the differences from baseline to final.

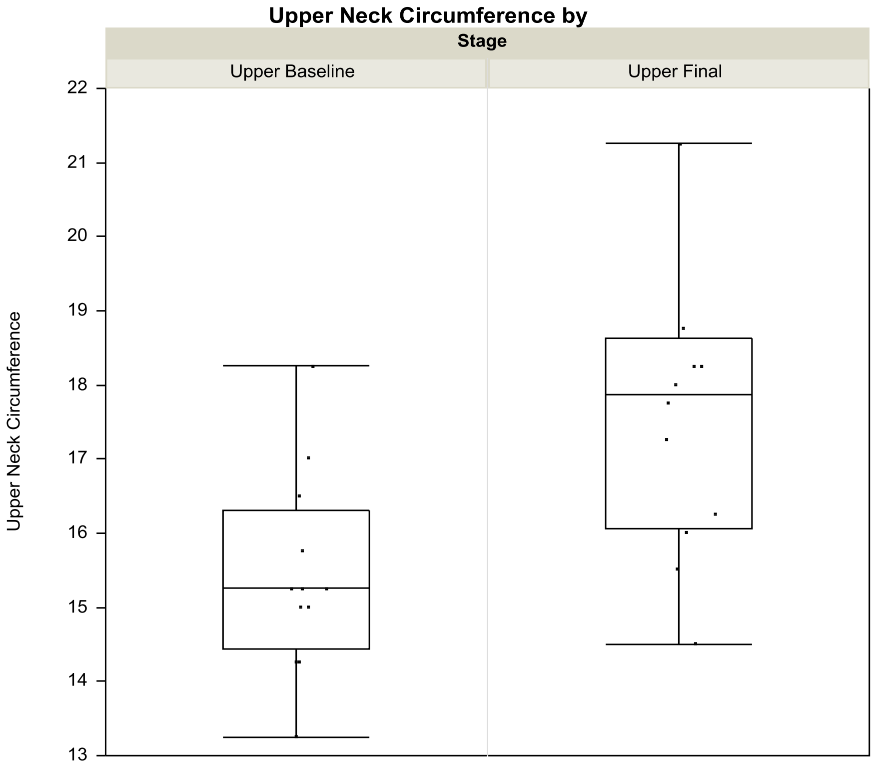
Mean and Standard Deviation

Mean	2.125
Std Dev	1.0028369
N	12

Paired t-Test (Final-Baseline)

Hypothesized Value	0
Actual Estimate	2.125
DF	11
Std Dev	1.00284

	t Test
Test Statistic	7.3404
Prob > t	<.0001*



Lower Neck Circumference Difference Analysis

The lower neck circumference study followed closely to the upper neck circumference study previously discussed. The first analysis involved a t-test to compare the difference in neck circumference for the control group and the active group. The highlighted p-value indicates that the differences in neck circumference (final-baseline) for the active participants were significantly greater than the difference for the control group. The box plots illustrate these differences.

Means and Standard Deviations

Level	Number	Mean	Std Dev
Active	12	2.2083	0.729518

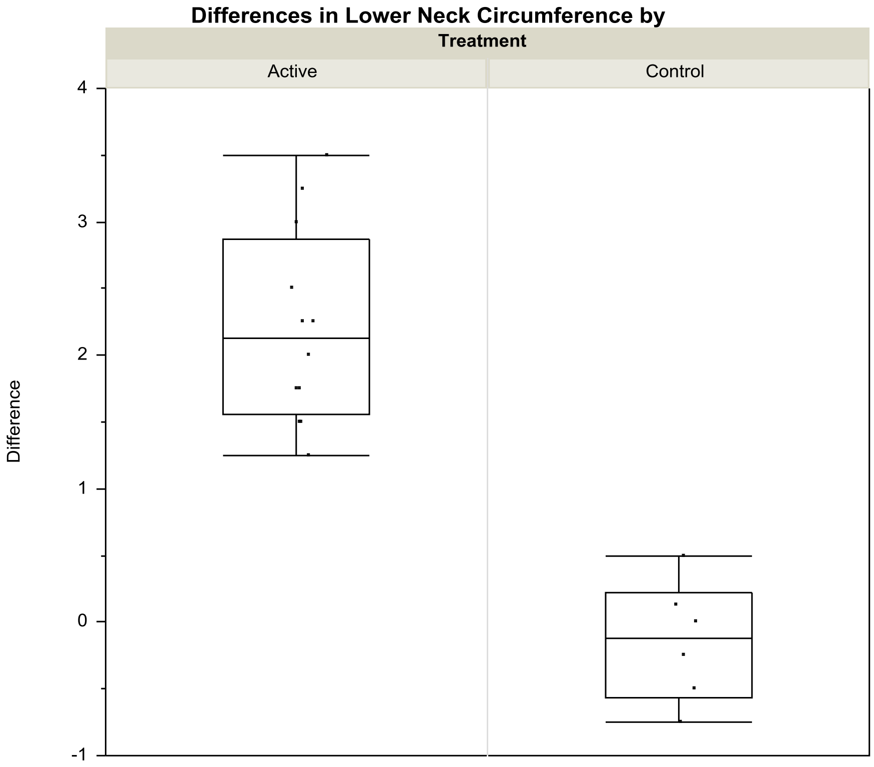
Level	**Number**	**Mean**	**Std Dev**
Control	6	-0.1458	0.450116

t Test

Control-Active

Assuming unequal variances

Difference	-2.3542	t Ratio	-8.42295
Std Err Dif	0.2795	DF	14.99863
Upper CL Dif	-1.7584	Prob < t	<.0001*
Lower CL Dif	-2.9499		
Confidence	0.95		



A paired t-test was also performed to determine if the lower neck circumference increased from baseline measures to final measures among the active participants. The highlighted p-value indicates that the lower neck circumference was significantly greater at final measures compared to baseline measures, which is also represented by the box plots.

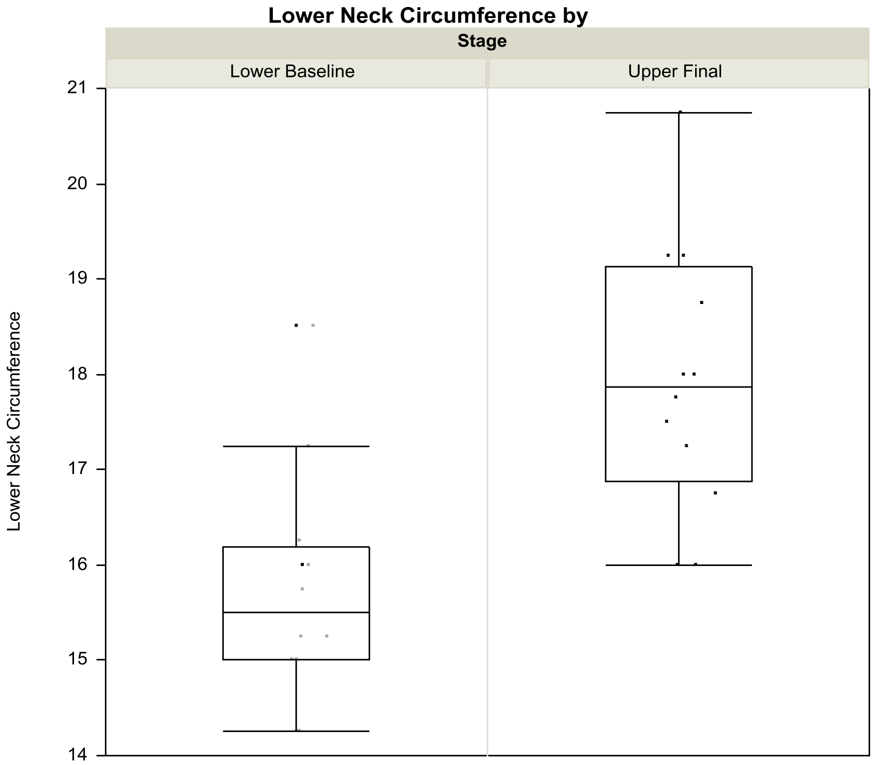
Mean and Standard Deviation

Mean	2.2083333
Std Dev	0.7295183
N	12

Paired t-Test (Final-Baseline)

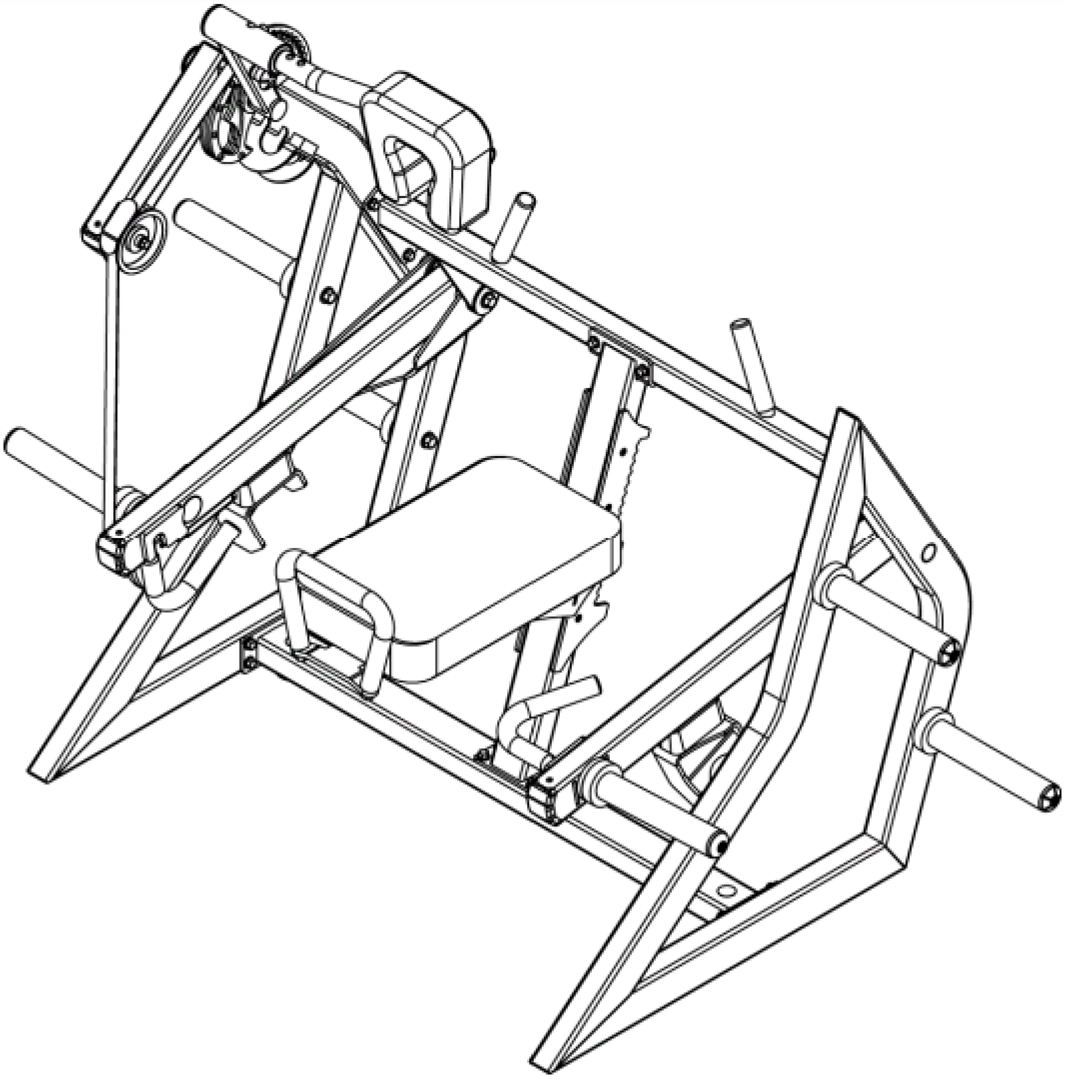
Hypothesized Value	0
Actual Estimate	2.20833
DF	11
Std Dev	0.72952

