COMPARING SHOULDER MANUAL MUSCLE TESTING WITH SCAPULAR RETRACTION AND CORE ACTIVATION

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ABSTRACT

The kinetic chain plays a large role in the force production of the body during activity. The core and the scapula are critical kinetic chain links to the upper extremity during overhead motions and should likely be accounted for when performing manual muscle testing of the shoulder. The purpose of this study was to manual muscle test the shoulder with a handheld dynamometer to determine the impact of scapular positioning, core activation, and the effect of the kinetic chain on force production. Forty (40) National Collegiate Athletic Association Division I athletes (23 females, 17 male) were tested in shoulder flexion and abduction in their relative posture, with the scapula retracted, and with the core activated. There were no significant differences within or between the three manual muscle testing conditions for shoulder flexion. Relative posture (15.8±5.0kg) and core activation (15.6±5.2kg) resulted in significantly greater force generation compared to the scapula retracted position (14.7±4.5kg) on the dominant arm for abduction ($p \leq 0.05$). Relative posture (16.6±5.8kg) and core activation (16.0±5.8kg) for abduction on the non-dominant arm resulted in significantly greater force generation than scapular retraction for the dominant arm (14.7±4.7kg) and non-dominant arm (15.0±5.0kg, $p \leq 0.045$). For the female subjects, abduction in relative posture (13.8±2.8kg) resulted in significantly greater force generation compared to the scapula retracted position (12.6±2.6kg) on the dominant arm ($p = 0.038$). For male subjects, non-dominant arm abduction in relative posture (20.5±6.7kg) and core activation (19.8±6.7kg) resulted in significantly greater force generation than scapular retraction (17.4±5.5kg) for both arms (17.9±6.0kg, $p \leq 0.018$). However, while the differences were statistically significant, the effect sizes were so small that the results may not be clinically significant. This suggests that full active scapular retraction or core activation may not aid force generation during shoulder flexion or abduction in high-level collegiate athletes.

Keywords: Shoulder, manual muscle testing, scapular retraction, core activation, handheld dynamometry, kinetic chain

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I. Introduction

Manual muscle testing is an evaluation tool that uses an isometric or eccentric force applied by a clinician to a particular body segment of the patient to determine functionality and strength[1,2]. This type of manual testing is most commonly used to assess the strength of a specific muscle or muscle group. After injury, it is important to be able to accurately test the strength of the muscles to be able to provide the best plan of care for the patient. This information can be used with resource such as the ICF (International Classification of Functioning, Disability and Health) model in which muscular function plays an important role[3]. The methods for manual muscle testing have varied throughout the years, and the efficacy of the practice has been questioned[4-6]. If details such as patient body positioning and clinician hand positioning are not carefully attended, the reliability and accuracy of manual muscle testing can be significantly diminished[1]. For example, muscles can appear stronger or weaker depending on which point of the motion range the limb is tested in. If the limb is tested in a slightly different range of motion than the previous test, the amount of force that the patient is able to produce will be different depending on the limb positioning, and it could provide a false sense of function. Furthermore, if the clinician changes his or her hand positioning when applying force or stabilizing the joint (proximal placement=shorter lever versus distal placement=longer lever), the force output can be altered[1]. To perform a quality manual muscle test, the clinician needs to standardize body positioning and hand placement to ensure that the muscles are being tested in the same way within and between patients in order to not alter the results of the test.

The interpretations of the results of a manual muscle test pose another issue. The strength of the patient is often described based on his or her effort instead of the force that is actually being produced[1]. A subjective 6-level scale has been routinely used to grade the manual muscle tests. It is graded as 5 – full motion with maximal resistance, 4 – full motion against some resistance, 3 – full motion against gravity, 2 – full motion in a gravity eliminated position, 1 – evidence of a contraction without motion, or 0 – no contraction at all[1]. One study measured manual muscle tests of the elbow, hip, and knee muscles and compared a grade 3 using the maximum gravitational moment and grade 5 using isokinetic testing[5]. The difference between the results of the grade 3 gravitational moment and the grade 5 isokinetic testing was examined, and the difference between the two tests was used to calculate the range that could be used to constitute a grade 4 for a manual muscle test. The findings showed that a grade 4 had the potential to include up to 86% of a muscle's strength. If one level on the grading scale is able to cover such a wide range of a muscle's strength, the reliability and accuracy of the grading method would be very low. The clinician would not be able to accurately represent a strength deficit that exists; and should another clinician perform the manual muscle test on the same patient, that clinician may choose a different grading level. The subjective grading method and variation in interpretation of that grading method pose a large need for objective measurements when performing manual muscle tests. Some available options for objective measurements are isokinetic testing, electromyographical analysis, and the use of handheld dynamometry. The two former options are not always practical options when performing a patient evaluation as they are expensive, and the methods of testing are time consuming. Furthermore, electromyography is designed to assess muscle activity, not force output, thus creating a methodological limitation in assessing muscle function. Handheld dynamometry would be a more practical and viable option for obtaining objective manual muscle testing results. This method of muscle testing has been shown to be consistently reliable by various authors[2,4,6-8]. However, it is not used across all clinical practices due to cost limitations. The financial costs of handheld dynamometry devices are not as high as the aforementioned isokinetic and electromyographic testing options, but the costs are high enough to classify them as capital purchases.

