A Golf Fitness Program to Develop Clinical Skills in Student Physical Therapists: A Program Proposal, Development and Recommendations for Implementation.

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A GOLF FITNESS PROGRAM TO DEVELOP CLINICAL SKILLS IN STUDENT PHYSICAL THERAPISTS: A PROGRAM PROPOSAL, DEVELOPMENT, AND RECOMMENDATIONS FOR IMPLEMENTATION

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This Scholarly Project, submitted by Derek Ferebee, Bradyn Just, Kathryn Puklich, Aaron Seefeldt, and Clair Ward in partial fulfillment of the requirements for the Degree of Doctor of Physical Therapy from the University of North Dakota, has been read by the Faculty Advisor and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

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ABSTRACT

PROBLEM: Golf is a fast-growing sport that is played by people all around the world of all ages and skill levels. The complexity of the golf swing and varying skill levels of participants leads to increased risk for injury. Acute and chronic musculoskeletal injuries can occur to the lumbar spine, shoulders, wrists, and elbows. The injuries are common among amateur, intermediate, and professional golfers. Studies show that the overall rate of injury in golfers is 15-20%. This is a surprisingly high amount of injuries for a low-impact sport. Physical therapists are an important healthcare provider for individuals with musculoskeletal injuries. The educational curriculum for physical therapists provides opportunities to perform various examination and treatment skills although much of this practice is performed on classmates with negligible musculoskeletal limitations. A golf fitness program performed by physical therapist students under the direction of a licensed physical therapist could minimize the risk of musculoskeletal injuries to golfers with evaluation of golfing movements and general fitness recommendations. Therefore, a golf fitness program could provide a needed community service and help develop the examination and communication skills of future physical therapists.

PROCEDURE/METHODS: A review of multiple research databases (DynaMed, MD Consult, InfoPOEMS, PubMed, CINAHL, etc.) was used to identify current literature related to optimal golf swing mechanics and common golf related musculoskeletal injuries. Physical therapy and exercise science literature was obtained to identify musculoskeletal limitations in range of motion and strength that are commonly linked to golf-related injuries. The golf injury information and optimal swing mechanics were developed into a comprehensive pre-golf musculoskeletal screening process. The screening process was presented to a small group of young adult golfers for feedback and recommendations. The small group feedback was incorporated to develop a final pre-golf evaluation form and process that can be used by the UND Department of Physical Therapy as a community service activity for first- or second-year students in the professional DPT program.

RESULTS: The final product is a comprehensive, pre-golf fitness and swing evaluation program. The program may be implemented in the spring semester when golfers are preparing for the upcoming summer season. The popularity of golf and high number of golf related injuries should drive interest in the program. The benefits to the current DPT students and local golfing community are symbiotic. Physical therapist students participating in the program may use this opportunity to enhance their evaluation and communication skills while golfers benefit from the comprehensive golf assessment program.

KEYWORDS Golf fitness program, Community based service learning, Physical therapy

INTRODUCTION/BACKGROUND

Physical therapy education began the transition from a master's of physical therapy to a doctor of physical therapy degree in 2006. The entry level doctor of physical therapy became the required degree for all accredited entry level programs in 2015. The didactic portion of the DPT education was extended which increased the time between classroom instruction and clinical application of the content. The prolonged time between learning a skill and applying that skill to a patient/client may result in decreased proficiency. Physical therapy educational programs have developed community-based service learning activities to provide students with opportunities to apply their clinical skills and develop professional behaviors earlier in their professional education. Community-based service learning (CBSL) is an educational strategy of structured teaching and learning experiences that includes learning objectives, preparation, and reflection. The CBSL activities are often related to wellness and prevention activities for community members in the local area.[23] Wise et al (2013)[23] demonstrated significantly increased self-assessment scores on altruism, compassion/caring, and integrity for students that participated in a CBSL activity. Similarly, Nowakowski et al (2014)[24] demonstrated increased knowledge, skills, and behaviors of DPT students participating in a CBSL activity for geriatric patients. The DPT students in the geriatric CBSL activity completed self-reflection assignments that enhanced their learning and decreased age bias. There are many different types of CBSL activities including informational talks, health screenings, and exercise programs.

However, CBSL activities with specific objectives, reflection, and a component to address health promotion, safety, mobility, and physical performance appear to provide the greatest benefit to both students and the participants from the community. The sport of golf provides an excellent CBSL opportunity due to its popularity among all ages and genders and the potential to prevent musculoskeletal injuries through screening and wellness instructions.

Golf is an individualized sport that is most often played on an outdoor course, in which a small ball is struck with various sized clubs from a series of starting points. The objective is to take the lowest number of shots to get the ball into a series of holes in the ground.[1] The birthplace of golf is reported to be St. Andrews, Scotland. The game became popular in the early-15th century when the sport obtained a large portion of its current shape, structure, and rules. However, historians can date the game's origin back to before the 15th century, when a similar stick-and-ball game called paganica was played in European countries.[1] It wasn't until the 1600s when golf became popular in the United States while the first course on record was built in 1888 in New York.[1] The game of golf continued to grow and over a thousand courses were built in America by 1900. Each year following, there is an increasing amount of golf courses opening within the United States and these numbers progressively keep growing.[2]

Recent research finds that golf is played in 206 countries by nearly 60 million people worldwide. Its global reach was also evidenced by its inclusion in the 2016 Olympic Games.[3] The game contributes to physical and mental health benefits and is associated with an increase in life expectancy.[3] Golf is a unique sport partly because participation is not limited by age. The game is particularly popular among middle-aged and older adults. It allows those with varying levels of fitness and mobility to participate at a recreational level.[3] With that being said, there is a large discrepancy in gender participation. The National Golf Foundation found that in 2019, 5.6 females ages 6+ played on-course golf. That is only 23% of the total number of golfers found to have played that year. The hope is, with the help of everyone involved with the game of golf, especially the Ladies Professional Golf Association, the percentages of females and minority groups will continue to grow.