	t Test
Test Statistic	10.4862
Prob > t	<.0001*


Lower Neck Circumference by
Stage
Lower Baseline
Upper Final
Lower Neck Circumference
21
20
19
18
17
16
15
14

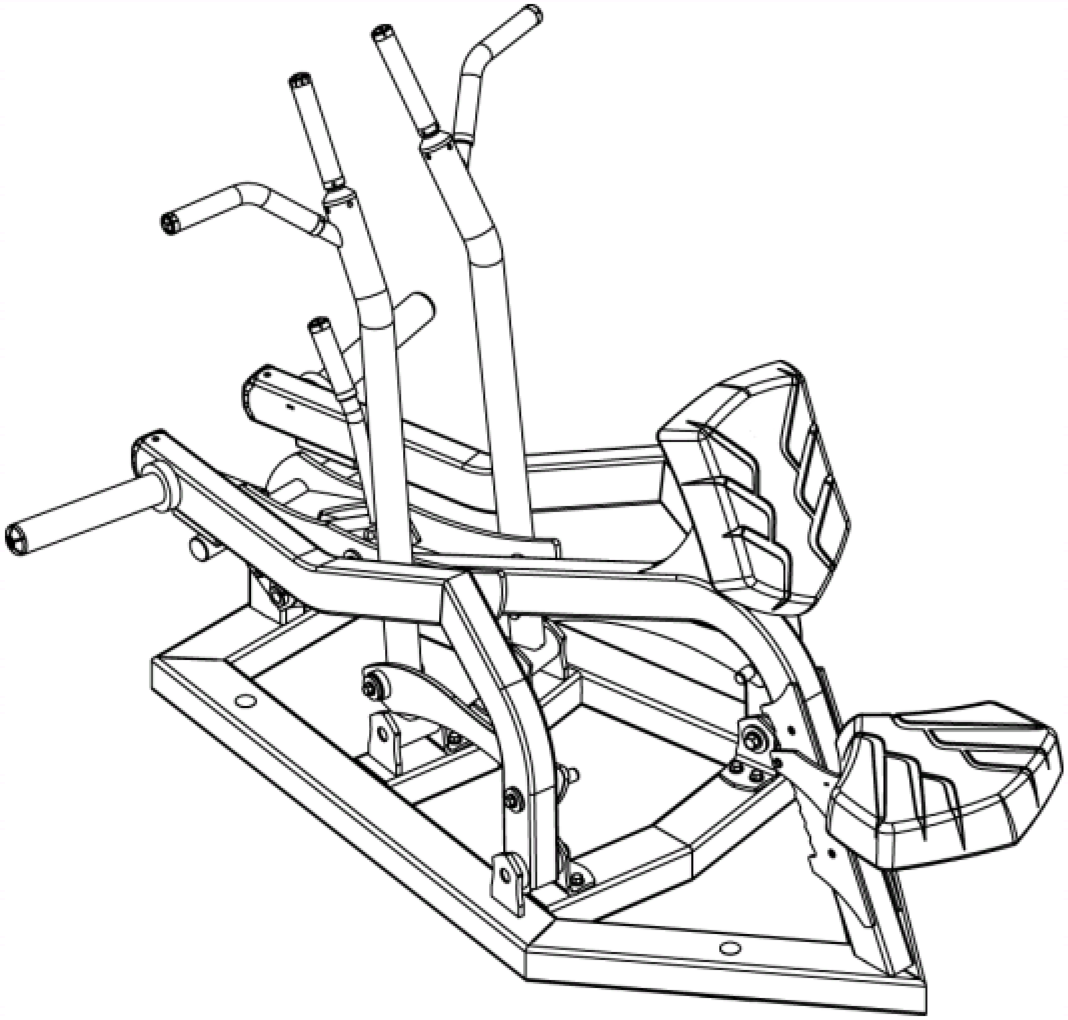
Head and Neck Machine/Shrug Machine

(Figure 28)



Isolateral Row

(Figure 29)



Power Rack

(Figure 30)

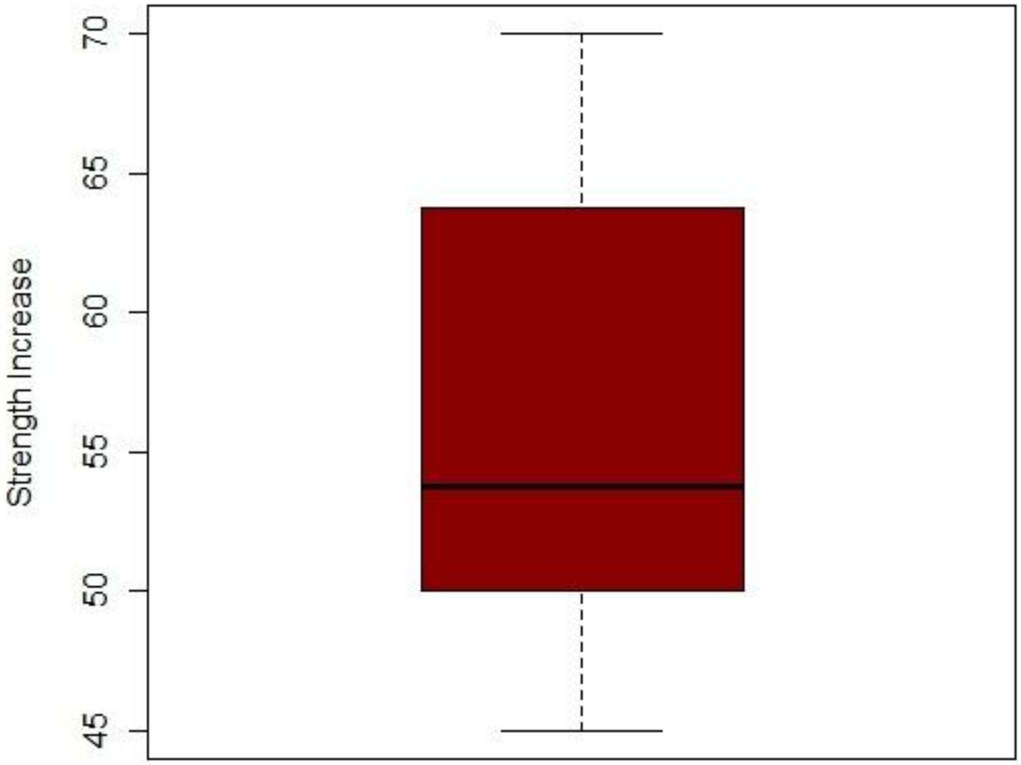
Extension

(Figure 31)

Permission granted to use likeness.

Neck Extension

(Figure 32)



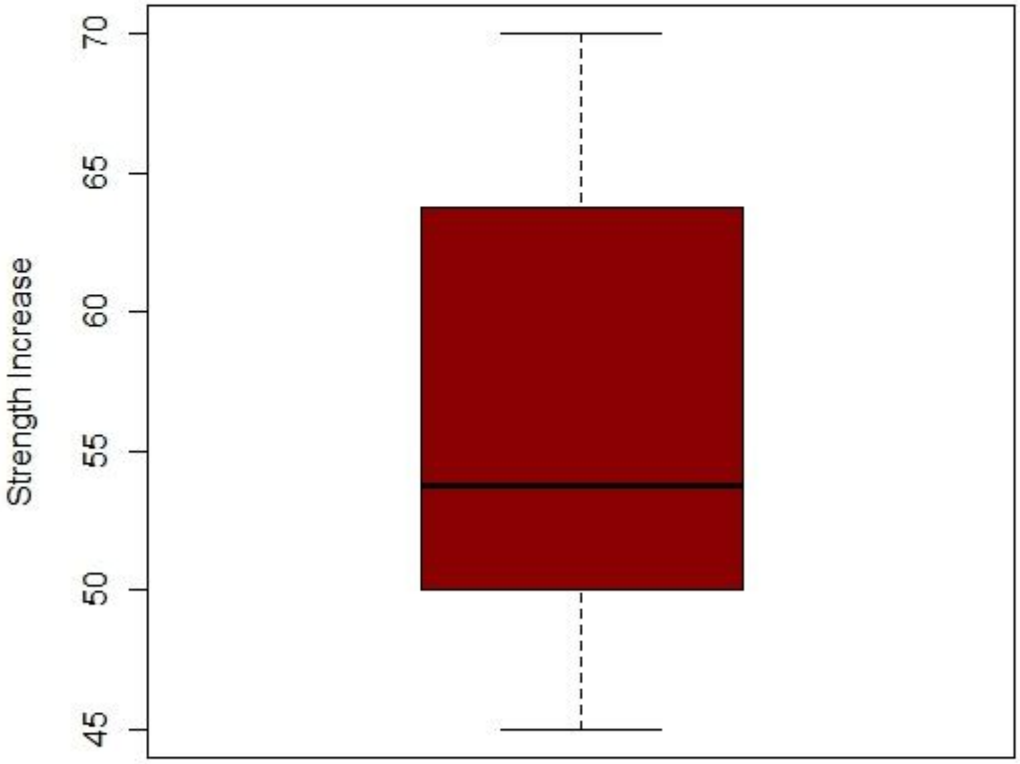
Neck Flexion

(Figure 33)

Permission granted to use likeness.

