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Scapular Stabilizer Muscle Force Output in Collegiate Softball Players Over the Course of a Fall, Non-traditional Season

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SCAPULAR STABILIZER MUSCLE FORCE OUTPUT IN COLLEGIATE SOFTBALL PLAYERS OVER THE COURSE OF A FALL, NON-TRADITIONAL SEASON

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Introduction

There is a growing topic in research relating to softball and the injuries caused by the biomechanics of a windmill pitch. There have been articles released relating to stress caused by the windmill pitch compared to the stress of an overhead pitch in baseball. Many articles in the softball field also look at the biomechanics and hip strength of the windmill pitcher and how a decrease in hip strength can affect the biomechanics of the pitching motion. Despite having an increase in available softball articles, there have not been any studies conducted that focus solely on scapular stabilizer strength over the course of a season. The importance of this would be to help prevent injuries, especially toward the end of the season. This study aims to fill the gap of the softball research by focusing solely on the strength of scapular stabilizer muscles (rhomboids major and minor, latissimus dorsi, upper and lower trapezius, and infraspinatus) in collegiate softball players of all positions over the course of a non-traditional fall-ball season.

Purpose

The purpose of this study is to look at dominant throwing arm scapular stabilizer strength within softball players over the course of the fall season. Measures will be taken at the beginning, the middle, and the end of the fall ball season by using a hand-held dynamometer. The different muscles that the softball players were tested on are lower trapezius (“Y”), middle trapezius (“T”), infraspinatus (“T with thumb up”), rhomboids major and minor (“Row”), and latissimus dorsi (“I”).

Hypothesis

The hypothesis of this study is that the scapular stabilizer strength of softball players will significantly decrease during the non-traditional fall softball season. Over the course of this shortened season, the Disabilities of the Arm, Shoulder, and Hand (DASH) scores will not have a significant decrease or increase over the course of the fall season. The population of this study is collegiate softball players in all positions; not one specific softball position will be looked at during this study but rather, the entire team will be evaluated.

Implications

The implications of the study are to see if softball players need to incorporate a scapular stabilizer strength program during their season to ensure that they do not suffer a decrease in strength about those muscles that are so important to overall shoulder function and health. Analyzing if a softball player's scapular stabilizer strength decreases within their fall softball season may be predictive of how much their strength decreases over the course of their spring season. Thus, this information could help influence practice and strengthening techniques.

Limitations

The limitations of this study are the small number of participants available. There are 23 softball players on the Otterbein Softball team, and since the study is completely voluntary, not everyone is going to participate. Another limitation is making sure all the participants show up at all data collection times held on the different days. A limitation for the study is the questions that the Disabilities of the Arm, Shoulder and Hand (DASH), because the questions they ask revolve around activities of daily living and are not specific to throwing or softball in general. The scores from the DASH could be limited due to pain from an injury.

Assumptions

One assumption with the actual testing process is that when using a hand-held dynamometer, the force read is only the force generated by the participant and not the researcher's force on the participant's arm.

Summary

Overall, the current available literature examining softball shoulder strength does not investigate how shoulder strength decreases in softball players over the course of the season. The research available primarily looks at injuries, biomechanics, and shoulder strength over the course of a weekend tournament. There are also limited studies about scapular stabilizers strength in softball players as well. This study will investigate the scapular stabilizer strength of college softball players of all positions. The goal of this research is to help fill the gaps in the literature between softball strength studies and baseball strength studies.

Literature Review

Background

Muscle fatigue in the glenohumeral joint of softball players has been evident after multiple days of playing (Skillington, 2017). There are two different reasons why muscle fatigue can happen: accumulation of lactic acid which inhibits myofibrillar proteins, and failure of calcium release (Allen, 2004). The shortening and force production muscles causes them to be damaged even after just one day of intense exercise and it could it take up to a week for the damage to be reversed. This causes an increase in resting calcium and sodium and a disorganization of the sarcomeres (Allen, 2004). By preventing an increase of sodium, the muscle will not be weakened as much after stretched contractions (Allen, 2004).

Looking at the strength of the scapular stabilizers from a study performed by Wang, Mcclure, Pratt, & Nobilini (1999), exercising horizontal abduction, internal rotation, and external rotation increased scapular stabilization and glenohumeral elevation strength. The study above is important because when looking at softball glenohumeral and scapular strength, exercises can be implemented that revolve around strengthening the rotator cuff. Wang et al (1999) also found that performance of this exercise program 3 times a week for 6 weeks not only increased the shoulder complex strength, but also produced more erect upper trunk posture and increased altered scapulohumeral rhythm.

Humeral-retrotorsion is the measurement of rotational difference between the humeral head and the axis of the elbow located at the distal humerus (Greenberg, 2015). This is important when looking at overhead athletes because with the specific mechanics of baseball and overhead throwing, it puts the humerus in a more posterior medial position, which creates more humeral-retrotorsion. (Greenberg, 2015).

The overhand throw is composed of different phases known as wind-up, stride, arm cocking, arm acceleration, arm deceleration, and follow-through (Maffet,1997). Hibberd, Oyama, Tatman, & Myers (2014) completed a study comparing the dominant-limb range-of-motion and humeral-retrotorsion in baseball and softball players. They found that baseball players had greater glenohumeral internal-rotation deficit, total-range-of-motion, and humeral-retrotorsion difference than softball players and male controls. The acceleration phase in overhead throwing is the primary cause of the baseball players having a greater humeral-retrotorsion than softball players due to the maximal external rotation that happens during this phase of overhead throwing (Hibberd, 2014). Passive external rotation measures in baseball players have been found to be significantly greater in the pitching side than the nonpitching side (Borsa, 2006, Davis, 2009, Rojas, 2009).

Comparing humeral torsion to posterior capsule tightness is the subject of a study that was completed by Myers et al in 2009. Many clinicians think posterior shoulder tightness is caused by soft tissue tightness, but Myers et al (2009), thinks humeral retrotorsion is a reason why there is less internal rotation in dominant arms compared to nondominant arms in baseball pitchers. Myers (2009) looked at 29 healthy baseball players and compared them to 25 healthy males around the same age that had no history of overhead athletics. The study found that the dominant limb of baseball players demonstrated greater humeral torsion and less internal rotation and total rotation range of motion compared to the control group. The baseball players were then corrected for torsion, and it was found there were no group or limb differences in internal rotation. There was a statistically significant relationships between the measures of posterior shoulder tightness and the amount of humeral torsion. Myers et al (2009) stated that this study was done assuming that humeral torsion does not change after skeletal maturity is reached and any change in internal rotation or horizontal adduction can be attributed to the change in soft tissue structure, but only if the athlete is skeletally mature. After humeral torsion is corrected, the difference between internal rotation in dominant and nondominant arms can be linked to a soft tissue flexibility issue.

There are two different ways we can measure posterior capsule tightness: side-lying or supine by passively moving the patient into glenohumeral internal rotation. Intrasession, intersession, and intertester reliability and precision for testing posterior tightness was tested for both positions in another Myers et al (2007) study. This study had the electromagnetic tracking devices attached to the participants to track the humeral and scapular motion while performing a side-lying and supine assessment in overhead athletes. The study found that the supine method of measuring posterior tightness was more reliable than the side-lying session. The baseball players and tennis athletes in the study had significantly less internal rotation range of motion and greater posterior shoulder tightness when measured in the supine position compared to the side-lying position.