Biomechanics and kinesiology of the swing

The golf swing is a complex movement composed of detailed motion throughout the body. The golfer must begin with a grip that is appropriate for the distance to be driven and club selection. The stance must begin with a solid base to move through the phases of the golf swing. The phases of the golf swing incorporate multiple body segments as the swing advances through the backswing, downswing, impact, and follow-through. The golf swing phases require adequate strength and range of motion in certain muscles and joints for a golfer to be able to perform an effective, powerful swing. According to Meister et al., utilizing the timing of shoulder, pelvic and trunk rotation is key in creating the most effective free moment arm to both have a powerful swing and prevent injury.[4]

Grip

Three common golf grips include overlap, interlock, and baseball grip. Overlap grip is the most common among pro golfers. This grip consists of the bottom hand overlapping the 5th digit over the 2nd digit of the top hand. The interlock grip is similar to the overlap grip except for the 5th digit of the bottom hand and second digit of the top hand wrap around each other or “interlock”. The baseball grip is simply gripping the club without any overlapping of the hands or fingers.

The strength of the grip makes a difference on the golf swing as well. Strong grips tend to translate to more power and distance. However, increased power may also produce an increase in errant shots. Weak grips provide a greater margin for error, but the distance of the shot decreases. The radial deviation range of motion in the lead hand can dictate how strong the grip is. If there is 20 degrees or more of radial deviation, the golfer tends to have a stronger grip.[2]

Backswing

The backswing is the first moving phase of the golf swing. The golfer begins by moving the club head away from the ball to initiate the backswing. During the backswing, the elbows stay extended and the arms create a triangle. This pattern is the same for all types of golf shots, including putting, chipping, and driving. The backswing should be a “one-piece takeaway”, which means the arms should stay in this triangle position and move in a linear fashion parallel to the target line through the golf ball.[2] In backswings for shots that require a full swing, the arms’ positioning changes as the club and hands pass the hips. This triangle position is disbanded and each upper extremity moves into different motions. The back arm will abduct, externally rotate, and flex at the elbow joint. The full backswing requires 75 to 90 degrees of shoulder abduction and 90 degrees of external rotation to obtain a consistent swing plane.[2] The front arm adducts and internally rotates through the backswing. The front elbow should stay extended but not locked to create a longer lever arm and eventually greater momentum.

In addition to the upper extremity movement, a small lateral weight shift towards the back foot should occur as well. The O-factor (pelvic obliquity) should be neutral at this point–with the anterior superior iliac spines (ASIS) of the pelvis remaining parallel with the ground.[4] Often, golfers will have an excessive lateral shift of the trunk–causing spinal rotation and a shift of bodyweight back to the front foot.[2] Golfers should avoid the lateral shift position to minimize the risk of lower back pain. At the same time, substantial rotation of the trunk on the pelvis is observed in skilled golfers. The level of rotation of the shoulders past the pelvis is called the “x-factor.” The level of x-factor rotation is a key difference between amateur and highly skilled golfers. Golfers with rotation impairments will compensate with other parts of the body–creating an unstable, inconsistent swing.

Finally, during the backswing, a 20-degree radial deviation is needed for the lead hand to avoid excessive wrist extension.[2] In addition, lead leg tibial internal rotation and lead foot pronation should be evident as well. Internal rotation of 30 degrees of the back hip is needed to avoid a chain reaction of compensations. If a golfer has limited hip IR, externally rotating the hip in stance will help avoid this compensation chain.[2]

In the last part of the backswing phase, the relative hip-shoulder rotation in the horizontal plane (X-factor) begins to reach its peak. This is due to the pelvis starting to turn towards the lead leg while the shoulders are still rotated towards the back leg. Because of this, the peak X-factor may contribute to peak free moment.[4] This occurred in all trials of professional golfers. However, amateur golfers often times have X-factors that occur at different times, which can cause injury–specifically in the low back.[4]

Downswing

There are two components in the downswing phase which consist of the forward swing and acceleration. Studies using electromyography (EMG) show that back leg hip extensors along with the lead leg adductor magnus help initiate pelvic rotation during the forward swing.[2] This pelvic rotation starts the downswing and contributes to the peak X-factor from the end of the backswing.[4] The kinetic energy continues from the ground up into the core, upper extremities, then the club itself. If properly done, the clubhead energy should exceed the sum of energy produced from the ground.[2] Professional golfers can use centrifugal force and the law of conservation of angular momentum to build clubhead speed with smaller efforts. Amateurs try to use this too early in the downswing. In addition, professional golfers consistently have peak free moment/kg at the beginning of this phase.[4] Amateurs lack this ability due to the peak X-factor occurring earlier–creating an insufficient downswing compared to professionals.[4]

The motions during this stage should be the opposite of the backswing phase. The lead arm quickly externally rotates and moves toward midline while the back arm internally rotates and adducts. The lead arm should stay fully extended and the back arm should be extended 10 degrees from full extension. The wrists should remain “cocked” for as long as possible to get the greatest benefit from the “2 lever 1 hinge” system.[2]

The 2 lever, 1 hinge swing is described by having one fixed center hub of rotation with a 2 lever, 1 hinge moment arm to transfer force to the ball. The center hub lies in the middle of the sternum and acts as a dynamic center of gravity.[2] The center hub acts as the fixed center of the golfer, which the moment arm rotates on a specific plane. This center hub acts like the hub and spokes (levers) on a bicycle wheel. In an effective golf swing, the center hub should be within the base of support throughout the entire swing. In the bicycle wheel example, if the center hub was moving freely and randomly, the bicycle would be ineffective. This is the same with a golf swing. The center hub cannot be moving freely and randomly in an effective swing. A center hub is crucial in executing an accurate, powerful swing as a stable hub will help the levers position themselves properly.[2]

The levers and the hinge are the moving parts of the 2 lever 1 hinge system that move around the center hub. The levers include the upper lever and the lower lever. The upper lever is the lead arm in the golf swing, and the lower lever is the shaft of the golf club. The hinge of the system is the wrists–which control the action of the 2 levers.[2] During the downswing phase, the wrists release prior to impact to merge the upper lever arm (lead arm) and lower lever arm (club shaft) into 1 long lever arm.[2] This action of the hinge produces what is called the final moment arm at impact.