Neck Flexion

(Figure 34)



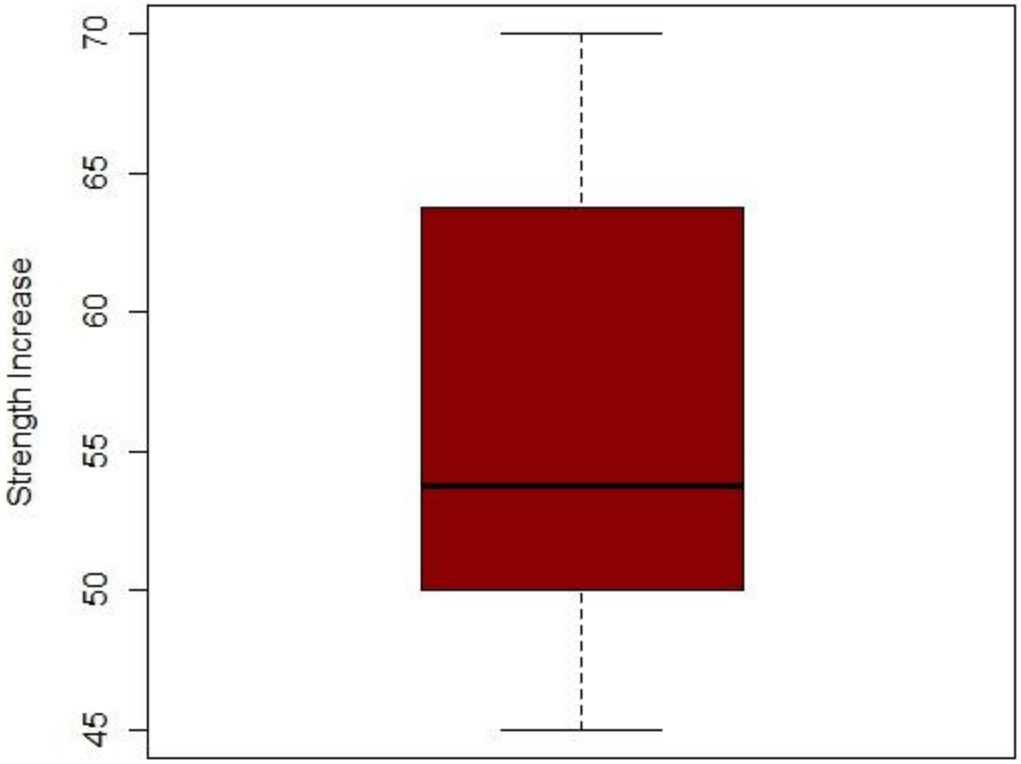
Lateral Flexion (right)

(Figure 35)

Permission granted to use likeness.

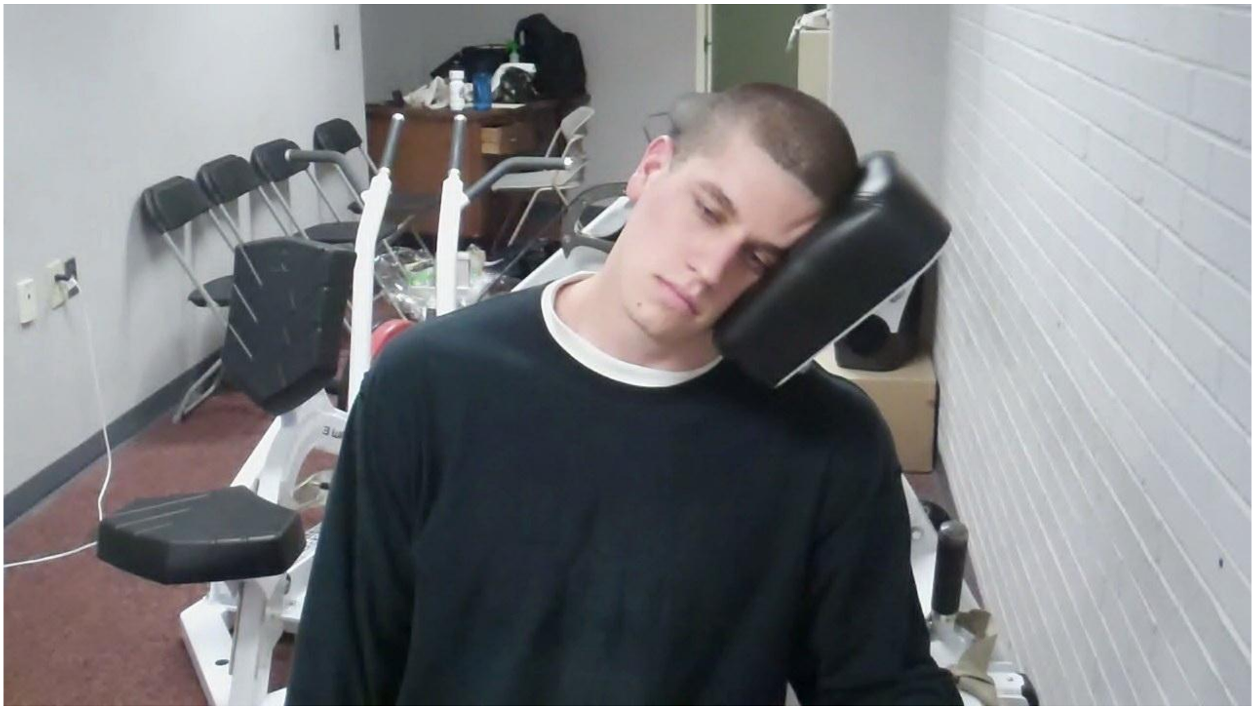
Neck Lateral Flexion (Right)

(Figure 36)



Lateral Flexion (Left)

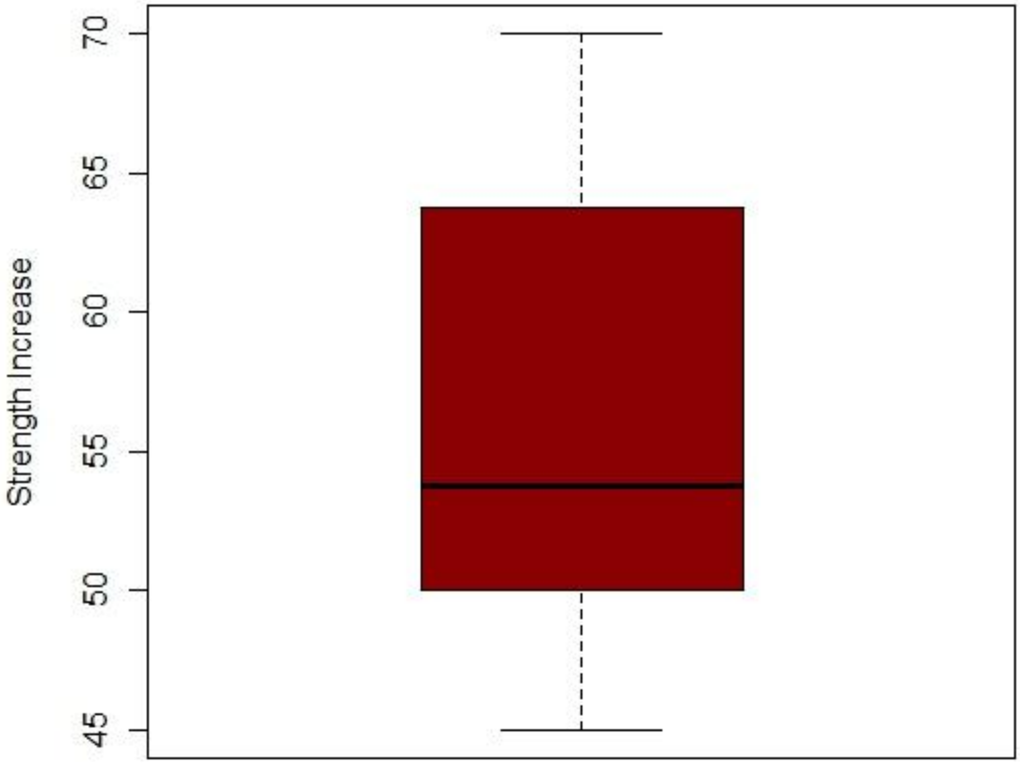
(Figure 37)



Permission granted to use likeness.

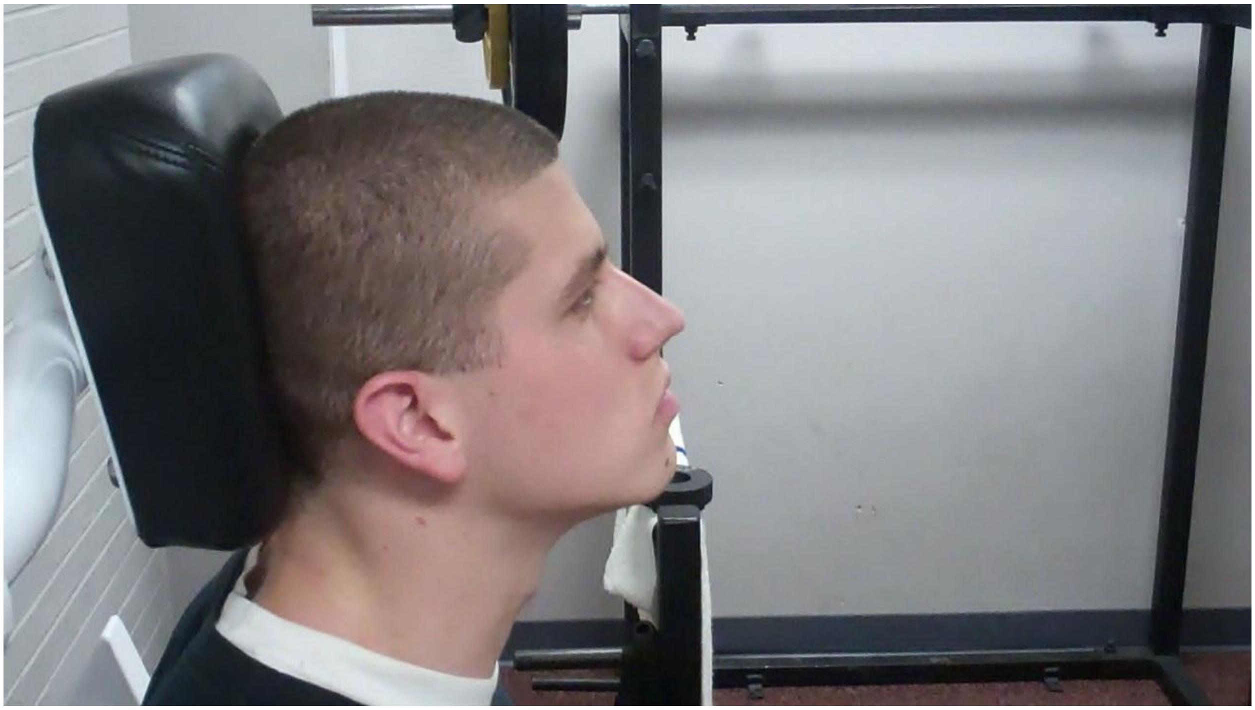
Neck Lateral Flexion (Right)