Shoulder and elbow injuries are common in youth baseball as a result of poor biomechanics. A study performed by Davis et al (2009) looked at 5 different common pitching parameters and compared them to youth pitchers age, humeral internal rotation torque, elbow valgus load, and calculated pitching efficiency. The goal of the study was to define the relationship between the common biomechanical errors and joint stress in the upper extremity using motion and video analysis. The five parameters the study reviewed were leading with the hips, hand-on-top position, arm in throwing position, closed-shoulder position, and stride foot toward home plate. The authors found that those who performed 3 or more of the parameters correctly, had a lower humeral internal rotation torque, elbow valgus load, and higher pitching efficiency than those who did not.

Allied Research

As it clear from the presented research, much of the work in overhead mechanics and upper extremity injury risk has been completed in baseball players. It is important to note that softball pitchers have an entirely different pitch delivery that baseball players. This section focuses on the difference between a windmill pitch and overhead pitch. It also focuses on the muscle activation patterns that occur during the windmill pitch. This section also focuses on the differences in pitch count between softball pitchers and baseball pitchers.

Compared to the overhead throw baseball pitchers use, softball pitchers have a more underhand, windmill source motion. There are specific studies that have found the biceps labrum complex also appears to be at risk with softball players because of the high magnitudes of shoulder distraction stress and elbow extension torque just before ball release (Werner, 2005). The biomechanics of this throw can cause great injury to the overhead pitchers if their biomechanics are not fundamentally sound.

Additionally, softball pitchers do not have a maximum number of innings or pitches they can throw in one week while elite baseball does (Werner, 2006). Also, the pitching motion is different for softball than it is for baseball and is believed to not put as much stress on the shoulder as the overhand throwing motion does. The windmill pitching motion is made up of 6 different phases: windup, 6 to 3 o'clock, 3 to 12 o'clock, 12 to 9 o'clock, 9 o'clock to ball release, and follow-through (Rojas, 2009). The windmill motion consists of activation of the shoulder, elbow, trunk and wrist. If any alterations happen during the sequence, a decrease in ball velocity and an increase in potential injuries occur (Oliver, 2011).

Few studies have looked at the muscle activation during the phases of the softball pitch. Maffet, Jobe, Pink, Brault, & Mathiyakom (1997) looked at the shoulder muscle firing patterns during windmill softball pitching. More specifically, he looked at 8 muscles: anterior and posterior deltoid, pectoralis major, serratus anterior, supraspinatus, infraspinatus, teres minor, and subscapularis. There were no significant findings with the pitchers' shoulder muscle activation during the wind-up phase due to the variation in how the pitchers perform the wind up phase. During the 6 to 3 o'clock phase, Maffet (1997) found that the anterior deltoid, supraspinatus, and infraspinatus had all maximally fired during this phase to keep the humeral head in the glenoid cavity and provide a fulcrum for deltoid elevation and prevent superior translation of the head. The 3 to 12 o'clock phase has the posterior deltoid and teres minor muscles produce maximal activity; they helped elevate and actively externally rotate the humerus. The next phase, 12 to 9 o'clock phase, the pectoralis major, subscapularis and serratus anterior all fired maximally during this phase and continue to fire at the same maximal intensity into the 9 o'clock to ball release phase. During follow-through, the teres minor remains the most active and all other muscle activity diminishes. Maffet (1997) says this is due to the lateral thigh hit that the pitchers do that help disperse the deceleration forces. Another study by Werner, Jones, Guido, & Brunet (2006) found that none of the pitchers who participated in their study used the thigh hitting release strategy and found that during the following phase, pitchers hips were moving toward a closed position and the shoulders were abducted 3° and flexed -5°. Every softball pitcher has a different windmill and follow-through strategy, therefore a generalization cannot be made about the muscle firing patterns in the shoulder during these phases.

Muscle activity during the windmill softball pitch in the lower extremity have been minimally examined. Those who have studied the muscle firing patterns in the lower extremity have looked at the gluteus maximus and gluteus medius firing. Gluteus maximus firing has been most prominent during the wind-up phase due to stabilization of the pelvis in preparation for the contralateral leg stride and then the second highest was during phase 4 of the pitch when the stride foot was planted. Gluteus medius was most active during the single leg phases to help give support (Oliver, 2011). Another study conducted by Oliver et al. in 2019 looked at the effects of hip abduction fatigue on trunk and shoulder kinematics during throwing and passive hip rotational range of motion in softball players. The study looked at hip abduction fatigue over the course of three consecutive sessions and how it affected overhead-throwing mechanics and hip passive range of motion in Division 1 collegiate softball players. The study found that hip abduction fatigue didn’t affect the overhead-throwing mechanics but found it affect hip internal rotation on the throwing side. (Oliver, 2019).

Another study completed by Oliver, Plummer, Washington, Saper, Dugas, and Andrews in 2018 looked at the pitching mechanics in female youth fastpitch softball players. The study wanted to examine the pitching mechanics of Little League softball pitchers and the relationship of the mechanics and participant anthropometrics to ball velocity (Oliver, 2018). The kinematic parameters looked at in this study were trunk flexion, trunk lateral flexion, trunk rotation, pelvis anterior/posterior tilt, pelvis lateral flexion, pelvis rotation, shoulder horizontal abduction, shoulder elevation, elbow flexion, stride leg knee flexion and stride length. The anthropometrics looked at in the study were the participants' age, height, and weight. The study looked at 23 youth softball pitchers and had each participant complete three fastball trials over the regulated distance to the catcher. The findings of the study included the older the pitcher, the greater ball velocity was achieved. The study also found the more trunk flexion a pitcher had throughout the pitching motion also caused greater ball velocity. There was no statistically significant finding about pelvis and shoulder mechanics increasing ball velocity and the significant relationships found between pitching mechanics and ball velocity only occurred at the trunk (Oliver, 2018).

A study performed by Varnell et al (2016) compared the musculoskeletal characteristics of intercollegiate baseball and softball players by both position and sport. This study hypothesized that baseball players and softball players would demonstrate unique musculoskeletal characteristics. The study found that no significant differences in ROM between baseball and softball position players, however the upper trapezius muscle was significantly weaker in the softball position players compared to the baseball position players. The study found that position players would need stronger shoulder internal rotators using the traditional throwing motion whereas the windmill pitchers need stronger external rotators. Softball pitchers need greater strength in the upper trapezius and serratus anterior muscles in order to perform the windmill pitching motion. The motion requires upward rotation of the scapula, meaning the serratus anterior and upper trapezius have to adapt to this change in order to keep glenohumeral alignment. Internal rotation torque generated by the delivering phase in windmill softball pitching was found to be similar in magnitude to overhead pitching (Oliver, 2011). The firing of the biceps brachii muscle during the windmill pitch compared to overhead pitch was found to be significantly lower in the overhand throw (Rojas, 2009). The maximum biceps brachii activity was found during 9 o'clock to ball release phase of the pitch. During this phase the elbow joint is in its minimum flexion angle, therefore using the biceps eccentrically (Rojas, 2009).