The lead arm during this phase dictates the plane of the club. The back arm follows this pattern and later provides power to the downswing. Successful coordination of the center hub, 2 levers, 1 hinge, and back arm force is important in creating a fundamental, successful swing that professionals are able to perform effectively.[2] Less successful golfers lack this coordination–leading to less power, accuracy, and reproducibility.[2]

Impact

The impact phase of the swing occurs as the club head returns to the original starting position of the swing. The major difference is that now there is a substantial amount of energy going forward through the ball and clubhead. The hands and wrists should be released from the cocking position. The lead arm wrist will uncock with passive ulnar deviation while having the wrist flexed 35 degrees and supinated. The back arm will move into pronation during this phase.

In a study by Job et al, EMG activity of the posterior shoulder muscles of the subscapularis, pectoralis major, and latissimus dorsi, demonstrated 80% activity leading up to the impact phase.[5] This EMG activity is very similar to the patterns observed in overhand throwing and tennis serving.[2] The posterior erector spinae showed peak EMG activity as well. Oblique muscles showed slightly more activity on the back side, possibly in preparation for slowing the trunk after the impact phase, but were moderately active bilaterally. The front oblique activity diminished as the swing reached the acceleration phase.

In the 2 lever, 1 hinge system, this is where the 2 levers combine into one due to the action of the hinge.[2] This creates a long lever arm which translates to more power. In addition, peak shoulder obliquity (S-factor) and peak pelvic obliquity (O-factor) occur in professional golfers immediately following impact.[4] Essentially this means the lead shoulder and hip are elevated compared to the back shoulder and lead hip, respectively. Peak clubhead speeds occur in this area as well. Speeds of the clubhead at this point in the golf swing range from 33 m/s to 57 m/s.[7, 8] Maximizing the use of the 2 lever, 1 hinge system, as well as timing of shoulder obliquity, pelvic obliquity, and trunk rotation leads to having clubhead speed in the higher part of this range. The impact phase poses the greatest risk for injury out of any of the phases due to the speed and force occurring in this phase.[2] The lead knee can be vulnerable during the impact phase as the weight is transferred to the lead leg and rotation at the tibia occurs as well. The back knee undergoes significant shearing stress as well which can stress the ACL.[2] This force doesn't happen at traumatic speeds, however, there can be an effect on patients with an injured ACL.

Follow-through

Deceleration of the club occurs during the follow-through phase of the golf swing. Stability of the scapula and trunk are important during this phase and the actions are the reverse of the backswing. The golfer's head should still be looking down where the ball was lying for the first portion of this phase in order to keep the trunk from rising and altering the shot. The weight is shifted to the front leg and absorbs a posterior, rotary, varus stress as the leg internally rotates.[2] The front foot goes into inversion and supination. Joint stability in the lead leg is important in this stage. Once full follow-through is reached, the body stabilizes and uses the club as a counterweight.

Common Golf injuries/Etiologies

With all the biomechanical motions occurring during a golf swing, injuries are bound to occur, whether acute or resulting from overuse of faulty biomechanics. Most injuries are the result of overuse and left untreated, they can further result in chronic musculoskeletal problems.[6] Incorrect swing mechanics and poor physical conditioning are the primary cause of acute injury in amateur golfers, whereas persistent play and practice are responsible for the majority of injuries in professional golfers.[2] Research has shown that the majority of golf injuries occur at or near the moment of impact during the downswing.[2] A 1-year study of golfers in Australia found an overall incident rate of injury of 15.8 injuries per 100 golfers.[6] Common areas where these injuries occur are the low back (15-36%), shoulders (6-10%), wrist (13-36%), and elbows (7-50%).[4] In addition, another survey that was conducted reported that low back and the hand-wrist complex were the most vulnerable sites for injury among amateur, professional, and tour golfers.[2] One study states that up to 52% of the injuries reported due to golf are related to low back pain.[6]

Low Back

The large amount of axial rotation involved during a golf swing contributes to the number of low back injuries in golf. During the swing, the lumbar spine is exposed to significant forces such as compression, anterior-posterior shearing, torsion, and lateral bending forces. The lumbar spine forces are related to the significant flexion and extension motions, moderate lateral bending, and a small amount of rotation. Notably, it has been reported that only 2-3 degrees of rotation at a specific segment in the lumbar spine can cause micro trauma to the facets. This shows the importance of proper form when performing a swing because most amateur golfers feel the need to load the lumbar spine to create torque. The excessive rotation in amateur golfers is connected to a large number of local soft-tissue injuries in the lumbar spine.

Another major injury that occurs with golfers is lumbar, spinal disc herniations. Repeated lateral bending combined with a large compression force and torsion is commonly associated with disc herniations. These factors are all keys to a golf swing which puts golfers, especially amateurs, at a higher risk of disc herniation. That is why it is important to teach proper swing mechanics to prevent injuries like these.

Shoulder

The shoulder is a commonly injured joint related to the golf swing. The lead shoulder (left shoulder for right-handed golfers) is three times more likely to be injured when compared to the trailing arm. For younger golfers, instability or a traumatic injury is most common whereas middle-aged adults are more susceptible to subacromial impingement, rotator cuff disease, or acromioclavicular disease. For the older population, injury to the rotator cuff and arthritis/arthrosis are most common.[17] This shows that any age group is susceptible to injury for a variety of different age-related pathologies.

Although golf is not considered an overhead sport, the end positions of the backswing and follow-through require a significant amount of overhead motion. For example, during the backswing, the lead arm undergoes significant internal rotation, forward flexion and horizontal adduction. This position puts the shoulder at risk of subacromial impingement and can exacerbate symptoms for the golfers over time. This position can also cause pain for golfers with posterior glenohumeral instability with the lead arm being horizontally adducted across the body.[17]

The biomechanics of the golf swing heavily impacts the shoulder joint. Torque is created in the lower extremity and accelerates energy to the upper extremity. Studies have found there is moderate muscle activity during the downswing involving pectoralis major, latissimus dorsi, and the rotator cuff muscles. With this increased energy accelerated up to the upper extremity, the nature of golf and doing repetitive motions, having abnormal swings, or a changing the motion can cause shoulder injuries.[21–22]