Another issue regarding manual muscle testing is that the joints in the body do not function as separate entities. Rather, they all rely on each other to operate as one unit known as the kinetic chain[9-12]. Each body segment works in a sequential manner to move and stabilize the body to produce the maximum amount of force available[12]. Each segment of the body must work together correctly by activating, deactivating, and stabilizing sequentially and synchronously to provide efficient and optimal motions[10]. Regarding upper extremity movements, the trunk and core are a pivotal portion of the kinetic chain[13]. The core simultaneously acts as a stabilizer and mover for the spine during upper extremity motions. Specifically, the multifidi, quadratus lumborum, and transverse abdominus provide stabilization to the spine as the body prepares for movement while the larger rectus abdominis, internal and external obliques, and erector spinae carries out the necessary planar movements that transmit energy up to the shoulder[12]. The energy transmitted from the trunk to the shoulder is made possible via the scapula[9]. The scapula provides the stabilizing link between the force production in the trunk and the energy transfer in the arm[9,11]. When the spinal stabilizers are not firing in the correct sequence, the stability of the spine and activation of shoulder muscles will be altered, thus altering the effectiveness of the desired movement; and if the scapula is not functioning properly within the kinetic chain, shoulder muscle and joint injuries will often be the result[14]. If at any point the segments of the kinetic chain do not function properly, the body will be at more of a risk for injury[15].

Once injury occurs, manual muscle testing is one of the methods often utilized to assess strength and functionality of the muscles. However, manual muscle testing has traditionally attempted to isolate muscles and/or joints, and it does not allow for the sequential activation of various muscles and anatomical segments that is characteristic of the kinetic chain. Since the muscles and joints do not work as isolated entities, performing manual muscle tests as such is a flawed system. Removing the effects of the kinetic chain on a joint could result in an inaccurate test that shows a weakness in the muscles that may not exist to the same extreme when the kinetic chain is utilized. The kinetic chain may have an effect on the amount of force that is able to be produced, and it needs to be taken into account when performing manual muscle tests.

The shoulder joint poses a very specific issue when it comes to manual muscle testing. The shoulder is extremely mobile; therefore, it is also a very unstable joint [16]. It relies on the muscles at the shoulder, scapula, and throughout the rest of the kinetic chain to provide the stability to the joint. Interestingly, the muscles attached to the scapula provide 90% of the stabilization during shoulder movement[16]. However, many clinicians do not consider how the positioning and movement of the scapula can affect the strength that is produced in relation to the shoulder. Although shoulder muscles may appear weak, the demonstrable weakness may in fact be due to altered scapular position or function. Altered scapular movement during arm motion is commonly termed scapular dyskinesis[17].

Scapular dyskinesis is seen as abnormal movement of the scapula[18]. It can result in excessive protraction, anterior tilt, and internal rotation[12,16]. Scapular dyskinesis has been identified as an impairment in many athletes as well as healthy individuals, and it can be viewed as a disruption within the kinetic chain[12]. This alteration of the kinetic chain is capable of causing injury to the shoulder and decreased ability to produce strength[19]. When the scapula is not able to provide the stable base for the shoulder muscles, they are not able to contract with their maximum potential[16]. The increase in scapular protraction can also inhibit the rotator cuff's ability to contract maximally as well as decrease the shoulder's ability to produce force during elevation[16,20]. Scapular dyskinesis does appear to disrupt the kinetic chain and decrease force output during overhead activities [11,12,15-17,19,21]. Scapular positioning while performing a manual muscle test is less certain. One study showed that any large deviation away from a patient's self-reported neutral either in protraction or retraction caused a decrease in force production[20]. Other studies showed increased force production from the supraspinatus when a researcher lightly held the scapula in retracted position[22,23]. However, these studies only examined the influence of scapular position on shoulder flexion.