Shoulder range of motion, pitch count, and injuries among interscholastic female softball pitchers was looked at by Shanley, Michener, Ellenbecker, and Rauh (2012). This study involved 12 uninjured female softball pitchers and measured their shoulder internal, external, total arc of rotation and horizontal adduction passive range of motion. This study found that passive range of motion for horizontal adduction was different in the dominant arm compared to the nondominant arm of the pitchers examined. Internal rotation, external rotation and total arc of rotation was found to be similar between the nondominant and dominant arm of those measured for the study. Shanley, Michener, Ellenbecker, & Rauh, (2012) then looked at how many pitches the pitchers threw a game and how many games they pitched over the course of a 10-week season. The study found that the average number of pitches thrown over the season was 745, with two pitchers throwing over 1500 pitches. Throwing over 1500 pitches a season is a lot for someone to do; this is the reason why we need to put a limit on pitch count during the week. Two pitchers were injured during the season, and each averaged almost 1200 pitches a season while the other 10 healthy pitchers threw 660 pitches a season. By using this study, coaches and athletic trainers can look at the pitch count that high school pitchers accumulate and why they might be injured. Coaches and athletic trainers can also use this study to help set a pitch count that windmill softball players can not go over; just like there are for baseball.

Critical Research

Although pitch count may be one important variable to consider, there is very little evidence on how or what the causes are for injuries in softball pitchers. Smith, Davis, Brophy, Prather, Garbutt, & Wright (2015) found that there were 18 injuries in the 48 youth softball pitchers he surveyed that were directly related to pitching. Eleven of the 18 injuries found were related to the shoulder and occurred in the first 6 weeks of the season. Nine of the 11 shoulder injuries were marked as "shoulder pain"; Four pitchers with this diagnosis did not miss any games while 3 pitchers were out for the whole season. Another study regarding softball injuries was performed by Loosie, Requa, Garrick, & Hanley (1992). They found that out of 24 collegiate pitchers, nine had shoulder injuries, four had elbow injuries, one involved the forearm, and three had hand injuries. The types of the injuries found were primarily strains and tendonitis, which demonstrates that softball pitchers do get overuse injuries. The information from these two articles illustrates a possible need for a rehabilitation program or a strengthening program for athletes to do prior to the season or during the season to help decrease the risk of shoulder and overuse injuries.

The question remains whether the softball pitchers need a different resistance training or conditioning program than their teammates. As stated previously, the windmill pitchers need greater upper trapezius and serratus anterior strength than those who throw overhand. According to Hill, Humphries, Weidner (2004), they surveyed 179 softball pitchers, and 125 responded that they do the same workout as their teammates. Out of the 125 who did the same workout, 89 pitchers were injured. No training factors emerged as being significantly related to injury incidence. A practical application Hill, Humphries, & Weidner (2004) suggests a position-specific training program that can incorporate some cross-training techniques. The program should hit target muscles such as the rotator cuff and groin areas but should prevent muscle imbalances and enhance joint stability. Cross training should also be implemented into the training programs to prevent overtraining of the muscles. Aerobic conditioning, pool workouts, and biking were all suggested to help reduce the stress placed on the body during the pitching motion. Another clinical application was limiting the number of pitches thrown over a week's time. The amount of specific pitches windmill pitchers throw can also be limited. For example, a pitcher can throw more fastballs than curveballs during the week. Pitchers can incorporate light days that focus on lower-body timing and wrist snaps rather than having a pitching workout every day. Even though this study did not separate the softball players into different positions, this study can be used to further the research in scapular stabilizer strength by separating the players into different positions and looking to see if there is a difference in strength between the different positions.

A study performed by Sauers, Dykstra, Bay, Bliven, & Snyder (2011) looked at the Health-Related Quality of Life (HRQOL) and upper extremity injury history. Twenty-five high school and collegiate softball pitchers were given a packet that contained the Disabilities of the Arm, Shoulder, and Hand (DASH), the Functional Arm Scale for Throwers (FAST), a self-report questionnaire of arm injury history, and a HRQOL. The packet was given to the pitchers during the later portion of the season by their athletic trainers. This study found that the DASH and FAST scores were significantly correlated and that having a history of arm injury is common in female high school and college softball pitchers. The study concluded that injury and elevated pain are associated with a lower HRQOL that extends past playing softball and into the daily lives of the pitchers in the study.

A study was done by Scarborough, McCunney, Berkson, and Oh in 2019 that looked at elbow alignment and kinematics on shoulder torque during the softball pitch. The elbow alignment was assessed by looking at the carrying angle and elbow passive range of motion extension angle. The study found that carrying angle correlated positively with shoulder extensive torque and forearm pronation at ball release. "Our findings suggest that stresses placed on the shoulder extensor muscles will be greater among pitchers with a larger carrying angle because the shoulder incurs greater extension torque than those pitchers with smaller carrying angles when the musculature creates the abrupt breaking motion for ball release." (Scarborough, pg. 362, 2019).

When looking at softball pitchers over the course of a multiple-day tournament, Skillington, Brophy, Wright, and Smith (2017) looked at the effect of pitching consecutive days in youth fast-pitch softball. The main focus of this study was on objective shoulder strength and subjective shoulder symptoms. Fourteen female fast-pitch softball pitchers were reviewed over the course of a 2 to 3-day tournament. Shoulder strength was measured by hand-held dynamometer in the motions of shoulder abduction, flexion, internal rotation, external rotation, elbow flexion, and elbow extension. The pitchers were assessed for strength before their first game of the day and after their last game of the day. The pitchers were asked to rate their shoulder pain and fatigue by using a visual analog scale (VAS) and asked on a scale of 0 to 10 what their pain or fatigue was. The study found that pitchers' shoulder pain increased by 1.3 and shoulder fatigue increased by 2.0 on the VAS. Over the course a single day, pitchers had lost a significant amount of strength in 7 of the 9 strength tests conducted; 8 out of 9 strength tests decreased over the course of the whole tournament, with only external rotation not reaching statistical significance. This study can draw the conclusion that the pitchers did not get enough recovery time between days. Shoulder pain, fatigue and strength did not recover to full strength over the course of the tournaments. Shoulder internal rotation, flexion, and abduction had the greatest strength changes seen during the study. This finding was found to coincide with the demands placed on the upper extremity while pitching. Skillington (2017) suggests that further research is needed to see if windmill pitchers are at a more predisposing risk to injury to the lack of recovery time between consecutive tournament days. How these biomechanical stresses change throughout the season has yet to be studied. In order to treat or prevent such injuries, further research should include the time of season that a softball pitcher is more susceptible.

Literature Summary

The current literature has a lack of studies focusing on the scapular stabilizers. When looking at all of the studies from this review, the researcher wanted to do a similar study to Skillington's due to the fact they used a hand-held dynamometer to obtain strength measurements. The researcher also wanted to use a patient-reported outcome (PRO) to see if loss of scapular stabilizer strength affected the softball player's activities of daily living. Focusing solely on the scapular stabilizers, stems from the researcher's experience working with a softball team and taking note that almost all the softball players who complained of "shoulder pain" had weakness in the scapular stabilizer muscles.

Methods

Participants

The participants of the study were collegiate softball players of all positions from a private, Division III university. Twenty-three players were contacted about the study, 13 reported for the first round of testing, and 11 reported for the second and third round of testing. The participants were contacted by email from a roster given to the researcher by their coach. They were contacted prior to the first round of testing explaining what the study entails and where/when it would take place. The initial email also explained that participation in the study is completely voluntary and will not affect the participants' relationship with the coaches or the team. All participants are right-handed and throw with their right hand. Each participant underwent the same process. Every participant served as their own control, meaning their pre-season data measurement will be compared to their mid-season data measurement and their post-season data measurement. This study was approved by the University Institutional Review Board.

Materials

The materials used in this study consisted of a micro-FET hand-held dynamometer with the units in Newtons, the threshold low, and using the circular pad. The patient reported outcome (PRO) that will be administered to participants is the Disabilities of the Arm, Shoulder, and Hand (DASH). These materials were used at all three data collections.