Elbow

Most injuries involving the elbow are due to overuse for both amateur and elite golfers. It can also be attributed to gripping the golf club tightly (which puts strain on the forearm muscles and hand), hitting the ball "fat" (hitting the ground behind the ball before hitting the ball), and/or hitting through heavy rough (thick and high grass). All of these cause a rapid deceleration of the club which transmits significant force through the hand and elbow.[6]

Two common injuries affecting the elbow are lateral and medial epicondylitis. Lateral epicondylitis is commonly seen in the lead arm on the lateral aspect of the elbow. The extensor carpi radialis brevis (ECRB) along with the other extensor muscles of the forearm help to stabilize the wrist during the downswing and into the impact of the ball. As stated above, anything that rapidly decelerates the club can add unnecessary stress to those extensor muscles and cause trauma at their origins around the elbow. Medial epicondylitis is similar but affects the trailing arm on the medial aspect of the elbow. The added force of rapid deceleration of the club to the flexors of the forearm is a major cause of this injury. Additionally, amateur golfers make the mistake of pushing the club down through the downswing with their trail arm instead of letting the lead arm pull the club down. This unnecessary pushing of the trailing arm adds significant force to the medial elbow over time and can lead to medial elbow pain.[6]

Wrist

Throughout the golf swing, both wrists go through a large range of motion. Although injuries can happen in both wrists, the lead wrist is most susceptible to injury. Similar to the elbow injuries, the added force from hitting the ball "fat" or hitting through heavy rough can lead to many acute wrist injuries. Additionally, injury can occur when the wrist is put into an excessive range of motion like radial deviation at the top of the backswing, ulnar deviation, and supination following impact which can lead to extensor carpi ulnaris instability, tears of the triangular fibrocartilage complex, and extreme deceleration of the club (like hitting a rock or root of a tree) where there is a significant amount of force transmitted into the hamate bone which is gripping the top of the club and can fracture due to the force.[6]

Injury prevention and return to play

The injuries associated with golf can be painful and very limiting, especially the impact of low back pain. A prevention program can improve strength and golf performance, but more importantly, it can reduce the frequency of golf injuries. There are many options for reducing the potential for golf-related injuries. First, the player should understand the effective swing mechanics and phases. A golf swing consists of many complex and coordinated movements and is repeated often during a round of 9 or 18 holes. Over time, if the person's swing is flawed, it can lead to injury. Proper posture of a golf swing starts with feet shoulder-width apart and rotated slightly outward with knees slightly bent. The trunk should be tilted forward and most of the movement should come from the hips. Poor posture of a golf swing can lead to neck and back strain. However, posture is only one component of a prevention program. Golfers who overswing can also place stress on their joints. Additional prevention strategies include warm-ups, starting slowly, strengthening the muscles (the stronger they are the less you are likely to be injured), focusing on flexibility, building endurance, lifting clubs carefully, avoiding hitting objects other than the ball, and using proper footwear.[10]

Return to play after a golf injury is dependent on what is injured and the severity. Injuries to the lower spine are very common for any level of player. The golf swing stresses and torques the lumbar spine. Seeing a doctor or physical therapist is recommended. The next step is to regain the flexibility and mobility of the spine. Stretching in all motion planes will help, but be aware not to cause another flare-up. Working slowly with putting and chipping and being pain-free for around a week is recommended prior to restarting a full round of golf.[12]

Medial epicondylitis, also known as “golfer’s elbow,” is the second most common golf-related injury. This is inflammation of the forearm tendons that attach to the bone at your elbow. This happens due to the repetition of the same motions, leading to pain and tenderness on the medial aspect of the elbow. To avoid this problem, you can strengthen these muscles and slow down your golf swing so there will be less shock when the ball is hit. Exercises to strengthen these forearm muscles include: squeezing a tennis ball, wrist curls, and reverse wrist curls.[14]

Rotator cuff injuries, in particular, the supraspinatus tendon is at risk for developing rotator cuff tendonitis. To prevent this injury, exercise and target the small and large muscles of the shoulder, keep a good posture, avoid sleeping on your side with your arm stretched overhead, don’t smoke, avoid activities with repetitive overhead arm action, massage with cold and hot compresses to help decrease inflammation.[15]

Purpose

The purpose of this scholarly project is to develop a service learning program for the University of North Dakota Department of Physical Therapy. The service learning program will utilize a Golf Fitness Program that will provide local golfers with an evaluation of their swing biomechanics, potential movement limitations, and recommendations for optimizing golf fitness to minimize the potential of future injuries and hopefully improve the golfing experience. A service learning program that incorporates golf fitness by UND PT students will provide opportunities for students to interact with a wide range of clients, enhance professional skills, and provide a health and wellness service to the local community.

CHAPTER II

METHODS

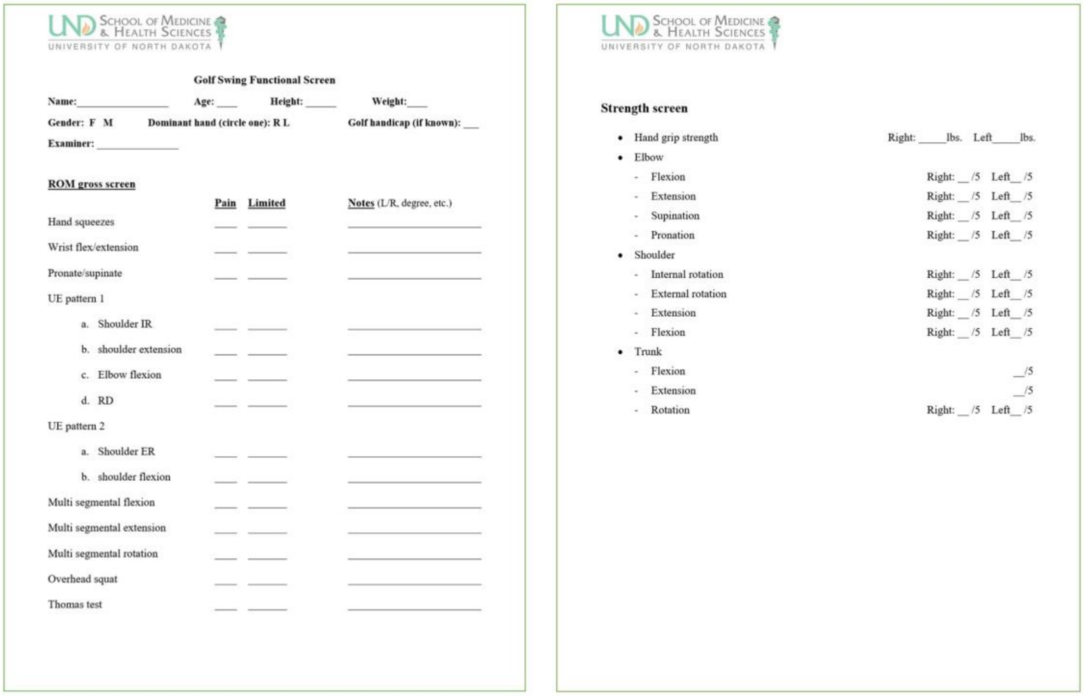
In this study, we developed a two-phase examination and evaluation process to screen for possible limitations throughout an individual's golf swing in order to make recommendations and reduce the likelihood of injury. A general functional screen as well as a swing analysis using VICON 3D motion capture technology were used for each participant.