(Figure 38)



25 Degree Head Tilt

(Figure 39)



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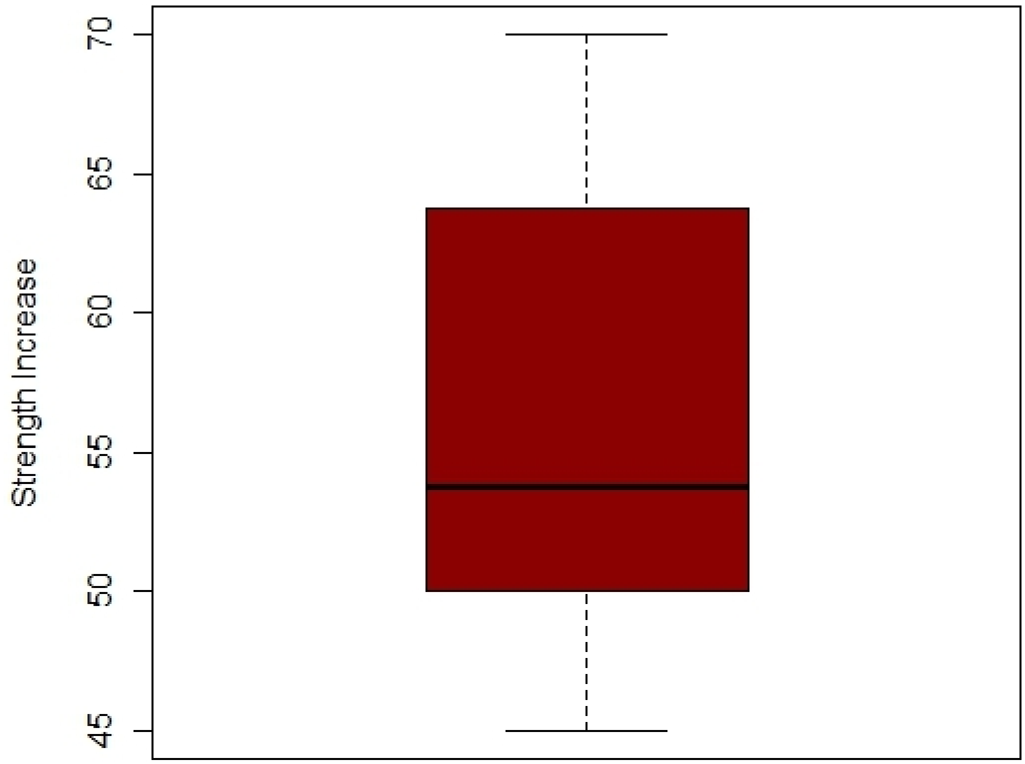
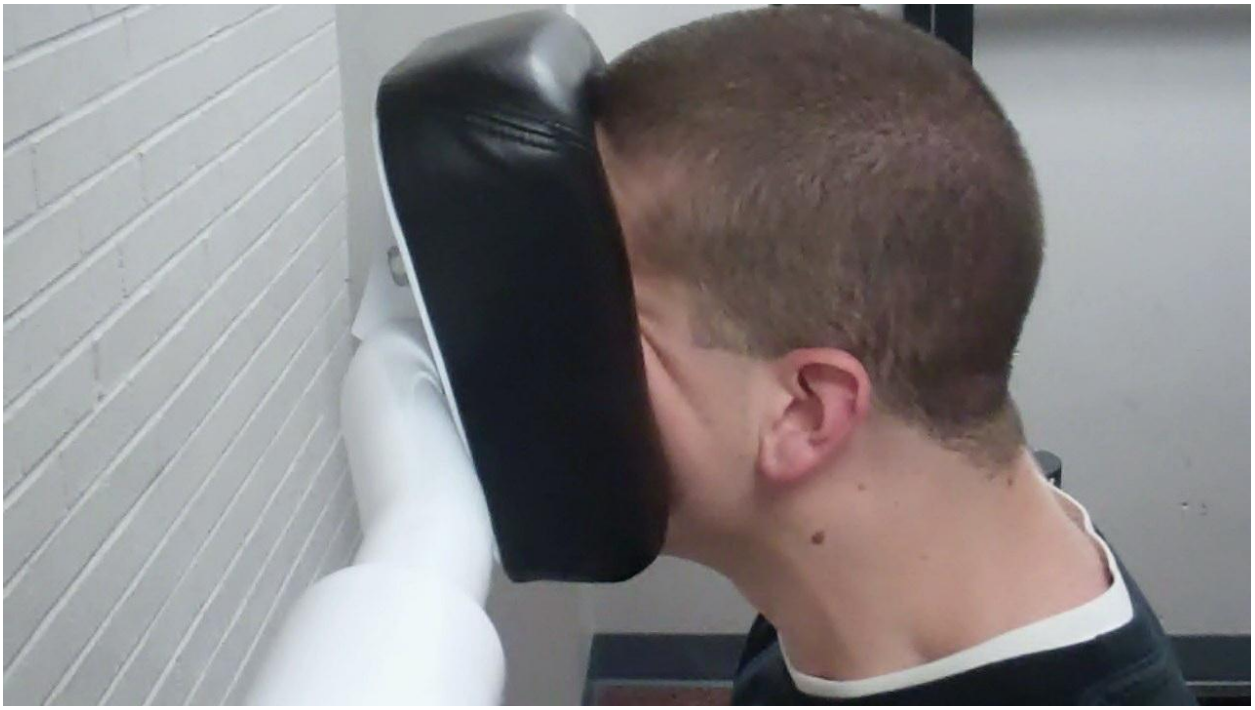
25 Degree Head Tilt

(Figure 40)



10 Degree Nod

(Figure 41)



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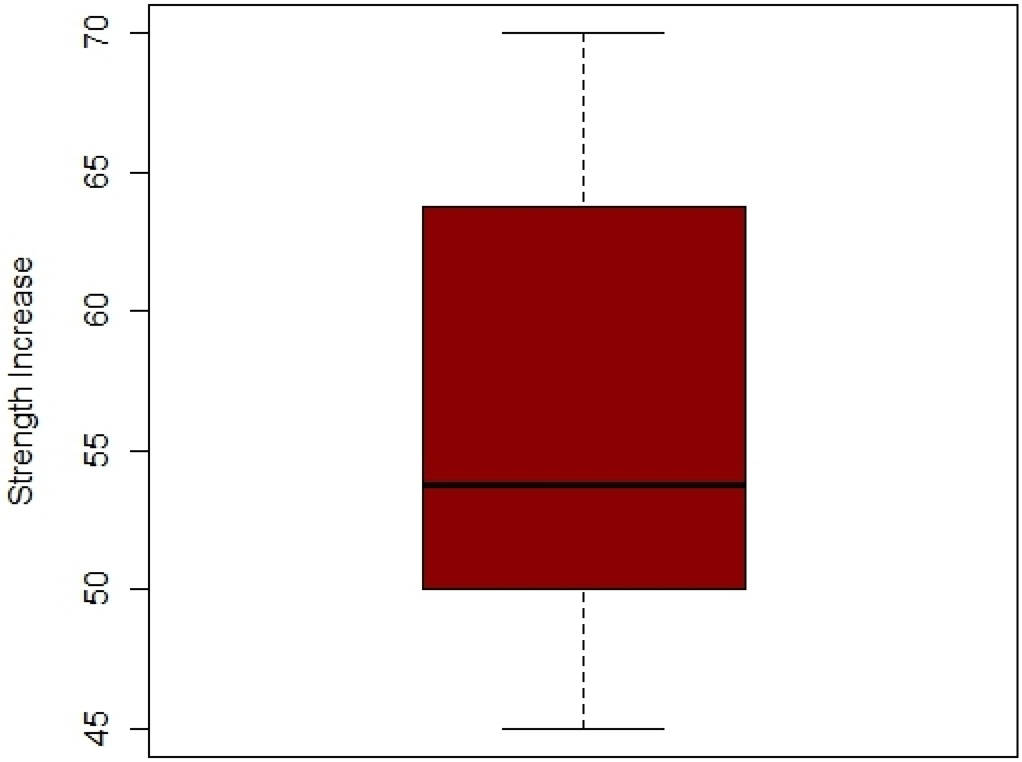
10 Degree Nod

(Figure 42)



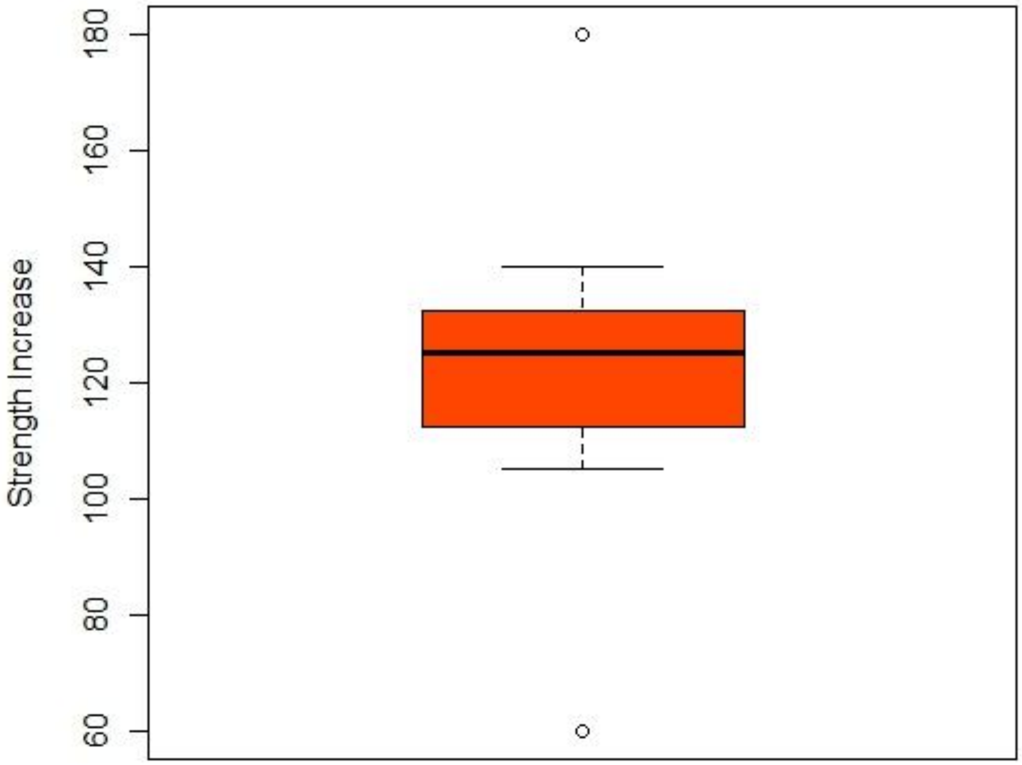
Bilateral Shrug

(Figure 43)

Permission granted to use likeness.