Design

The design of the study is a repeated measures design because it is looking at the strength of scapular stabilizer force output over the course of a fall season and used each subject as their own control. There is a relationship between the time in which the measurements are taken and whether the softball players have strength deficits over the course of a 4-week season. There are three different levels to the independent variable, and each level is the different testing time, pre-season, mid-season, and post-season. The dependent variable is the recorded strength measurements recorded. Each softball player is their own control in the study, meaning their baseline will be what we compare the different measurements too.

Procedure

Prior to the beginning of testing, a pilot study was run to gain intrarater reliability and to gain practice when using the hand-held dynamometer. The results from the pilot study can be found in tables 1 and 2.

Table 1: Day 1 of Pilot Study * = position change between days one and 2 of pilot study

Day 1 Participant #	Y average	T average	T w/ thumb up average	*Row average	*I average
1	38.96	44.0	23.66	111.6	57
2	33.03	46.1	32.9	71.6	39.6
3	33.03	27.2	21.76	30.9	18.8
4	34.93	46.9	35.56	68.6	40.9

Day 2 Participant #	Y average	T average	T w/ thumb up average	*Row average	*I average
1	44	47.2	31.7	61.8	48.4
2	45.63	50.83	36.86	43.57	24.7
3	29	33.8	34.3	42.9	27.8
4	44.4	50.4	43.1	45.8	37.8

Table 2: Day 2 of Pilot Study * = position change between days one and two of pilot study

There were a total for 4 participants in the pilot study and there was a 48 hour time period between the two testing days. During the pilot study, between days one and two, the examiner position changed due to finding a more optimal position to not allow force exerted by the examiner to be recorded. To help with this problem, during testing, the examiner stood on a box during the rhomboids major and minor (“Row”) testing position and the latissimus dorsi (“I”) testing position.

Each participant was asked to sign a consent form in order to help with study. Measures were taken at the beginning, the middle, and the end of the fall ball season by using a hand-held dynamometer. The different muscles that the softball players were tested on included the lower trapezius (“Y”), middle trapezius (“T”), infraspinatus (“T with thumb up”), rhomboids major and minor (“Row”), and latissimus dorsi (“I”). Pictures of the testing positions can be found in Appendix A.

The instructions for the various positions were as followed: for the prone Y position, participants were asked to lie on their stomach with their throwing arm hanging off the table. The participant was then asked to bring their arm up in a diagonal direction with their thumb pointing toward the ceiling. The investigator then placed a hand-held dynamometer close to their wrist and asked the participants to push upward into their hand. This position was testing the strength of the lower trapezius. For the prone T position participants were asked to lie on their stomach with their throwing arm hanging off the table. The participant was then asked to bring their arm up straight to the side with their thumb pointing parallel to the floor. The investigator then placed a hand-held dynamometer close to their wrist and proceeded to ask the participant to push upward into their hand. This position tested the middle fibers of the trapezius. The participant was then asked to rotate their arm until their thumb was pointing to the ceiling. The investigator then placed a hand-held dynamometer close to their wrist and proceeded to ask the participant to push upward into their hand. This position was testing the infraspinatus. For the prone row, participants were asked to lie on their stomach with their throwing arm hanging off the table. The participants were then asked to bend their elbow and bring their hand toward their armpit so their elbow will form a 90° angle. The investigator then placed a hand-held dynamometer on the bent elbow of the participant and proceeded to ask the participant to push upward into their hand. This position tested both the major and minor rhomboids. For the prone I position participants were then asked to lie on their stomach with their throwing arm hanging off the table. The participants were then asked to bring their arm up parallel to their leg with their thumb pointing perpendicular to the floor. The investigator placed a hand-held dynamometer close to their wrist and proceeded to ask the participant to push upward into their hand. The position tested the latissimus dorsi. After the strength measures were taken, the participants will complete a DASH form. The DASH scores and strength measurements were then inputted into an Excel sheet for data analysis to occur. Each subject had three trials measured for each variable at each point in the season. For analysis, the average of those three trials was calculated and used for all further analysis. In order to examine the parametric data or interval data, an explore procedure was completed within SPSS to provide the investigators with descriptive statistics for each variable. After each variable was examined for descriptive statistics, the investigators also evaluated each variable for skewness and kurtosis to determine if we could proceed with parametric analysis. All data points met the criteria to proceed with further parametric analysis and therefore a repeated measures ANOVA was used to examine each variable across the course of the season. A p value of ≤ 0.05 was set for all data analysis.

Results

After completing an ANOVA analysis of the data, the investigators found a statistically significant difference between the baseline and mid-season data collection for the Y position ($p = 0.000$), T position ($p \leq 0.001$), T with thumb up ($p \leq 0.002$), and I ($p \leq 0.001$). A statistically significant difference was also found between mid-season and end-of-season data for the T with thumb up ($p \leq 0.000$), T ($p \leq 0.000$), and Y ($p \leq 0.011$). Between the beginning of the season measurements and the end-of-season measurements, all five strength measurements were found to have statistically significant decrease in strength. There was no statistically significant difference in DASH scores between the three different data measurements. The mean values of each position and DASH scores over the course of the pre-season, mid-season, and post-season can be found in Table 3.

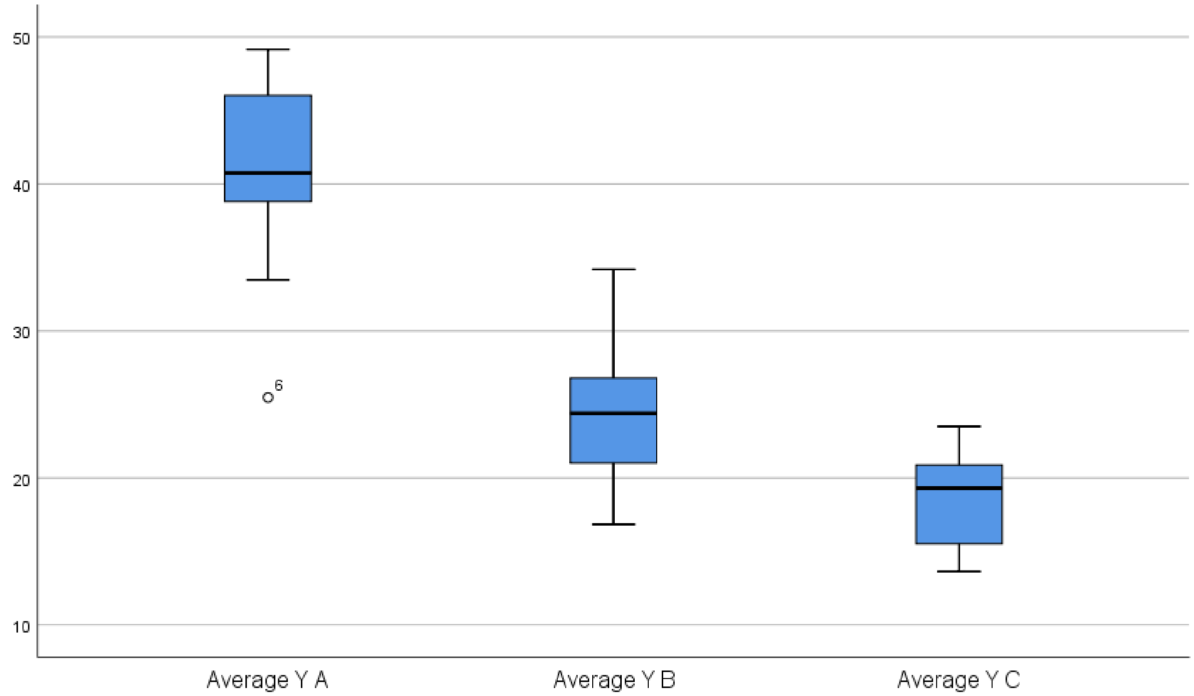
Testing Position	Pre-Season Mean ± SD	Mid-Season Mean ± SD	Post-Season Mean ± SD	P-value between pre & post season