We determined that 6 individuals with either professional, competitive, or recreational golf experience would provide preliminary information to develop the feasibility of a golf fitness program. Six individuals with golf experience agreed to participate in this class project. The six individuals participated in a functional and biomechanical screening process to provide feedback about the proposed program activities. The six participants were between the ages of 21 and 27.

Initially, each participant went through a functional screening process to test strength and range of motion. (see Figure 1 below) The functional screening process measured strength and range of motion in motions necessary for a golf swing (thoracic rotation, hip rotation, etc.) Following the screening of each participant, Vicon markers were placed on centers of the body that focused on rotations in accordance to the golf swing. The markers were placed by the same researchers, on the same body parts for each participant, which gave us high reliability. To analyze the swing itself, the BiPED Laboratory at the University of North Dakota was utilized with the guidance of Dr. Jesse

Rhoades, who has extensive experience in this system and 3D motion capture in athletes.

Figure 1: Functional screening and assessment tool



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Golf Swing Functional Screen

Name:________ Age: ___ Height: ____ Weight:___
Gender: F M Dominant hand (circle one): R L Golf handicap (if known): ___
Examiner: ________

ROM gross screen

	Pain	Limited	Notes (L/R, degree, etc.)
Hand squeezes	___	___	______
Wrist flex/extension	___	___	______
Pronate/supinate	___	___	______
UE pattern 1			
a. Shoulder IR	___	___	______
b. shoulder extension	___	___	______
c. Elbow flexion	___	___	______
d. RD	___	___	______
UE pattern 2			
a. Shoulder ER	___	___	______
b. shoulder flexion	___	___	______
Multi segmental flexion	___	___	______
Multi segmental extension	___	___	______
Multi segmental rotation	___	___	______
Overhead squat	___	___	______
Thomas test	___	___	______

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Strength screen

- Hand grip strength — Right: ____lbs. Left____lbs.
- Elbow
  - Flexion — Right: __ /5 Left__ /5
  - Extension — Right: __ /5 Left__ /5
  - Supination — Right: __ /5 Left__ /5
  - Pronation — Right: __ /5 Left__ /5
- Shoulder
  - Internal rotation — Right: __ /5 Left__ /5
  - External rotation — Right: __ /5 Left__ /5
  - Extension — Right: __ /5 Left__ /5
  - Flexion — Right: __ /5 Left__ /5
- Trunk
  - Flexion — __/5
  - Extension — __/5
  - Rotation — Right: __ /5 Left__ /5

During the process of obtaining the information, each participant took ten recorded swings in the lab with up to 3 warm up swings with each club. Five swings with a driver and then five with a 7 iron. Markers were placed on the clubs to help the software recognize the club to body relationship during the swing, all participants used the same two clubs.

All golf swings for each volunteer were analyzed with the BiPED Lab's VICON motion analysis system. The system tracked the movements of each swing to find the X-factor, S-factor, and O-factor. The timing of these movements was also monitored in order to specify the factors' fluctuation throughout each phase of the golf swing. The variables of X-factor, S-factor, and O-factor were chosen because of their relationship to an ideal golf swing. The X-factor is the difference between the shoulder rotation angle and hip rotation angle throughout the swing. With a higher peak X-factor, generally, the greater the clubhead speed at impact as more torque is created with the golf club. The S-factor is described as the angle in the frontal plane of the shoulders throughout the swing. Finally, the O-factor is the angle of the pelvis in the frontal plane during the swing. Consistency with these last two factors creates repeatable loft and contact with the golf ball.

After completion of the analysis of the swings, each individual's swing performance was compared to measurements from professional golfers. The analysis provided a general idea of the potential phase of the golf swing and the anatomical region that may be predisposed to a less consistent golf swing and injuries. The Vicon information was then compared to the findings from the functional screening to determine whether the results can be attributed to a mobility dysfunction or a stability dysfunction. It is assumed that the findings can provide a guideline for treatment to lead to a safe, effective, and consistent swing.