Bilateral Shrug

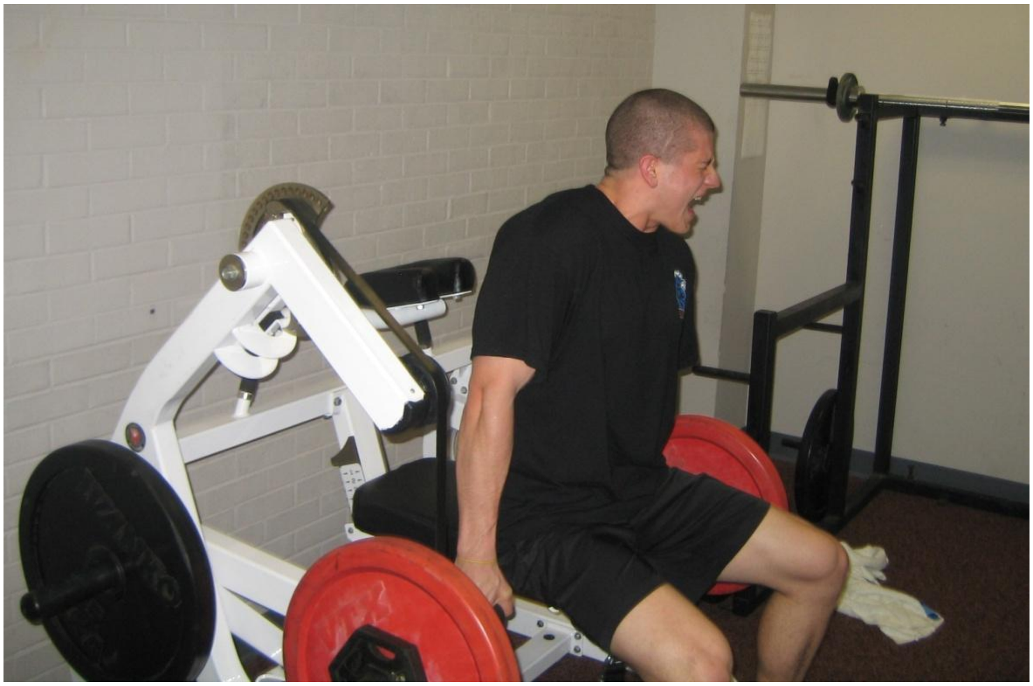
(Figure 44)



Unilateral Shrug (left and right)

(Figure 45 - top) & (Figure 46 - bottom)

Permission granted to use likeness.



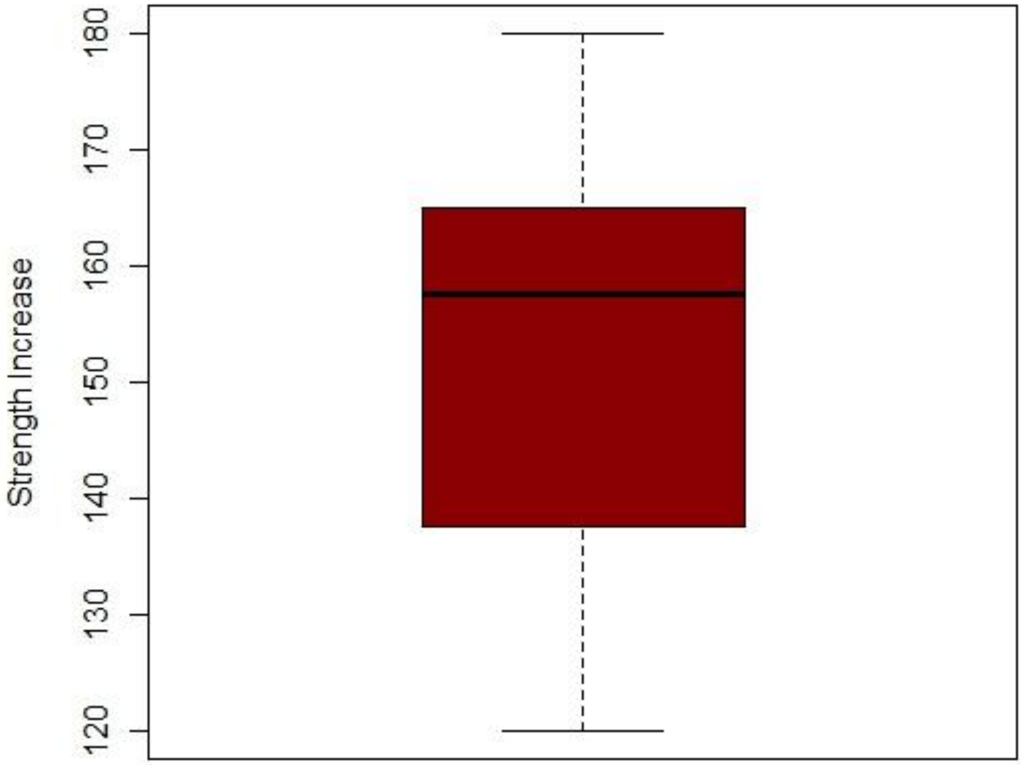
Neutral Grip Row

(Figure 47)

Permission granted to use likeness.

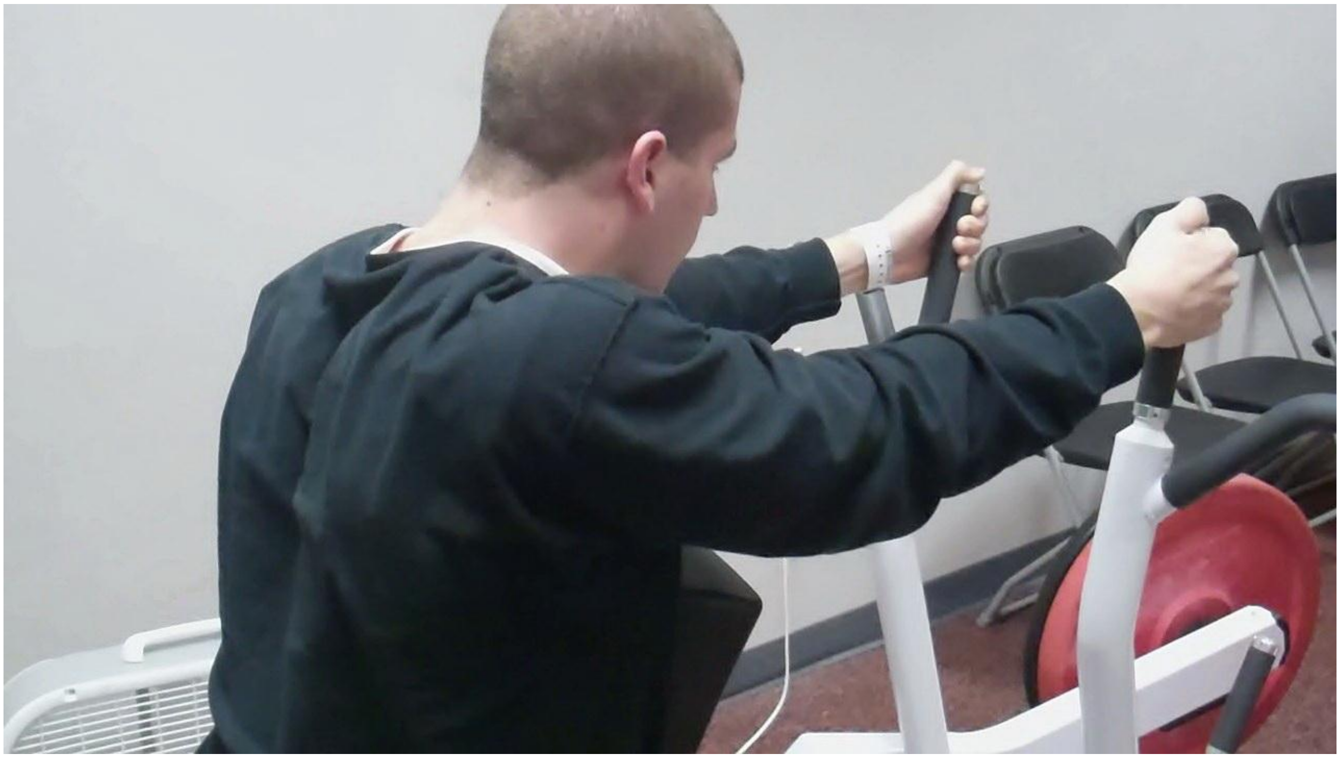
Neutral Grip Row

(Figure 48)



Scapula Retraction

(Figure 49)