Considering the aforementioned literature only examined one shoulder motion and the impact of scapular positioning on force output, a prominent gap exists for clinical practice regarding scapular positioning during manual muscle testing of the shoulder. Therefore, the purpose of this study is to manual muscle test the shoulder with a handheld dynamometer to determine the impact of scapular positioning, core activation, and the effect of the kinetic chain on manual muscle testing. The researchers hypothesize that the subjects will be able to produce more force with scapular retraction and core contraction. This research could help to give insight on how these two factors affect the manual muscle testing of the shoulder.

II. Literature Review

Manual muscle testing has been used for many years to assess the strength and functionality of a muscle to help determine whether there is a weakness or compensation present. This method is used by various clinicians including chiropractors, physical therapists, orthopedic surgeons, neurologists, physiatrists, and athletic trainers. It is an economical way to test the functionality of a muscle or muscle groups. It can give practitioners insight to the injury, strengths, weaknesses, and disabilities of that particular person. Manual muscle testing is an important component when attempting to assess the disability and functionality level of a patient. This is especially true when using resources such as the ICF (International Classification of Functioning, Disability and Health) model in which muscular function plays an important role[3]. When used correctly, manual muscle testing can be a helpful tool to use in the evaluation and rehabilitation process. It can be used initially in the evaluation to assess strengths and weaknesses that can lead the clinician to a better understanding of the injury or issues that the patient is dealing with. It can also be used throughout the rehabilitation process to track progress. Setting goals throughout the rehabilitation process can help to maintain motivation and effort[24]. Using manual muscles tests to show how the patient has increased in strength could be very useful in helping with goal setting. It may also be helpful to the clinician in assessing the effectiveness of their rehabilitation program.

Uses of Manual Muscle Testing

Manual muscle testing has many uses in the evaluation process. It is the use of isometric or eccentric force from a clinician on the body segment of the patient, and the most common use for manual muscle testing is to test the strength and function of the muscle[1,2]. When a patient is injured, performing manual muscle tests can help detect which muscles are weak or inhibited to gain a better understand of the injury sustained.

Manual muscle testing can also be very helpful for testing neurological function. Myotomes are sections of the musculoskeletal system that are innervated by a specific nerve. Performing manual muscle tests can help to detect weakness due to nervous system injuries[25]. When a neurological injury is present, the muscle will not be able to hold up against any pressure when performing a manual muscle test[26]. It can be helpful in testing the muscle strength in those with neurological diseases and those with head injuries that could have a potential nerve involvement.

Beyond the evaluation, manual muscle testing can be utilized to track patient progress to assess the effectiveness of the rehabilitation program and to demonstrate improvements that have been made to the patient. Tracking progress is necessary to properly progress patients through their rehabilitation program. It can also reveal what weaknesses may exist in the program by assessing the strength of the muscles that are the desired target of the program. This is a necessary step in ensuring that the patient is receiving the best care possible. Throughout rehabilitation, it is also important that the patient have goals to reach to maintain motivation. When they are able to see progress, the desire to continue working to their best ability will often increase. Manual muscle testing is a very useful tool in the goal setting process.

Methods of Manual Muscle Testing

Manual muscle tests are designed to test the strength of the primary mover; however, there will always be activity from secondary movers and stabilizers. This is especially true in the shoulder where many of the muscles connect to the scapula. This common link can make isolating a specific muscle nearly impossible[12]. The goal is to put the arm in a position where the target muscle will have higher activity than any of the secondary movers[27]. To correctly test the functionality and strength of a muscle, the body needs to be in a precise position, and any shift in the position can recruit different muscles or change how that particular muscle works[28]. Because any small change in body positioning can affect the results of a manual muscle test, there have been many studies done over the years to normalize manual muscle tests and to discover the best method of testing the strength and functionality of a muscle.