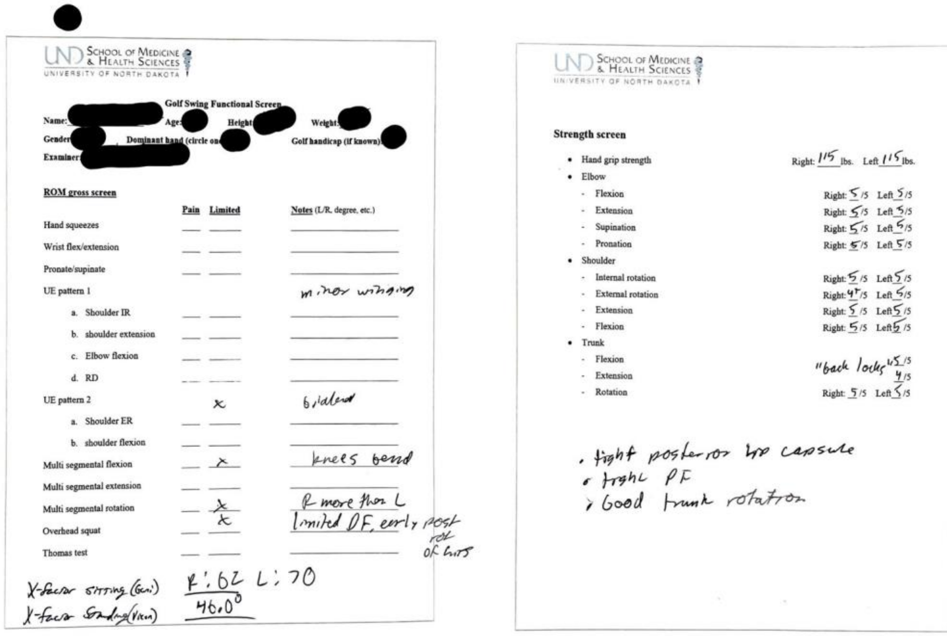
The VICON three-dimensional motion analysis system was able to get results from four of the golfers' drives. The four golfers were given their results 1 month following the functional screening and the VICON motion analysis. They were then asked to give the researchers feedback on what they thought of the results and how they felt about the experience.

CHAPTER III

RESULTS

Due to the amount of time required to collect data and the availability of the VICON lab, it was determined that six participants would allow for a sufficient amount of data for the study. The six individuals who volunteered were able to participate in both portions of the golf fitness screening which included the functional screen and VICON 3D motion analysis. Four of the six participants had viable data from the VICON motion analysis. The complexity of the golf swing and the large number of body markers may have resulted in substandard data for two of the six participants. The substandard data included missing markers and body segments that are required for analysis of the variables of interest. Additionally, the data that was extracted and compiled into graphs were only the five golf swings with the driver. The four individuals with complete data were given a general overview of the screening which included strength and flexibility measurements, an explanation of the factors measured in the VICON motion analysis, and graphs of each of the measured biomechanical factors. At the end of the overview, they were provided with general advice on creating a more effective and safe golf swing based on these findings. The overview also included an example of the functional screen we did with them. We received responses from the individuals to gauge how they valued the screening, what could be done better, what time of the year would be appropriate for the screening, and an estimate of monetary value for a screening of this nature if they were a community member.

The process of collecting data was assessed to determine the amount of time to complete the analysis and the value to the participants that play golf. The estimated time to collect the data was 30 minutes with 15 minutes allocated to the VICON 3D motion analysis and 15 minutes for the functional screen. The first portion of the study was the functional screen. This screening process was expected to last no more than 15 minutes. The same skilled individuals completed the functional screen for the participants, making this section of the data collection move ahead of schedule and more efficiently than anticipated. The efficient functional screen allowed for more time to apply markers and prepare the individual for the VICON lab biomechanical analysis of the golf swing. The functional screening was limited to most of the ROM, strength, and gross movement screening prior to the VICON aspect. A lack of equipment and smaller examination area prevented us from doing certain tests we originally planned. However, we were still able to find meaningful limitations of movement during the screening that was utilized. Common findings were reduced trunk extension mobility, lack of scapular control, and hip hypomobility. We also measured X-factor in a seated position, which could be compared to the VICON findings. We were able to find that some subjects had adequate trunk mobility compared to professional golfers. However, they did not utilize all of their available motion when performing a golf swing. An example of a completed functional screen is shown in Figure 2.



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Golf Swing Functional Screen

Name: [redacted] Age: [redacted] Height: [redacted] Weight: [redacted]
Gender: [redacted] Dominant hand (circle one): [redacted] Golf handicap (if known): [redacted]
Examiner: [redacted]

ROM gross screen

	Pain	Limited	Notes (L/R, degree, etc.)
Hand squeezes			
Wrist flex/extension			
Pronate/supinate			
UE pattern 1			minor winging
a. Shoulder IR			
b. shoulder extension			
c. Elbow flexion			
d. RD			
UE pattern 2		x	bilateral
a. Shoulder ER			
b. shoulder flexion			
Multi segmental flexion		x	knees bend
Multi segmental extension			
Multi segmental rotation		x	R more than L
Overhead squat		x	limited DF, early post rot of hips
Thomas test			

X-factor sitting (Gemini) R: 62 L: 70
X-factor standing (Vicon) 46.0°

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Strength screen

- Hand grip strength — Right: 115 lbs. Left 115 lbs.
- Elbow
  - Flexion — Right: 5/5 Left 5/5
  - Extension — Right: 5/5 Left 5/5
  - Supination — Right: 5/5 Left 5/5
  - Pronation — Right: 5/5 Left 5/5
- Shoulder
  - Internal rotation — Right: 5/5 Left 5/5
  - External rotation — Right: 4+/5 Left 5/5
  - Extension — Right: 5/5 Left 5/5
  - Flexion — Right: 5/5 Left 5/5
- Trunk
  - Flexion — "back locks" 5/5
  - Extension — 4/5
  - Rotation — Right: 5/5 Left 5/5

- tight posterior hip capsule
- tight PF
- Good trunk rotation

Figure 2: Functional screening and data from a random subject in the project.

A large portion of the time during the study was dedicated to donning of the markers which allowed the motion analysis camera to pick up the individuals' joint positions. Although the study leaders were prepared and educated on the application of the markers, there were challenges during the motion capture component of the project. Participants that wore loose or baggy clothing made clear captioning of the markers throughout the swings difficult. Due to the speed and force of the golf swing, the markers would often fall off of the subject, making the collection of data slower and the necessary repetition of swings to obtain better data. Another time-consuming aspect of the data collection of the motion analysis was the calibration of the cameras to the participants. Participants had to go through a series of motions that helped the computer recognize joint positions. This data was then used to help analyze the swings of the participants. The accuracy of this calibration was important and took time. Once the participants were set up to be able to complete the swing analysis portion of the study, the amount of time needed to capture the final swings was significantly less than the time taken to set up. In general, the time in the VICON 3D motion analysis was greater than expected which resulted in longer participant waiting times. Although the VICON portion was longer than expected, the efficiency of the functional screening process still allowed participants to complete both steps within the allotted 30 minutes. The time to complete the data collection is an important factor as future participants may be unwilling to spend substantially more time than the 30 minutes allotted.