"Y" - lower trap	40.41 $\pm$ 2.21	24.19 $\pm$ 1.58	18.89 $\pm$ .99	0.000*
"T" - mid trap	39.61 $\pm$ 2.00	27.59 $\pm$ 1.10	19.38 $\pm$ 1.31	0.000*
"T w/ thumb up" - infraspinatus	32.95 $\pm$ 1.77	25.69 $\pm$ 1.20	19.33 $\pm$ 1.37	0.000*
"Row" - Rhomboids	37.37 $\pm$ 2.68	29.29 $\pm$ 2.75	25.35 $\pm$ 1.7	0.000*
"I" - latissimus dorsi	35.24 $\pm$ 2.15	24.25 $\pm$ 2.49	21.41 $\pm$ 1.35	0.000*
DASH	9.44 $\pm$ 2.58	8.74 $\pm$ 3.33	8.85 $\pm$ 5.35	1.000
Sport DASH	8.75 $\pm$ 2.50	11.25 $\pm$ 3.46	11.88 $\pm$ 6.00	1.000

Table 3: Results * = statistically significant finding

The "Y" position had a mean value of 40.41 in the first round of testing, 24.19 in the second round of testing and 18.89 after the third round of testing. The values and standard deviation of the "Y" values after each round of testing in Figure 1, a box-and-whisker plot. The "Y" values were found to have statistically significant difference in values between the first round to the second round of testing ($p \leq 0.000$), from the second round of testing to the third round of testing ($p \leq 0.011$), and the first to the third round of testing ($p \leq 0.000$). The pairwise comparison of the statistically significance can be found in Table 4.

Figure 1 Box and Whisker Plot of Y force output values. The box and whisker plot shows the average values of the three trials between the 11 participants.



Pairwise Comparisons

Measure: MEASURE_1

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	16.218*	2.499	.000	8.887	23.549
	3	21.517*	2.466	.000	14.285	28.749
2	1	-16.218*	2.499	.000	-23.549	-8.887
	3	5.299*	1.361	.011	1.307	9.291
3	1	-21.517*	2.466	.000	-28.749	-14.285
	2	-5.299*	1.361	.011	-9.291	-1.307

Based on estimated marginal means

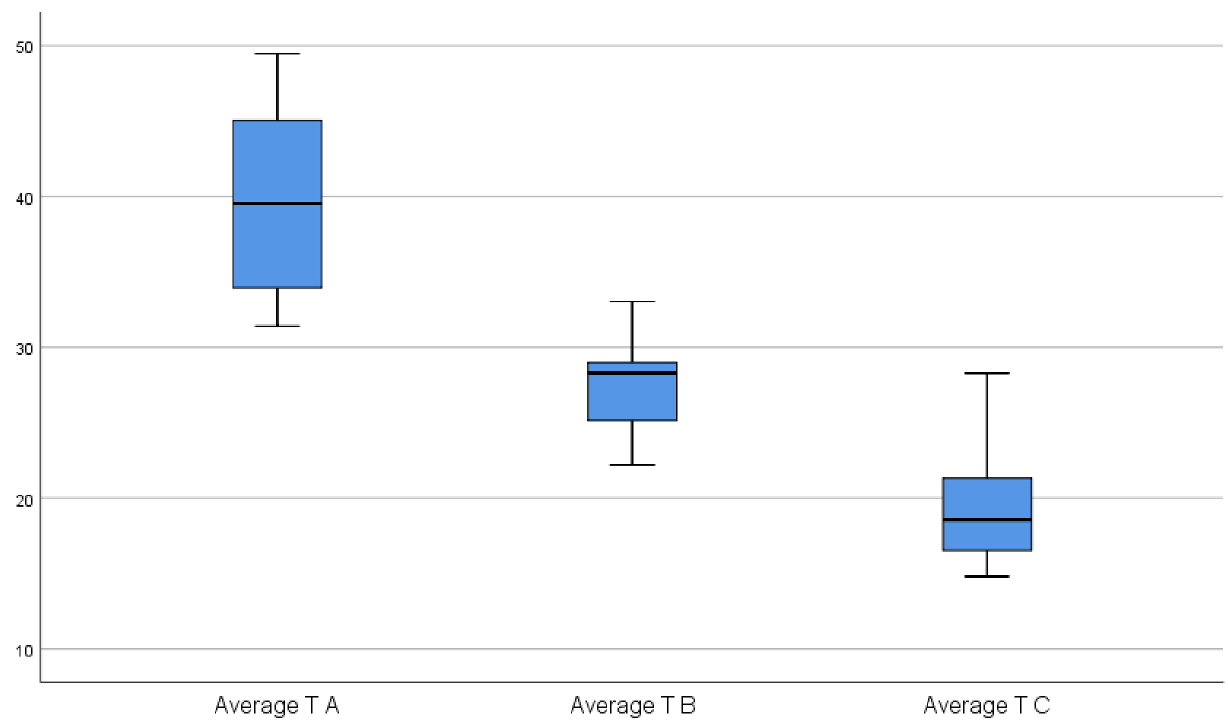
*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Table 4: Pairwise Comparison of the force output values of "Y" from data collections pre-season, mid-season, and post-season.

The mean “T” values in the pre-season between participants were found to be 39.61, 27.59 at the mid-season data collection, and 19.38 at the post-season data collection. The average values of the different participants can be found in Figure 2. There was statistically significant difference found between the pre-season data collection and the mid-season data collection ($p \leq 0.001$), between the mid-season and post-season ($p \leq 0.000$) and between pre-season and post-season ($p \leq 0.000$). The pairwise comparison of the “T” values can be found in Table 5.

Figure 2 Box and Whisker Plot for “T” force output values.



Pairwise Comparisons

Measure: MEASURE_1

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	12.017*	2.131	.001	5.767	18.267
	3	20.230*	2.026	.000	14.286	26.174
2	1	-12.017*	2.131	.001	-18.267	-5.767
	3	8.213*	1.131	.000	4.895	11.531
3	1	-20.230*	2.026	.000	-26.174	-14.286
	2	-8.213*	1.131	.000	-11.531	-4.895