Two of the most common methods of manual muscle testing are make tests and break tests[29]. Make tests are more of an active contraction. The patient applies force to the practitioners stationary hand, and the amount of force applied is compared bilaterally and graded[29]. Break testing is more of a passive or eccentric test. The practitioner will apply force to the patient as the patient attempts to hold their limb in place[29]. Break tests are done in the midrange of motion to better differentiate between muscle and ligamentous involvement[30]. The break test is the method that is most commonly used. To perform a break test correctly the clinician will apply force to the body as the patient resists. The clinician will do this until no increase in force is felt and apply slightly more pressure that should not last more than 1 second[26]. Strong muscles will be able to adapt to this change, while weak muscle would not be able to hold against the increase in pressure[26]. With both of these methods, the practitioner must be able to apply more force than the patient. If the patient is able to easily overpower the practitioner, an accurate test is not likely. Other methods such as isokinetic testing on a Cybex can be used. However, this method is very costly, and it will not be performed very often. Make tests and break tests are two methods that can be used to test the integrity, strength, and functionality of a muscle.

The shoulder can be a particularly difficult location when performing manual muscle tests. The muscles of the shoulder often work together to perform motions, and it can be very difficult to isolate a specific muscle. Studies have been conducted to discern which manual muscle tests would provide the most EMG activity to better test one muscle over another. One study looked directly at manual muscle test for the rhomboids. The rhomboids which are primarily used for elevation, retraction, and downward rotation of the scapula can be difficult to isolate as they often act as synergists with other muscles of the shoulder[30]. It was found that there is more EMG activity in the rhomboids in an upright position as the rhomboids both move and stabilize the scapula[31]. The prone position is helpful for isolating the movement of the rhomboids from their stabilization purposes. In the prone position, the shoulder should be adducted, extended, and externally rotated with the elbow flexed provided the most EMG activity in the rhomboids[31]. Along with the rhomboids, the rotator cuff muscles can provide a particular challenge to clinicians when trying to perform manual muscles tests. The rotator cuff poses issues such as differentiating it from other synergists and pain in testing positions[28]. In the study by Kelly, the optimal position for the supraspinatus muscle is flexion at 90° and external rotation at 45° (full can position), for the infraspinatus muscle the optimal position external rotation at 0° of scapular flexion and 45° of internal rotation, and the optimal position for the subscapularis muscle is the Gerber push off with force[28]. These tests provided the highest EMG activity in the rotator cuff muscles. In an effort to find manual muscles test that are able to provide high activity in all shoulder muscles, a few researchers sought to come up with a normalized method for testing the shoulder. Three very important studies were done to test the for a normalization for these tests. Together these studies concluded that the empty can test, flexion at 125°, internal rotation at 90°, and the palm press (shoulders flexed to 90°, elbows flexed 20°, palms pressed together) provided the most activation of the shoulder girdle muscles including the rotator cuff muscles, the trapezius, the serratus anterior, the latissimus dorsi, the deltoid, and the pectoralis muscles[32-34]. The studies done by Boettcher and Ekstrom utilized break tests measured by electromyography[32,33]. The third study done by Kelly utilized isometric make tests measured with electromyography[34]. The empty can test provided high activation for the supraspinatus, all three sections of the trapezius, the serratus anterior, all three portions of the deltoid, and the upper subscapularis[32]. The flexion at 125° test provided high activation for the supraspinatus, the infraspinatus, all three portions of the trapezius, the serratus anterior, the anterior and middle deltoid, and the upper subscapularis[32]. The internal rotation at 90° test provided high activation for the latissimus dorsi and the upper and lower subscapularis[32]. The palm press test provided high activation for the serratus anterior, the pectoralis major, and the lower subscapularis[32] A fourth study was done that used the research from these three people to create an updated list of shoulder normalization tests that included the rhomboid muscles and teres major that had been excluded from the previous studies[35]. These researchers recommended that extension at 30° abduction be added to the previous list of standard shoulder manual muscle tests to provide a test that would have a high likelihood of activating the rhomboid major and teres major. All these muscles are pivotal in the movement of the shoulder as well as its stabilization. These tests provide the best information about the strength of the shoulder girdle muscles.

Measurement of Manual Muscle Testing

The measurement of manual muscle testing has been a continuing issue for many years. The 6-level grading system, which is the most commonly used grading method, has low interrater and intra-rater reliability especially when it comes to grades four and five on the 6-level scale[30]. A method of measurement that is objective and reliable is very much needed to provide better information of any strength deficits that may be seen. Three other possible ways to measure manual muscle tests are handheld dynamometers, electromyography, and isokinetic measurements.