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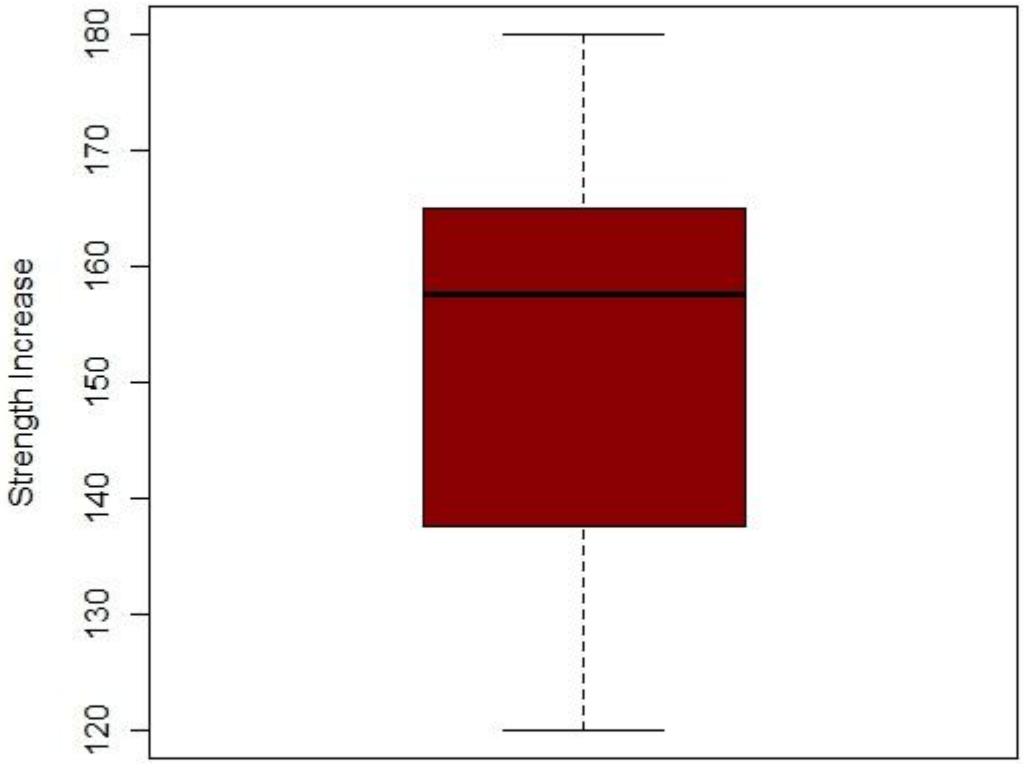
Scapula Retraction

(Figure 50)



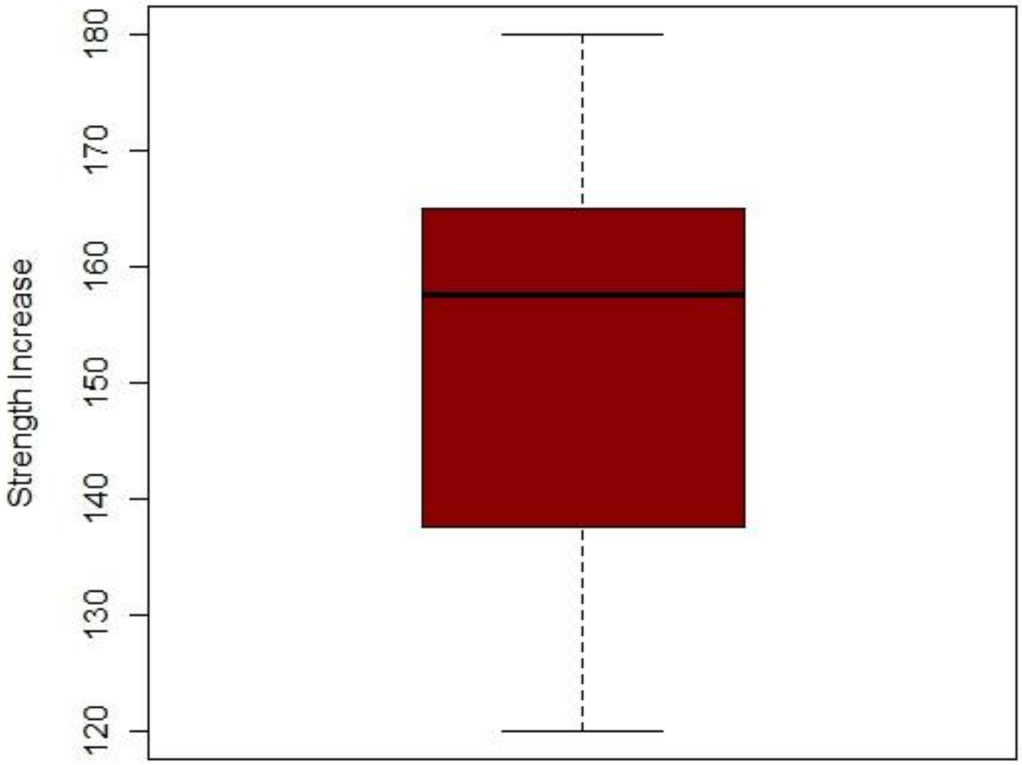
Scapular Retraction and Row

(Figure 51)

Permission granted to use likeness.

Scapular Retraction and Row

(Figure 52)



Levator Scapula Shrug (Week 1)

(Figure 53)

Permission granted to use likeness.

Levator Scapula Shrug (week 7)

(Figure 54)

Permission granted to use likeness.

(Figure 55)

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Chapter 6

Literature Review of Concussion Research Changes Over the Last Thirty Years

A review of relevant literature from the mid-1970s to the early 1990s reveals a critical emphasis on the importance of training the neck in injury prevention. In general, this study underscores the importance of protecting the athlete by means of practical intervention. For example, in 1974, Ohio State University implemented the first mandatory neck strengthening program in response to athletes' neck problems, including bracial plexus injuries, concussions, and cervical spine injuries. This athletic injury-prevention program was a collaboration between team physician Dr. Robert Murphy, head athletic trainer Bill Hill, and legendary head football coach Woody Hayes. Hill reported a one-inch increase in male neck circumference along with neck strength increases accomplished during the short "spring ball" training period. Neck injuries were reduced for the subsequent 1974 season, which prompted Dr. Murphy to declare neck strength training a requirement not only for the football team, but for every athlete competing in university varsity sports (Hill, 1975).

Similarly, in 1975, the United States Military Academy at West Point was conducting research concerning strength training and its effects on athletic performance. The study, dubbed "Project Total Conditioning," had a neck strength research component that examined how the neck and trapezius muscles responded to resistance training using the progressive overload principle. The study provided research which helped to prove that the neck reacts to progressive resistance training like any other muscle of the human body. Researchers found that the neck became stronger with increases in resistance, and neck circumference also increased in healthy male subjects. The head strength and conditioning coach during the research at West Point was

Dan Riley; fortuitously, Joe Paterno had the foresight to hire Riley as his head strength coach at Penn State University two years later (Peterson, 1975).

Penn State is an educational institution steeped in football tradition. Dan Riley was hired to protect the athletes who defended that legacy. In 1979, Riley's first move was to institute a year-round neck and trapezius strength program. The message delivered by hiring Riley was clear: any athlete involved in a sport which exposes the head and neck to potential injury should strictly adhere to a neck strengthening program. Riley's program made training the musculature of the neck and trapezius a top priority. In an article titled *Strength Training the Neck* (1981), Riley explains how the muscles of the neck were prepared for competition "the Penn State way." The article explains the dangers of ignoring the neck, why the neck should be trained, and when the neck should be trained. Riley expounds on why training the neck before a practice or game would put the athlete at a greater risk of playing with a fatigued neck. Penn State is known for producing some of the best linebackers in college football history, many of whom moved on to play football professionally. The linebacker position is known for its high-impact collisions. Without the proper preparation, these individuals would never survive the rigors of the sport. The sensitivity of the neck warrants expert attention if results are to occur without injurious false movements during training the neck (Riley, 1981).

The early success of Riley's program prompted an invitation for Riley to address the National Athletic Trainers Association in 1982. His topic was strength training *Program Organization and Proper Neck Development*; his agenda was to thoroughly explain and share his techniques and philosophy associated with protecting the athlete through properly training the neck, and his goal was that the athletic trainers attending the conference would come away with a better understanding of the importance of how the human neck must be protected. Riley emphasized the importance of strength training, remarking that “it is the responsibility of trainers and coaches to provide the athlete with a program that produces the best results, consumes the least amount of time, and best prepares the athlete for competition.”

Riley described the two rules observed for athletes’ developing neck muscles at Pennsylvania State University: (1) never exercise neck muscles before a game or practice, and (2) never perform an isometric or static contraction for the neck muscles. Athletes will develop maximum gains in strength in the least amount of time if proper attention is paid to rules stating that: (a) exercise must be in the full range; (b) muscles must be allowed to raise the weight; (c) lowering of weight must be emphasized; (d) athletes must exercise to the point of momentary muscular failure; and (e) exercise must be supervised (Riley, 1981).

During this period, there was great concern for cervical spine injuries and not only a collegiate mandate. The Atlanta Falcons, a franchise of the National Football League, were disseminating knowledge about protecting the athletes from injuries to head and neck. George Dostal, the director of strength training for the Falcons in 1983, wrote a very descriptive article in the *Journal of Strength and Conditioning Research*. In the informational article, Dostal takes a painstaking approach to training the neck, cautioning coaches at all professional levels not to neglect the most important part of the body because of lack of knowledge or insufficient funds. Through detailed guidance and instruction, including a descriptive pictorial, Dostal makes a compelling case to include neck strengthening in every coach’s program. Education and knowledge seem to be the message Dostal is conveying to coaches, athletic trainers, and team physicians—the need to protect the most vital region of the body through strength and size increases.

The impetus for Matt Brzycki's (1986) article entitled *Strengthening the Neck: Reducing Risk of Cervical Injury* was the education of the individuals charged with ensuring an athlete's safety. In the article, Brzycki emphasizes the importance of increased neck strength and size for athletes competing in competitive sports. The article is grounded in Brzycki's guidelines and "hands-on" approach, which illustrates how to prudently and practically train the muscles of the neck and trapezius. The reasoning for why an athlete should strengthen the neck is fully clarified by Brzycki, who asserts that "a thick muscular neck is essential to reducing cervical spine injuries." The muscles of the neck surround the cervical spine and protect it from structural failure. An increase in muscle strength from within the neck helps reduce head and neck movement exerted by outside forces. Brzycki is currently a coach at Princeton University, and many of his former athletes have become successful brain surgeons. Therefore, he has trained the heads and necks that have protected the brains of future brain surgeons.

Similar research was conducted by Dr. Stephen Reid at Northwestern University, who examined how to prevent head and neck injuries in athletes competing in collegiate sports. In a 1981 article titled *Prevention of Head and Neck Injuries in Football,* Dr. Reid and his son investigated the background and causation of head and neck injuries in football. The article discusses how athletes can better protect themselves and asserts that simply being well-conditioned reduces an athlete's probability of injury. Organically, the head and neck protects itself by several means, one of which is the soft tissue that supports, connects and surrounds the body. The reduction of injury is accomplished with tendons and ligaments that restrict unwanted cervical spine movement. The muscles encompass the head and neck, surrounding the cervical spine with protective tissue. Thus, a properly prepared athlete can enhance his or her body's ability to reduce injury. In the article, the Reids also look to programmed movement, or practicing responses to impact, to reduce injury by allowing the body to respond much quicker. The reduction in lag time would give the body needed milliseconds to prepare for impact.