Based on estimated marginal means

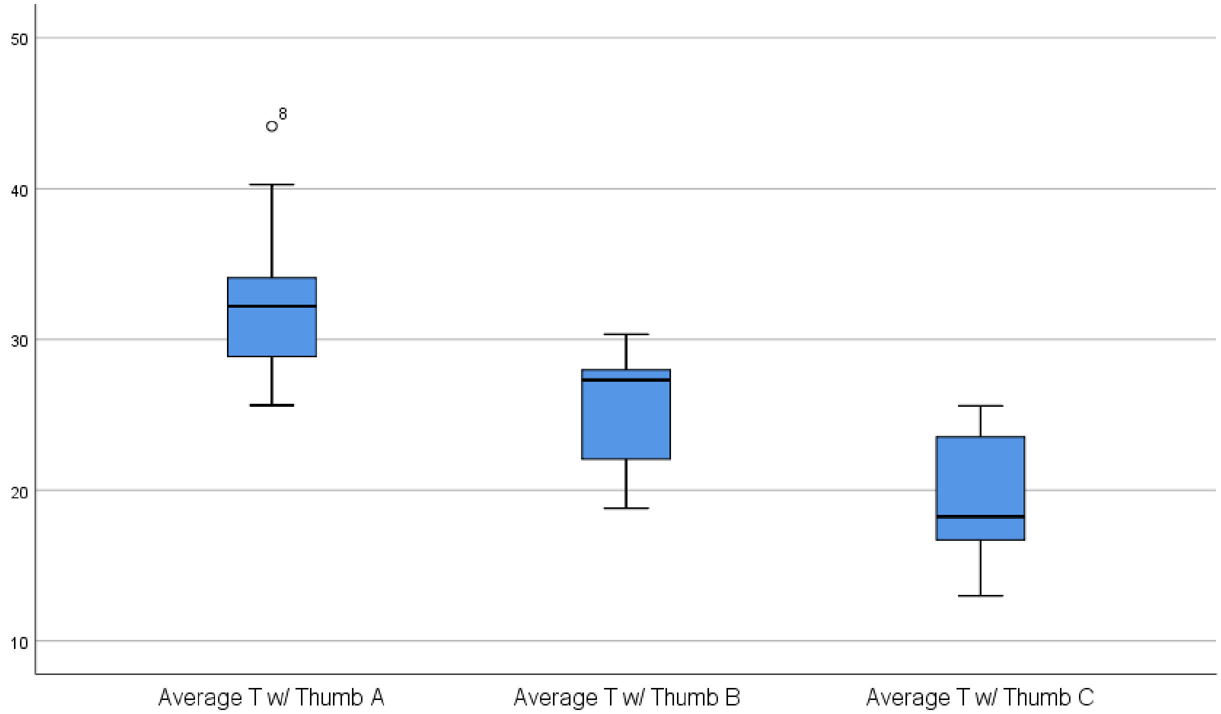
*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Table 5: Pairwise Comparisons of the pre-season, mid-season, and post-season for "T" force output measurements.

The "T with thumb up" force output measurements were found to have a mean value of 32.95 at the pre-season data collections, 25.69 at the mid-season data collections, and 19.33 at the post-season data collections. The average values of "T with thumb up" can be found in Figure 3. There was found to be a statistically significant decrease in force output between the pre-season data collection and mid-season data collection ($p \leq 0.002$), mid-season and post-season ($p \leq 0.000$), and between the pre-season and post-season data collections ($p \leq 0.000$). The pairwise comparisons of the three different data collections can be found in Table 6.

Figure 3: Box-and-Whisker Plot of the average values from the three different data collections for "T with thumb up".



Pairwise Comparisons

Measure: MEASURE_1

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	7.253*	1.387	.002	3.185	11.321
	3	13.617*	1.463	.000	9.326	17.908
2	1	-7.253*	1.387	.002	-11.321	-3.185
	3	6.364*	.869	.000	3.814	8.914
3	1	-13.617*	1.463	.000	-17.908	-9.326
	2	-6.364*	.869	.000	-8.914	-3.814

Based on estimated marginal means

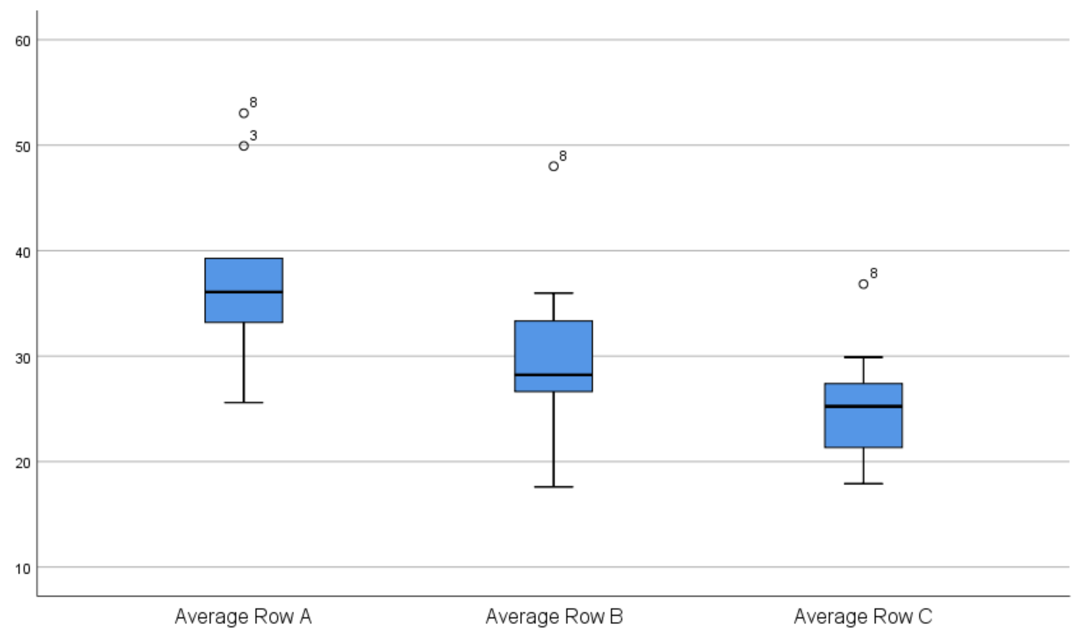
*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Table 6: Pairwise Comparison for "T with thumb up" force output for the pre-season, mid-season, and post-season

The “Row” force output measurements had a mean value of 37.37 in the pre-season, 29.29 in the mid-season, and 25.35 in the post-season. The average values can be found in Figure 4. The “Row” did not have a statistically significant decrease in force output between the pre-season and mid-season data collection ($p \leq 0.053$) and between mid-season and post-season data collection ($p \leq 0.168$). There was a statistically significant decrease between the pre-season and post-season data measurements ($p \leq 0.000$). The pairwise comparison can be found in Table 7.

Figure 4: Box-and-Whisker Plot of “Row” force output values pre-season, mid-season, and post-season.



Pairwise Comparisons

Measure: MEASURE_1

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	8.083	2.793	.053	-.109	16.275
	3	12.025*	1.734	.000	6.939	17.111
2	1	-8.083	2.793	.053	-16.275	.109
	3	3.942	1.797	.168	-1.328	9.212
3	1	-12.025*	1.734	.000	-17.111	-6.939
	2	-3.942	1.797	.168	-9.212	1.328