6-Level Grading. While the 6-level grading scale has been shown to have low interrater and intra-rater reliability, it is still necessary to discuss as it the most used method of grading a manual muscle test. The 6-level grading scale first came into use in 1915[5]. This type of measurement is subjective in nature and can vary from clinician to clinician. A grade 0 shows no sign of contraction in a muscle. A grade 1 shows a slight contraction of the muscle; however, the muscle will not be able to move the joint. With a grade 2 the patient will be able to move their joint through full range of motion with gravity eliminated. A patient with a grade 3 will be able to move through full range of motion with gravity. A grade 4 is defined as having complete range of motion with some resistance. Lastly, a grade 5 is defined as being able to go through full range of motion with full resistance[1]. This was created with the idea that they were testing through a set range of motion, but it has since been adapted to grade isometric testing as well. This grading system has posed many issues to the measurement of manual muscle testing. One major issue is the amount of strength covered by grade 4 alone. To demonstrate this, one study compared a grade 3 muscle potential using antigravity static muscular movements and grade 5 muscle potential by measuring using isokinetic testing[5]. The resulting information showed that a grade 4 covers 86% of a muscle's strength. For example, they found that for the elbow and knee muscles, the muscle could be generating as little as 10% of its maximum strength and be considered a grade 4. This wide range makes it difficult to truly assess how strong a person is. It has been shown that a difference in muscle strength of 20% when compared bilaterally likely indicates that there is some type of pathology present[1]. If this is true, then a grade 4 which has the potential to cover 80% of a muscles strength is a flawed grading system. A grade 4 could be at the higher or lower end of the muscle's strength and that would not be communicated well. While this grading system has its flaws, it is the cheapest and most available method to use clinically.

Dynamometer. Since the typical grading method is subjective and leads to a variability of results, an objective measure is needed. Dynamometers offer an objective form of measuring a muscles strength. The most commonly used dynamometer in clinics is the handheld dynamometer. This provides clinicians with an objective measurement at a more affordable rate. However, dynamometers still cost a decent amount of money. Clinics with low budgets are still unlikely to use them. The main use for dynamometers is in the research setting to provide objective measurement of the force subjects are able to produce during manual muscle testing. It has been shown that using a handheld dynamometer with a make test or a break tests has excellent intra- and inter-rater reliabilities when performed on the elbow extensors of young adults[7]. Another study showed an extremely high intra-rater reliability when performing break tests for the shoulder extensors and internal rotators using a handheld dynamometer[4]. The results of the study showed near perfect levels of reliability. A third study was able to demonstrate the validity of using a handheld dynamometer by comparing it to isokinetic testing of the rotator cuff in overhead athletes[36]. These studies, along with many others, help to demonstrate the reliability and validity of measuring muscle strength using a handheld dynamometer. It can be a very useful tool in finding an objective measure of muscle strength both in the clinic and research settings.

Electromyography. Electromyography is a very useful tool to quantify muscle activation. This method does not test muscle strength, but it measures electrical discharges from motor units to assess the activation of the muscle[37]. Surface or needle electrodes can be used to measure the electrical activity in a muscle during contraction. This method of studying muscle contraction is widely used in research as it provides reliable and measurable data. One study researched the validity and reliability of surface electromyography over two weeks and found that there were high levels of both during exercise and daily activities[38]. Another study looked at shoulder manual muscle tests and motions using a handheld dynamometer and electromyography. They compared the results from one day to the next and found that both methods had high levels of reliability in testing the strength and activation of shoulder muscles[8]. These two articles, along with many others, have shown the ability for electromyography to be a reliable method of testing muscle activity. While this is a great tool to use in the research setting, electromyography is an extremely expensive and cumbersome method of testing muscles. This often makes it impossible to use in the clinical setting. It is not practical to use for evaluation and rehabilitation.

Isokinetic. Isokinetic testing can be a great method of comparing strength bilaterally. Regardless of the amount of force applied by the patient, the arm will only move at a set speed. Thus, isokinetic testing can be used to look at the maximum force produced through the range of motion regardless of velocity variances[39]. This is most commonly used as a diagnostic tool and a measurement tool of strength in postoperative patients. While it is a commonly used tool to measure strength, it has some rather large weaknesses. The cost of an isokinetic machine is very high. They are expensive to purchase, and there are not a lot of different manufacturers. Having an isokinetic machine easily available is unlikely in most clinical settings. Another disadvantage is that it requires maximum effort from the patient throughout the entire test. It is easy to stop giving full effort when the resistance will only move at a set speed. The patient must be sure to give full effort throughout the test. While this is not the most practical method of testing strength in the clinical setting. It can be helpful in research, especially when comparing muscle strength bilaterally. It can be very helpful in providing strength deficits, but the cost and time it takes to run make it an impractical tool for use in most settings.