Research into head and neck protection continued across the globe into the 1990s. For example, Japanese researchers conducted several studies examining the subject of how the neck responds to resistance training. Meada (1994) looks at the results of dynamic neck training over an eight-week period. The study reveals that the neck can become stronger and male subjects can gain neck girth. This is very significant because a larger neck dissipates more energy than a smaller neck; a stronger neck is also less compliant with outside forces directed at the head and neck region. Additionally, another study from Japan that exemplifies the interest researchers have with regards to properly training the neck is the Tsuyama study. In 2006, Tsuyama observed three different combinations of neck resistance training and how the combinations elicited different adaptations in research subjects. The study determined that a combined neck muscle training protocol is effective for developing the neck extensor muscles but not the muscles of the head.

Both of the Japanese studies cite Brzycki's research about neck strength. Significantly, both studies mirror Brzycki's *Strengthen Your Neck for Function & Safety* (1998), published thirteen years after *Strengthening the Neck: Reducing the Risk of Cervical Spine Injury* (1985). In the 1998 article, Brzycki .is unyielding in his conviction in—and confidence regarding—the protective benefits of neck strength and neck size. He warns of the dangers of neglecting the most vital part of the body: the head and neck.

In 1992, the Washington Redskins, another National Football League franchise, believed there was a direct correlation between neck injury and the level of neck strength. Dan Riley, now the head strength and conditioning coach for the Redskins, brought with him the same philosophy that had driven a very successful Penn State program during his tenure there: the athlete’s health and well-being is the first priority. In his article titled “Strengthening the Neck,” Riley states that “the primary objectives of the Redskins’ strength training program are to prevent injuries and to enhance the player’s strength, speed, power and explosiveness.” This article is not unlike Riley’s other publications explaining neck strength importance. He still espouses the benefits of a well-rounded strength program which includes an emphasis on training the neck in order to reduce neck injuries. In this article, Riley expands on the skills of manual neck strength training and adds a lateral flexion component to enhance the protection of the athlete. This article also differs from former Riley articles in that he advises coaches not to spend thousands of dollars on new facilities and new equipment; instead, he points out that the most vital pieces in any weight room are the units that address the neck and trapezius strength of the athletes. Riley’s vigilance and steadfastness on the subject of training the neck are evident when he says that “if we only had fifteen minutes to train our players, we’d spend that time strengthening the neck.” The ultimate goal is to have players return with gratitude for such protection from injury—and, importantly, with their brains intact.

Robert Cantu, M.D., addresses protecting the human brain in his 1992 research article, *Cerebral Concussion in Sports.* Cantu states several key points regarding the mechanism of injury for concussions and head and neck injuries. Concussion management, concussion awareness, and return to play guidelines are identified and discussed in this study. What differentiates Cantu’s study is that there are proactive intervention components that are designed to aid the athlete before the first concussion occurs. Cantu asserts that “the best prevention is a strong neck and wise use of the head. Cantu is one of the few published medical doctors who realize there are proactive measures to reduce the likelihood of becoming concussed (Cantu, 1992).

Dr. Cantu has now become the exception rather than the rule. Few recent research studies on concussions present an antidote to the problem being examined. Observation and studying the causation of the concussion is very important, but it does not address solving the concussion dilemma. The literature seems to suggest a paradigm shift on the subject of concussion reduction. The change came about in the mid-2000s, when knowing how someone concusses became more prominent in the literature then interventions to prevent the concussion. Medical doctors, athletic trainers, strength coaches, and biomechanical researchers appeared to collaborate less than in the past. Data collection about the concussive event became (and is still) the standard in present day research.

For example, the Athletic Trainers Association’s (2004) position paper addressing the management of concussions contains a preponderance of information concerning concussions. There are instructions on awareness, recognition, return to play decision-making, and when to disqualify an athlete from competition—completely unlike the 1974 article written by Hill, the head athletic trainer for Ohio State University, thirty years before this document existed, which spoke to proactive interventions for reducing injuries to the head and neck and focused on strategies to avoid injuries. There is an abundance of concussion information, but no real interventions to provide the athletic trainers working in the “trenches” with viable contingencies for preparing and protecting their athletes.

In a biomechanics literature review of head injuries written by Wayne State University, researchers examine the head injuries resulting from sports, military service, and transportation crashes, along with everyday head injury occurrences (Hardy, 1994). Entitled *Literature Review* *of Head Injury Biomechanics*, the review takes meticulous care in explaining numerous injury scenarios, outcomes, and the biomechanics of the injury. The review extracts information from over 111 research studies which address head responses to mechanical impact, a wealth of information which allows researchers to hypothesize about brain injury mechanics, brain injury criteria, and mathematical models of head injury. These theoretical measures of head kinematics give researchers head and brain tolerances during impact—but how does that help prevent the real injury in real-world situations? Several past research studies have shown that head kinematics can be changed in a positive manner, thus reducing the severity of injury to the head and brain. The amount of research reviewed in this study gives great insight into how injuries can occur—but, unlike research completed in prior years, the Wayne State researchers fail to recommend a plausible solution for any of the injury scenarios and overlook the possibility of disseminating valuable knowledge about how knowledge of kinematics can be used to reduce injury possibilities.

Data collection is paramount in research. Knowing how much stress and strain the body can withstand without injury is very important. In a study by Guskiewicz (2007), collegiate football players' head impacts are observed and measured at low and high magnitude impacts. A helmet telemetry system is used to record collision data, and the validity of such measurement devices is also examined. The researchers look for an injury threshold, with the measurement of g-forces as a quantity of evaluation. The amount of g-force tolerance for the brain was thought to have a ceiling of 90 g-forces, and the recipient would exhibit signs and symptoms of concussion. The most important finding of this study was that players were able to withstand g-forces greater than 90-g and still pass basic functional, balance, and neurological tests within 24 hours of impact. The observation and gathering of information while witnessing concussive events is necessary for the furthering of science. Unlike some studies from the 1970s, 1980s, and 1990s, once the dilemma was identified and deemed not to be in the best interest of the research participants, a solution was suggested to reduce further possibility of injury to the participant. More research is almost always a good idea to push the envelope of knowledge. Brain tolerances to impact are important, but knowing how to increase brain tolerances to impact must be a balance of research and remedy.

Prevention, by definition, is the action of stopping something from happening prior to the actual event. In a 2004 study titled *Unreported Concussion in High School Football Players – Implications to Prevention* , McCrea investigated the frequency of unreported concussions and how to estimate the actual number of concussions in high school football. The research looks at the possible ramifications of unreported concussions and the unknown damage of the cumulative impacts which go unreported on a concussed athlete. A look back to the studies from 1970 to the 1990s would provide instructions and directions for how to actually intervene and prevent the damage McCrea describes. If the researcher's assumption is that there are many concussions that go unreported, then there should be a contingency plan for concussion prevention. If all football players are likely to sustain unreported concussions, then logic would dictate that all football players should be prepared as if they all have unreported concussions. Early research did just that: Hill, Riley, and Cantu all provide proactive measures to ward off injury.

Another type of prevention is legislative, both in government and in changes to the rules of the game (Adler 2011). The Lystedt Law was enacted in the state of Washington in response to the tragedy that befell Zack Lystedt, a high football player who suffered an undocumented concussion in the first half of a football game. Zack played the second half and suffered a concussion which caused brain swelling, a phenomenon now known as Second Concussion

Syndrome. This caused Zack to suffer brain damage and nearly die from the second concussion. The Lystedt Law states that if an athlete exhibits signs and symptoms of having suffered a concussion, he or she should be removed from the game and not allowed to return. In *Changing the Culture of Concussion: Education Meets Legislation,* Adler declares that "this law would prevent preventable brain injuries." Although a very important law and a major step in the right direction, the law only protects athletes if the coaches, officials, and athletic trainers involved actually follow the letter of the law. This article represents a type of prevention that requires adherence by the participants in order for the law to be effective, while the articles written in the past three centuries relay on prudent preparation before the athlete ever takes to the field of competition.

The majority of sports are played by children under the age of14 years old, and children make up 70 percent of the athletes playing the sport of football. In the 2013 study titled *Head Impact Exposure in Youth Football: Elementary School Ages 9-12 Years and the Effort of Practice Structure*, Cobb et al. examine how to apply their data to improve the safety of youth football. The study is well designed and well intentioned. The researchers' anticipation of data collection and then the extrapolation for examination of content is promising. If this study were conducted, for instance, by Dr. Reid of Northwestern University in the 1970s and 1980s, there would have been a conclusion section to their research explaining what occurred during the study; the difference is that Dr. Reid would have looked for a solution or possibly suggested that, if youth football cannot be conducted safely, then we should remove the element of contact until all questions of safety can be answered.

During the last thirty years, the individuals conducting concussion research changed. Peer-reviewed journals welcomed the individuals that actually administered the research being conducted. Research is not immediately applicable when compared to studies conducted in the 1970s and 1980s. Following the timeline, there were research-based interventions and contingencies that gave people tools to protect their athletes and ensure safety. That “more research is needed” is a very common conclusion of recent research; it is also a conclusion which offers no protocol to change the outcome of a real-life situation, such as a concussion epidemic. There seems to be a void in the way research is disseminated to the professionals who might benefit from the present day research, creating adisconnect between the lab and the training room which deprives professionals in the field of relevant knowledge.

It may be that there is a different generation of researchers who see data collection as the end of the research study. An assumption could be made that there is less collaboration among medical doctors, athletic trainers, coaches, team physicians, and researchers. In 1974, Bill Hill had the skill set to safely and properly train the human neck. Does the separation between researcher and real world professional account for a loss of skill sets that were common place in the 1970s into the 1990s? This review of a literature illustrates a void which suggests significant change in the way research is conducted and circulated. Research should look for resolutions as well as results.

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Chapter 7

Conclusions

A standardized head and neck resistance training protocol is desperately needed and should be adopted nationwide. As concussion rates continue to increase, a preponderance of evidence is mounting which shows that stronger, larger head and neck muscles lower the susceptibility of an athlete to concussion.