Based on estimated marginal means

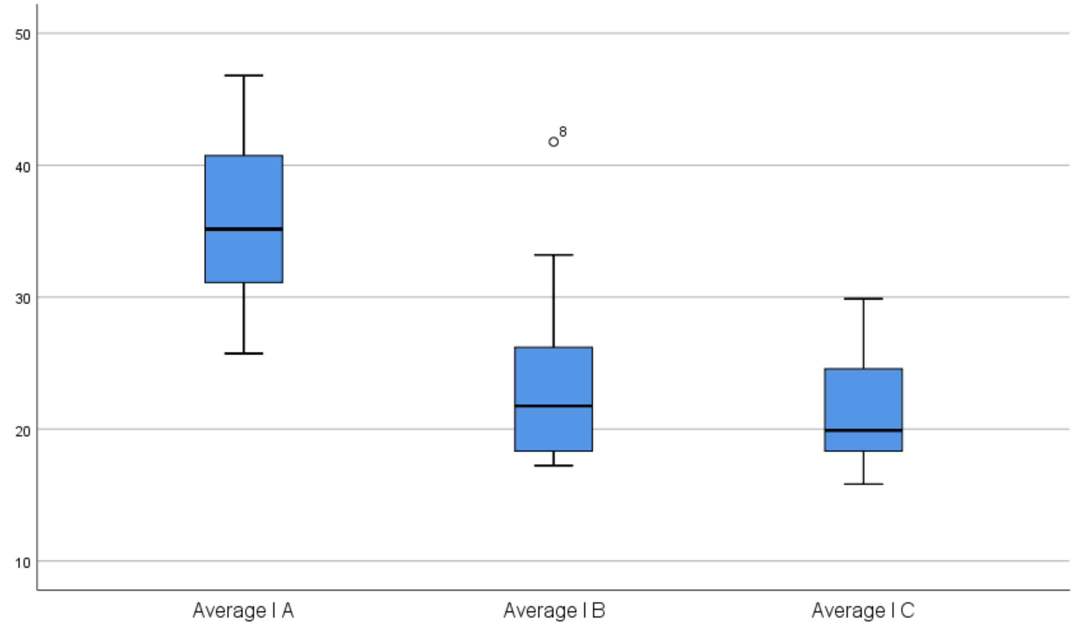
*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Table 7: Pairwise Comparison of "Row" force output values, pre-season, mid-season, and post-season

The "I" had a force output measurement mean of 35.24 in the pre-season data collection, 24.25 at the mid-season data collection, and 21.41 at the post-season data collection. The average values of the "I" force output measurements can be found in Figure 5. The "I" position did not have a statistically significant difference between the mid-season and post-season data collections ($p \leq 0.694$). There was a statistically significant decrease in force output measurements between the pre-season and mid-season ($p \leq 0.001$) and between the pre-season and post-season data collection ($p \leq 0.000$). The pairwise comparison can be found in table 8.

Figure 5: Box-and-Whisker plot of the average force output values of the "I" position pre-season, mid-season, and post-season.



Pairwise Comparisons

Measure: MEASURE_1

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	10.989*	1.907	.001	5.397	16.581
	3	13.836*	2.063	.000	7.784	19.888
2	1	-10.989*	1.907	.001	-16.581	-5.397
	3	2.847	2.218	.694	-3.658	9.352
3	1	-13.836*	2.063	.000	-19.888	-7.784
	2	-2.847	2.218	.694	-9.352	3.658

Based on estimated marginal means

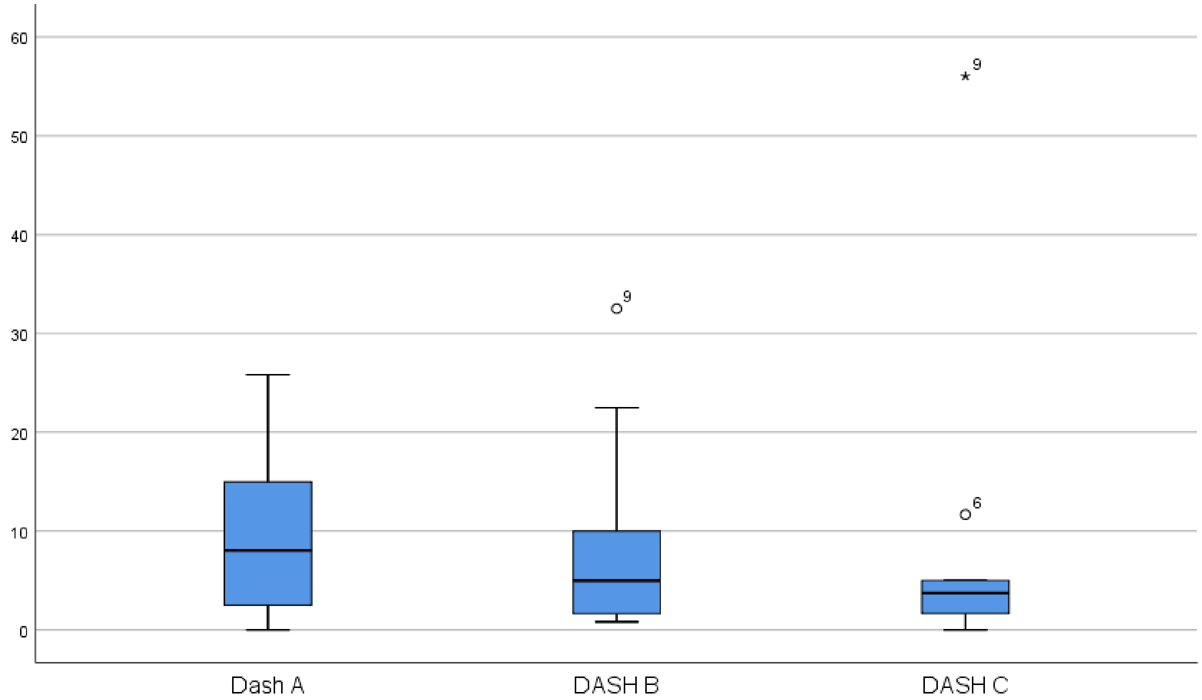
*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Table 8: Pairwise Comparison of the "I" position in the pre-season, mid-season, and post-season force output measurements

The DASH had a mean value of 9.44 in the pre-season data collection, 8.75 in the mid-season, and 8.85 at the post-season data collection. The average values of the DASH scores can be found in Figure 6. There was no statistically significant decrease in scores between the pre-season and mid-season (p ≤ 1.000), mid-season to post-season (p ≤ 1.000), and pre-season to post-season (p ≤ 1.000). A pairwise comparison between DASH scores can be found in Table 9.

Figure 6: Box-and-Whisker plot of the average DASH scores of the course of the pre-season, mid-season, and post-season.



Pairwise Comparisons

Measure: MEASURE_1

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	.696	2.212	1.000	-5.794	7.186
	3	.590	4.721	1.000	-13.259	14.439
2	1	-.696	2.212	1.000	-7.186	5.794
	3	-.106	2.838	1.000	-8.431	8.219
3	1	-.590	4.721	1.000	-14.439	13.259
	2	.106	2.838	1.000	-8.219	8.431

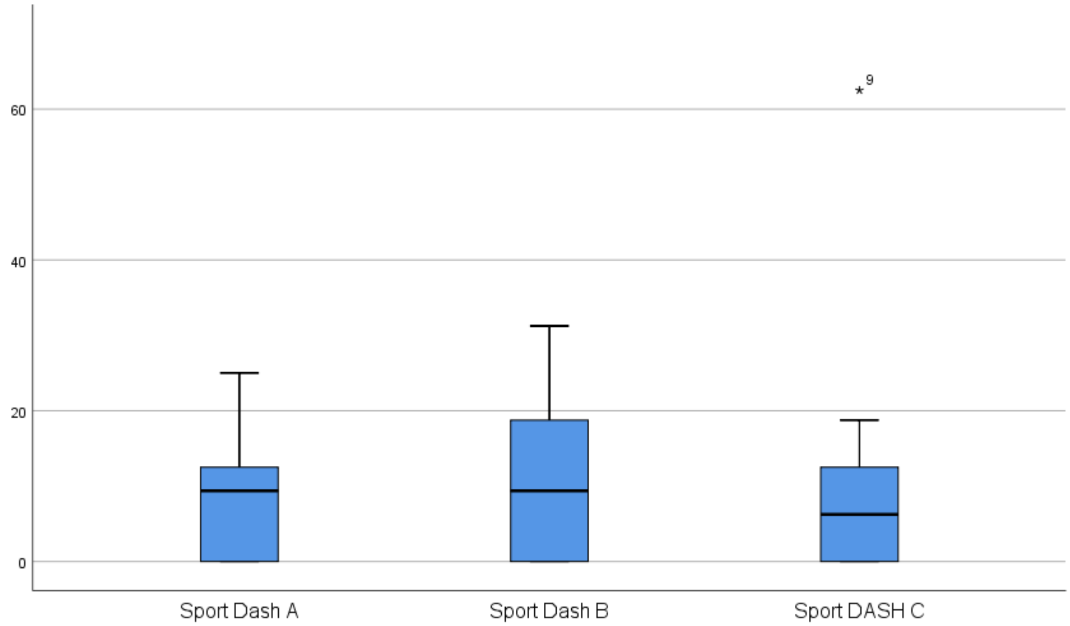
Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Table 9: Pairwise Comparison of the DASH scores between the pre-season, mid-season, and post-season data collections