We were able to use the data from the VICON motion analysis and create graphs of each factor with the contribution of Dr. Rhoades. An example of a graph is shown in Figure 3. These graphs provided a visual in regard to the timing and consistency of each subject. All subjects were amateur golfers, so the swings did vary across all factors that were assessed. When compared to professional golfers, two subjects were within limits of pro golfers for the X-factor, one for the S-factor, and two for the O-factor. The individuals that were not within limits, all had lower values in these areas. The limited performance of these amateur golfers suggests they are either hypomobile, or do not utilize their mobility effectively throughout their swing—based on results found with the functional screen. For example, subject 4 had limited X-factor in both the functional screen and the VICON motion analysis. This shows he is hypomobile, specifically in trunk rotation. Whereas subject 5 had adequate X factor in the functional screen, but not during the VICON motion analysis. This demonstrates the subject's inability to utilize the range available. In addition, one subject was within limits for all three factors, however, his factors were inconsistent throughout the five swings and varied by 20 or more degrees. This shows that professionals have exceptional mobility, consistency, and the ability to utilize their mobility in a repeatable manner. Intervention and advice for the individuals in this project were geared towards producing a mobile, consistent swing.

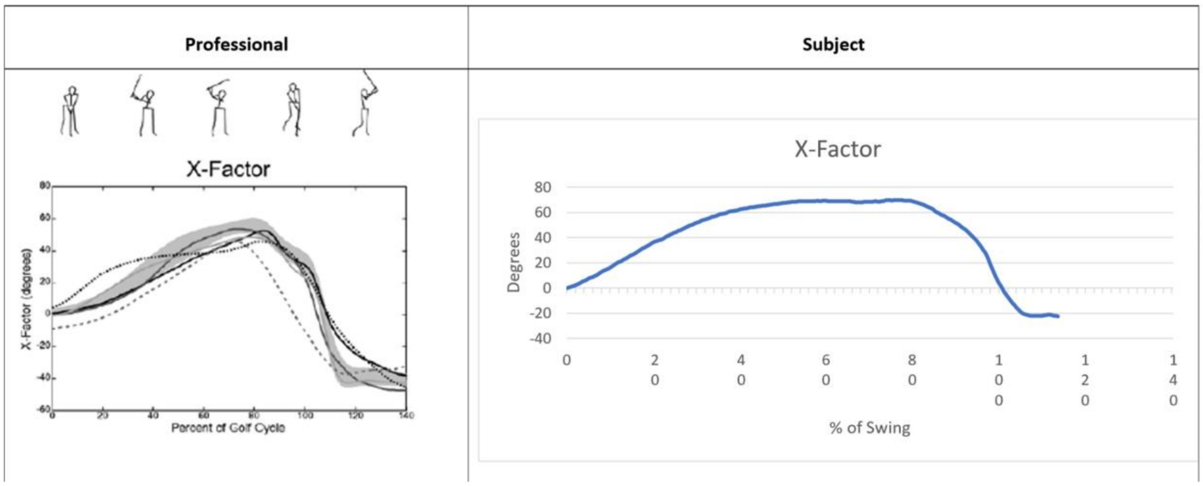

Figure 3: An example of the X-factor graph given to one of the participants.

For swing improvement advice, we were able to use anatomical terms as our participants were all doctor of physical therapy students. We included intervention ideas to help with X, S, and O factor limitations. We also provided advice to help with mobility and strength deficits that contribute to less effective and unsafe swings. Common advice between participants for the functional screens was centered around trunk extension mobility (4/4 participants) and scapular stability/control (2/4 participants). Decreased hip mobility and shoulder rotation pain was also found in participants.

An explanation of the importance of these impairments was included in the feedback to increase participant acceptance and engagement with the proposed recommendations. Trunk extension is important in essence to decrease the probability of a “slice”. Decreased trunk extension limits the ability to maintain balance while shifting weight to the front foot during the follow-through phase. As a result, golfers will compensate by not weight shifting properly, making the club in the follow-through phase turn in the posterior direction early. This creates an “outside-in” swing–putting a clockwise spin on the ball creating a “slice”. Scapular stability advice was given to help create a consistent and power-producing backswing. Decreased rotation of the back shoulder limits the ability to create an adequate backswing. The back shoulder requires around 90 degrees of external rotation in order to perform an effective swing.[2] In addition, if the back shoulder scapula lacks stability, the angle of the golf club during the backswing can vary especially in weaker positions. This creates a lack of consistency when it comes to ball impact. These were the common explanations given to subjects.

For X, O, and S factor improvement, advice was centered around improving the consistency and timing of each factor through repeated practice. Common issues between subjects were generally inconsistent O factors and outlier swings to varying degrees in all factors. The peak X factor should occur at the beginning of the downswing to create torque from the ground up. The S and O factors should occur right after impact and should occur simultaneously. If the timing of these is altered, the prevalence of ineffective swings and risk of injury increase. Further detail was provided to help the participants visualize each of the factors. After further explaining these, they were given advice to swing on the practice range while emphasizing each of the factors individually, then working on utilizing all of them together. Eventually then, applying these to each club. Ultimately, practicing these in repetition will help the participant reach an autonomous stage of learning–creating a safe, effective swing.

Participants commented that the feedback helped them visualize what could help them create an improved swing. However, they thought having more explanation on each of the factors would be helpful. Seeing video examples or other visual demonstrations could be helpful for future screenings.

CHAPTER IV

DISCUSSION

This project allowed University North Dakota of Physical Therapy students to develop a community-based service learning activity program for golf fitness using local amateur golfers. This program can be used by the University of North Dakota Physical Therapy program to quickly evaluate a local golfer for weaknesses in their golf fitness that may lead to injury in the future. With the evaluation's findings, recommendations can be given to the local golfer to help limit these weaknesses. At the same time, the program will allow DPT students to perform examination and assessment skills, critical analysis of biomechanical movement and musculoskeletal examination findings, and development of professionalism that requires interaction with a patient/client situation like CBSL. The hope is that this program will reduce the risk of injuries to local golfer’s while enhancing knowledge, skills, and abilities of DPT students.