Simple physics tells us that a larger area will disperse more energy over that larger surface area. Viewing the human neck as a cylinder, when that cylinder's circumference increases there is concomitant increase in its ability to dissipate larger forces from impact and translate that energy into heat. Instead of managing concussions better, we should prepare our athletes better. Not having a concussion would be much better for an athlete than managing one.

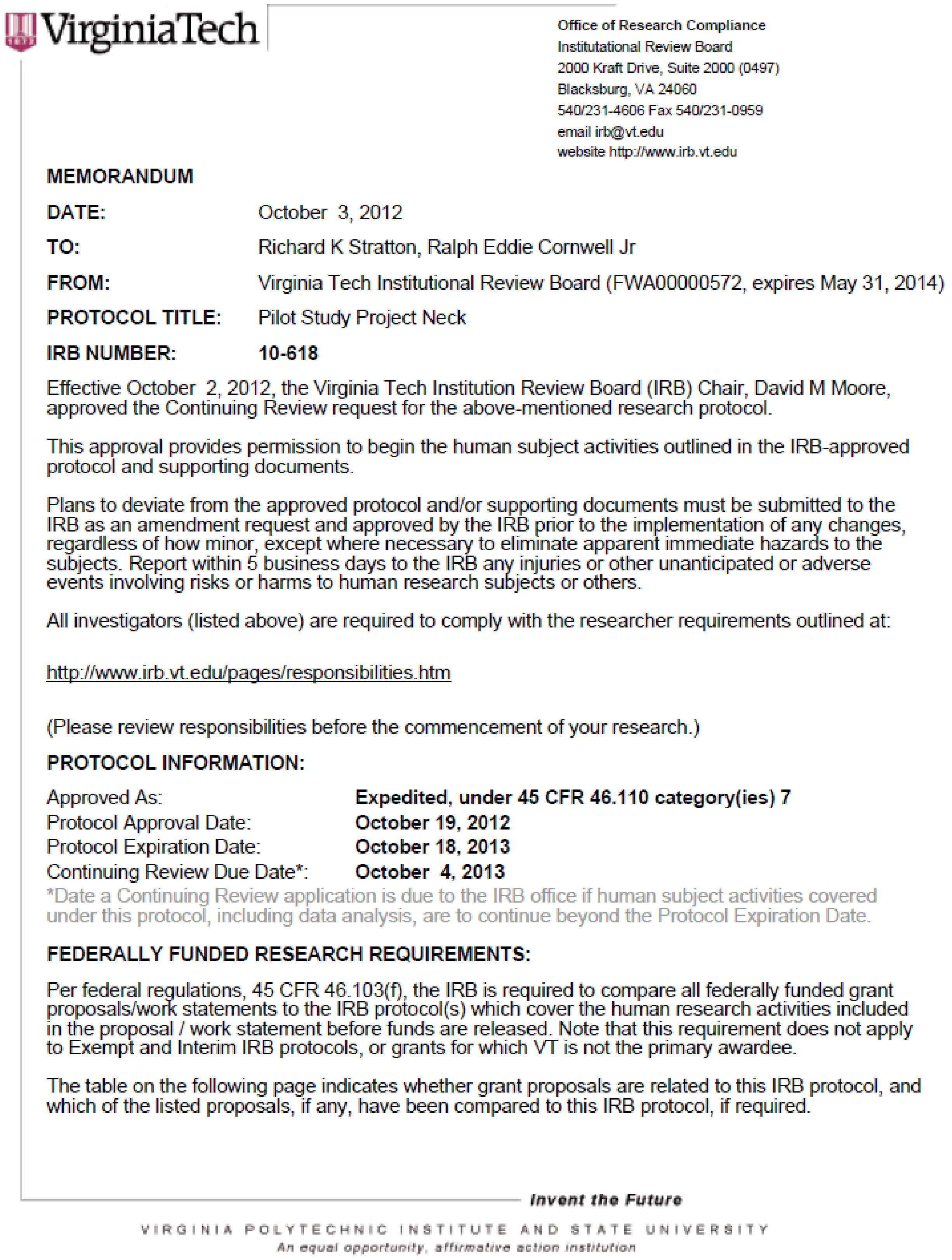
The results of this study demonstrate that females can increase neck and upper body strength safely and without significant muscular size gains. Conversely, the male participants increased muscle size and strength. During this study, the females did not exhibit the hypertrophy of their male counterparts.

Despite the enormous amount of concussion research, the scientific community is still looking for answers to alleviate this debilitating condition. If we don't have an antidote for concussions, it would be intuitive, logical or just common sense to prepare individuals that are likely to be exposed to concussive forces. Prudently preparing those that might experience a concussion would do no harm or cause long lasting effects. The results of the study shows male and female alike can efficiently and effectively train their body to ward off concussive forces.

At the completion of the study, our collected data revealed tremendous strength increases that should translate into more resilient athletes who can tolerate the forces, both concussive and sub-concussive, of their particular sports.

It should be noted that there were no adverse effects from training the head and neck during this study.

Appendix A



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MEMORANDUM

DATE: October 3, 2012
TO: Richard K Stratton, Ralph Eddie Cornwell Jr
FROM: Virginia Tech Institutional Review Board (FWA00000572, expires May 31, 2014)
PROTOCOL TITLE: Pilot Study Project Neck
IRB NUMBER: **10-618**

Effective October 2, 2012, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the Continuing Review request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As: **Expedited, under 45 CFR 46.110 category(ies) 7**
Protocol Approval Date: **October 19, 2012**
Protocol Expiration Date: **October 18, 2013**
Continuing Review Due Date*: **October 4, 2013**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

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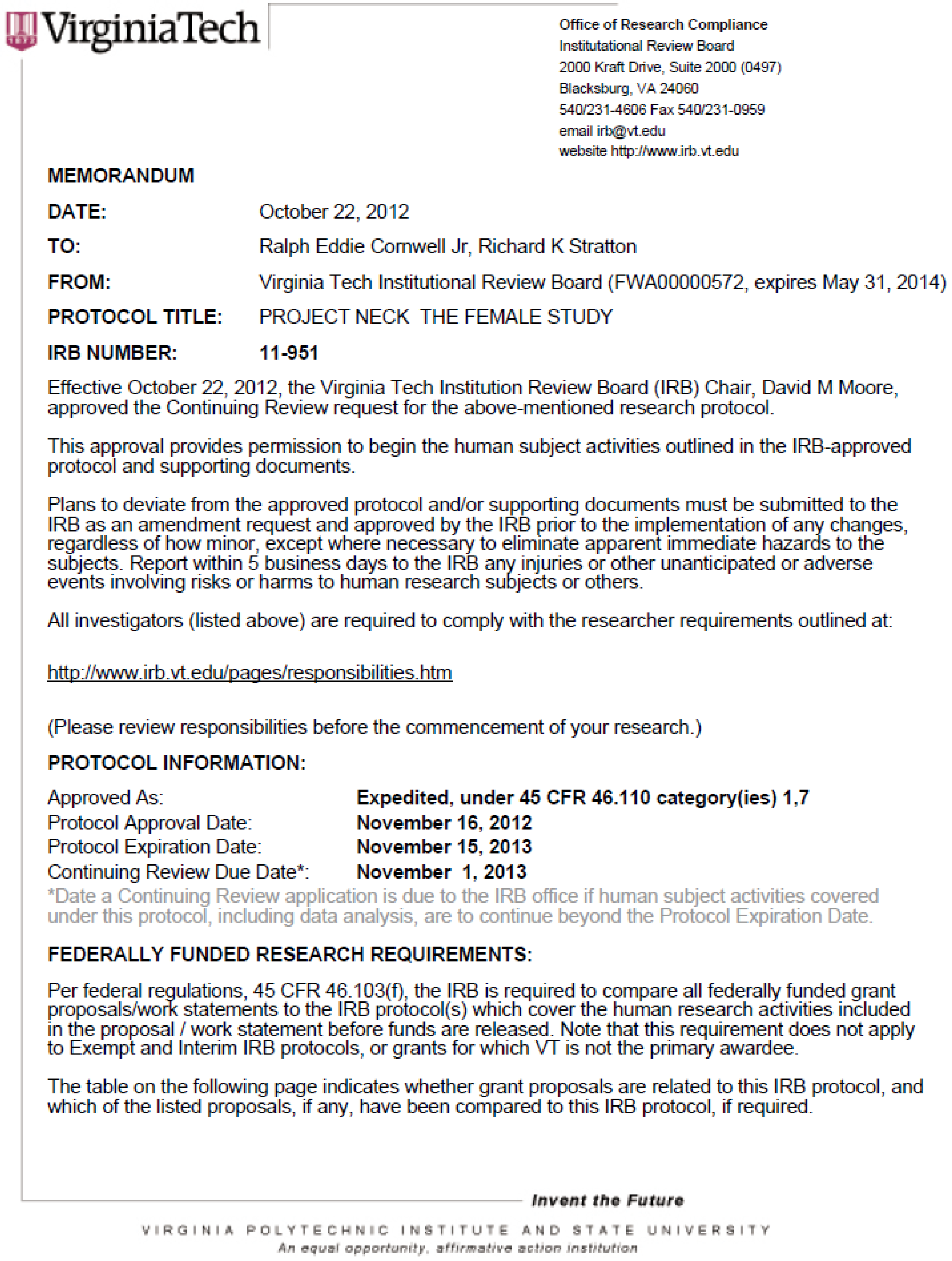
Date*	OSP Number	Sponsor	Grant Comparison Conducted?

* Date this proposal number was compared, assessed as not requiring comparison, or comparison information was revised.

If this IRB protocol is to cover any other grant proposals, please contact the IRB office (irbadmin@vt.edu) immediately.

Appendix B



VirginiaTech

Office of Research Compliance
Institutational Review Board
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, VA 24060
540/231-4606 Fax 540/231-0959
email irb@vt.edu
website http://www.irb.vt.edu

MEMORANDUM

DATE: October 22, 2012

TO: Ralph Eddie Cornwell Jr, Richard K Stratton

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires May 31, 2014)

PROTOCOL TITLE: PROJECT NECK THE FEMALE STUDY

IRB NUMBER: **11-951**

Effective October 22, 2012, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the Continuing Review request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 1,7**
Protocol Approval Date:	**November 16, 2012**
Protocol Expiration Date:	**November 15, 2013**
Continuing Review Due Date*:	**November 1, 2013**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Invent the Future

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Date*	OSP Number	Sponsor	Grant Comparison Conducted?

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If this IRB protocol is to cover any other grant proposals, please contact the IRB office (irbadmin@vt.edu) immediately.