The mean value of the Sport DASH during the pre-season data collection was 8.75, 11.25 at mid-season, and 11.88 at post-season data collection. The values of Sport DASH can be found in Figure 7. There was no statistically significant decrease or increase in scores between the pre-season and mid-season ($p \leq 1.000$), mid-season to post-season ($p \leq 1.000$), and pre-season to post-season ($p \leq 1.000$). A pairwise comparison of the values can be found in Table 10.

Figure 7: Box-and-Whisker Plot of values of the Sport DASH in the pre-season, mid-season, and post-season.



Pairwise Comparisons

Measure: MEASURE_1

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-2.500	2.500	1.000	-9.833	4.833
	3	-3.125	4.395	1.000	-16.016	9.766
2	1	2.500	2.500	1.000	-4.833	9.833
	3	-.625	5.389	1.000	-16.431	15.181
3	1	3.125	4.395	1.000	-9.766	16.016
	2	.625	5.389	1.000	-15.181	16.431

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Table 10: Pairwise Comparison of the Sport Dash scores between the pre-season, mid-season, and post-season.

Discussion

This purpose of this study was to help bridge the gap of literature between softball and baseball players with a focus on the strength of the scapular stabilizers. This study found that there was a statistically significant strength decrease in the lower trapezius, rhomboids major and minor, infraspinatus, middle trapezius, and latissimus dorsi in softball players over the course of a fall, non-traditional season. These findings are consistent with the results of the Skillington (2017) study that looked at softball pitchers and tested the strength of the pitchers over a 2-3-day tournament in the actions of shoulder flexion, abduction, internal and external rotation, and elbow flexion and extension. Skillington (2017) found that the strength in the softball pitchers decreased over the course of the tournament which was only a 2-3-day period, especially in the internal rotation, abduction and flexion motions. This study found significant strength decreases across all 5 strength measures of the scapular stabilizer muscles.

When looking at the DASH scores of this study, there was no statistically significant decrease or increase in scores. Another aspect of the DASH that could be looked at is the Minimal Clinically Importance Difference (MCID). A study done by Franchignoni, Vercelli, Giordano, Sartorio, Bravini, and Ferriero (2014) looked at the MCID on the DASH and QuickDASH and found that the MCID of the DASH was 10.83, which was on the lower bound of the reported MCID from the DASH website. The study had 255 patients take the DASH before and after a physical therapy program was implemented and found the test and retest reliability was high and that the minimal detectable change was 10.81. When looking at the DASH scores from our study, there were three times that DASH scores were greater than or equal to the MCID of 10.83. One participant had a score of 17.50 in the preseason, 32.50 at the mid-season, and a 56.03 during the postseason; each of these values went up at least 1 factor of 10.83, which shows the participant's activities of daily living function went down.

Another aspect that could be discussed about this study was researcher fatigue. When taking into consideration further, researcher fatigue should be considered because taking three measurements, at least because something the hand-held dynamometer would slip off the wrist of the participant and make the trial incomplete, at five different positions for 11 participants adds up to total of at least 165 strength measurements. After the first testing period, the researcher experienced soreness in their arm the following day, but never experienced fatigue while the data collection was happening. This needs to be taken into consideration when using a hand-held dynamometer in a bigger study; the research may experience fatigue after taking many data collections which can affect the data of the study.

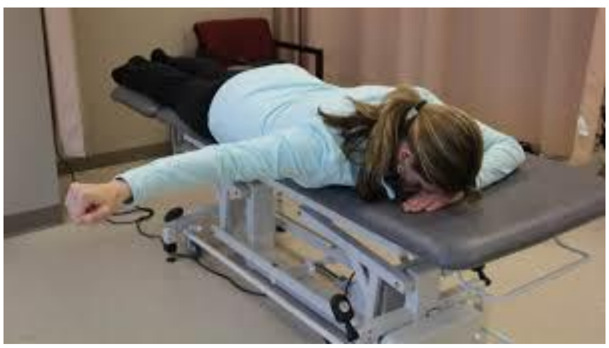
The last point of discussion would be practice using a hand-held dynamometer. Prior to the pilot study, the only experience that the researcher had using hand-held dynamometer was in a classroom setting once or twice prior. The reason for the pilot study was to gain practice using the hand-held dynamometer prior to the actual data collection. Another factor could be over the course of the study, the researcher gained confidence using the hand-held dynamometer and increased her skills when it came to using it on the various testing positions. Practice using a hand-held dynamometer should be done prior to initiating a study of this nature to ensure that the researcher knows how to operate the material and to gain consistent and reliable results.

Conclusion

Scapular stabilizer force output in softball players decreased in all standard test positions from pre-season to post-season over the course of a Fall, non-traditional season. Four of the five positions had statistically significant decreases in force output measurement between pre-season and mid-season data collections. Three of the five standard positions had a statistically significant decrease on force output between the mid-season and post-season data collections. More studies need to be completed over the course of a full softball season measuring scapular stabilizer strength.

Appendix A: Testing Positions

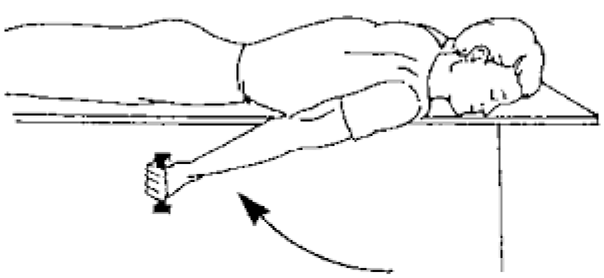
The "Y" testing position Retrieved from: Sears, B. (2019, November 23). Get Control of Your Shoulder and Scapula With These 4 Exercises. Retrieved from http://www.verywellhealth.com/shoulder-stabilization-exercises-2696620



The "T" testing position Retrieved from: Sears, B. (2019, November 23). Get Control of Your Shoulder and Scapula With These 4 Exercises. Retrieved from http://www.verywellhealth.com/shoulder-stabilization-exercises-2696620

The "T with thumb up" testing position Retrieved from: Prone T's. (n.d.). Retrieved from https://www.thestudentphysicaltherapist.com/prone-ts.html

The "Prone Row" testing position Retrieved from: Sears, B. (2019, November 23). Get Control of Your Shoulder and Scapula With These 4 Exercises. Retrieved from http://www.verywellhealth.com/shoulder-stabilization-exercises-2696620



The "I" testing position Retrieved from: Jobe's Shoulder Exercises

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