The game of golf has always been popular, but in recent years has been shown to continue to grow in popularity among people of all ages and skill levels around the world. The complexity of the golf swing has been studied for years and how, if not performed in a correct and safe way, it can lead to increased risk for injury. Both acute and chronic musculoskeletal injuries can occur in areas such as the lumbar spine, shoulders, wrists, and elbows. These injuries are common among amateur, intermediate, and even professional golfers. Studies show that the overall rate of injury in golfers is 15-20%. For golf being considered a leisure and low-impact sport, this is a surprisingly high amount of injuries. Due to the high rate of injury in a sport that should be a relatively safe sport, a question about injury prevention should be asked. As musculoskeletal experts, physical therapists are in a position to provide screening and instruction to limit injuries provided they have an effective screening process.

The educational curriculum for physical therapists provides opportunities to perform various examination and treatment skills although much of this practice is performed on classmates with negligible musculoskeletal limitations. A golf fitness program performed by physical therapist students under the direction of a licensed physical therapist could minimize the risk of musculoskeletal injuries to golfers with an evaluation of golfing movements and general fitness recommendations. Along those lines, incorporating student physical therapists will provide direct client evaluation opportunities to enhance student evaluation technique development and various components of professionalism including communication skills, altruism, compassion/caring, and integrity by interacting with the golfing community.

The process and program attempted during this project would benefit from additional refinement. The first recommendation is to develop specific objectives for the CBSL program. Additionally, the use of written reflection has demonstrated increased learning for CBSL programs using geriatric patients with stroke. There are additional procedural changes such as during the VICON motion analysis recording participants could bring in their own clubs to swing. This would allow the participants to see how they specifically swing the clubs that they are going to bring onto the golf course. This project had all the participants use the same driver and 7 iron. The clubs that were used could have been a different size or weight than the golfers normally use, therefore changing their swing mechanics.

Another possible improvement could be to allow the golfers to swing with more than one iron. This would allow the evaluators to see if a participant's swing changes depending on the iron that they are using. Each iron has a slightly different shape which could alter one's mechanics. Although this would increase the amount of time to do the screening and calculate the data, taking more total swings could improve this program. Two of the golfers that volunteered were not able to get results due to the VICON motion analysis not reading their swing properly. With more swings, VICON’s cameras have more of an opportunity to pick up their swing allowing it to be analyzed for results.

In addition to measuring the X, S, and O factors, it would be helpful if we could find a VICON model to calculate club head speed as well. Calculating the three factors as well as club head speed may provide opportunities to assess a correlation between these factors. This data could also help us analyze if they are maximizing their mobility and power, or if they are putting themselves at an increased risk for injury.

As far as timing for this program, it would most likely be best used if done at the end of the winter or early spring when golfers are anticipating a return to the golf course for the first time. A CBSL golf activity prior to the first round of golf would allow participants to address their weaknesses before the golf season starts. This will hopefully give golfers the best opportunity to reduce the risk of injury.

This research proposal had a limited budget, UND School of Medicine and Health Sciences was able to provide the tools necessary to complete it. The primary tool used was the VICON motion analysis. This, along with the software license, can range from $4,200-12,500. The other tools used were a set of irons cost ~$1,000 (although only one of the clubs was utilized during this study), a driver cost range of $300-600, foam balls costing $15, and a hydraulic hand dynamometer ~$300. The UND PT students were able to perform the other tests and measures by hand including MMT and special tests. The maximum cost comes to a total of $14,415.[18−20] However, since this was a University led activity with all equipment available already, the expenses for the screening were essentially $0—aside from the time spent by all involved. As far as potential profit from the screening, participants commented that if they were a member of the community, they would likely pay between $50-$100 for a screening like this.

Continuing this program in the future would help create opportunities for adjustments and improvements in the screening process. This initial program included a broad spectrum screening examination for potential musculoskeletal limitations that may result in injuries. As time goes on, the program can be altered to focus on specific areas of the body such as the shoulder, elbow, or back that are more often injured during golf. Additionally, an increase in participants will give feedback on how to further improve or simplify the program. With that, if participants return, reputation will build and connections with other researchers can be built to enhance credibility.

Overall, we had some issues with the VICON system registering swings but still got useful data for most of the subjects. We were able to condense these findings and use evidence to formulate a solution to some swing faults that can prevent injuries. This also gave student physical therapists an opportunity to apply evaluation and research skills. Local golfers could utilize this opportunity to improve their golf game and wellness while students can gain confidence in their skills.

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APPENDIX

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Golf Swing Functional Screen

Name:_________________ **Age:** ____ **Height:** ______ **Weight:**____

Gender: F M **Dominant hand (circle one): R L** **Golf handicap (if known):** ___

Examiner: _______________

ROM gross screen

	Pain	Limited	Notes (L/R, degree, etc.)
Hand squeezes	____	_______	_________________________
Wrist flex/extension	____	_______	_________________________
Pronate/supinate	____	_______	_________________________
UE pattern 1			
a. Shoulder IR	____	_______	_________________________
b. shoulder extension	____	_______	_________________________
c. Elbow flexion	____	_______	_________________________
d. RD	____	_______	_________________________
UE pattern 2			
a. Shoulder ER	____	_______	_________________________
b. shoulder flexion	____	_______	_________________________
Multi segmental flexion	____	_______	_________________________
Multi segmental extension	____	_______	_________________________
Multi segmental rotation	____	_______	_________________________
Overhead squat	____	_______	_________________________
Thomas test	____	_______	_________________________

Strength screen

- Hand grip strength Right: _____lbs. Left_____lbs.
- Elbow
  - Flexion Right: __ /5 Left__ /5
  - Extension Right: __ /5 Left__ /5
  - Supination Right: __ /5 Left__ /5
  - Pronation Right: __ /5 Left__ /5
- Shoulder
  - Internal rotation Right: __ /5 Left__ /5
  - External rotation Right: __ /5 Left__ /5
  - Extension Right: __ /5 Left__ /5
  - Flexion Right: __ /5 Left__ /5
- Trunk
  - Flexion __/5
  - Extension __/5
  - Rotation Right: __ /5 Left__ /5