The Kinetic Chain and Core Relation to Shoulder Strength

The kinetic chain is the sequential cooperation of interdependent segments of the body as it moves[10,12]. To perform any action the muscles must activate, deactivate, mobilize, and stabilize the body to produce dynamic movements[10,12]. The body does not work as separate segments when performing complex motions. When performing overhead movements, the majority of the force at the arm is produced by the lower extremity, hips, and trunk[9,12,21]. That force is then transferred through the scapula to the arm to perform the needed function[9,12,21]. The core and the trunk are very important to the kinetic chain for the upper extremity. Core stability is needed to align and stabilize the trunk throughout the motion[12]. One study explored the idea of spinal segmental stability during motion by examining timing of the firing of the multifidi compared to extremity muscle activation. They found that those who were able to segmentally roll without compensation always had multifidi activation before anterior deltoid activation, and they found that those who were not able to segmentally roll had faulty firing timing in that the anterior deltoid always fired before the multifidi[14]. This shows that there is a connection between stabilizers and prime movers during movement. Future research needs to be done on how the firing of the prime mover before the spinal stabilizers affects movements and force production. Another study sought to explore the kinetic chain relationship between the trunk muscles and the activation of the serratus anterior at the shoulder by using EMG to look at the activation of muscles during a punching motion. Those motions that produced more gluteus maximus activation also produced more serratus anterior activation as the force was transferred through the thoracolumbar fascia, into the latissimus dorsi, and finally into the serratus anterior[9]. This was evident more in those positions that were closed chain compared to open chain. The results support the idea that the connections between the activity in the trunk muscles may alter the activity in the upper extremity[9]. Another study looked at the effects of trunk rotation and scapular movements[15]. Three-dimensional kinematic recordings of the scapula showed that when the trunk is rotated towards the tested scapula, the scapula showed decreased internal rotation and increased upward rotation, and a rotated trunk away from the tested scapula increased activity of the upper trapezius and serratus anterior. These studies demonstrate that there is a connection between the core and trunk and the activity of the upper extremity.

The core is composed of the muscles of the lumbar spine, abdomen, hips, and pelvis, and it is essential in producing efficient movements of the body[40]. The core is what provides stabilization of the body as it moves. Many sport specific movements begin from the core. Few studies have been conducted to test the effect of core strength or contraction on the strength of the shoulder. However, one study investigated the effect that core musculature fatigue had on shoulder strength in different planes of movement[40]. Participants were manual muscle tested using a dynamometer in the sagittal, transverse, and frontal planes before and after a core-fatigue program. There was a significant decrease of shoulder strength in both the frontal and transverse planes after participating in the core-fatigue program. A weak or unstable core has also been shown by numerous studies as a risk factor for shoulder injuries[12,41-43]. They demonstrate how the core is important in the kinetic chain and how it is able to affect the biomechanics of the shoulder. It has been shown that a strong core provides more efficient and safe shoulder movements, and a weak core can predispose someone to shoulder injuries. Therefore, core strength is able to affect shoulder strength whether through biomechanics or the kinetic chain. However, more research needs to be done on how the core is able to effect isometric shoulder strength.

Effects of Scapular Positioning on Isometric Shoulder Strength

The scapula is the attachment site for many of the muscles that comprise the shoulder complex[16,21]. The scapulothoracic joint, while not a true joint, is critical in shoulder motion. The muscles that attach to the scapula help to stabilize it during motion thus providing a strong foundation for the shoulder joint to move upon[16]. When performing manual muscles tests, it is imperative to consider the scapular positioning of the patient. If one position is stronger than the others, this provides a baseline for scapular positioning while focusing on strengthening of the shoulder. To demonstrate this relationship, one study explored the relationship between scapular positioning and isometric shoulder strength[44]. This study isometrically tested shoulder elevation in patients with chronically protracted scapulas and neutral scapulas and compared their strength in a neutral and protracted position. Both groups were weaker in the protracted position; however, there was a bigger strength deficit in those with scapulas that were naturally in a neutral position. Those naturally in scapular neutral were also stronger when tested in that position than those who were naturally protracted. Another similar study tested the isometric shoulder elevation strength in scapular protraction, neutral, and retraction[20]. This study also demonstrated that shoulder elevation is stronger in scapular neutral, but it also provided the information that the shoulder was similarly weak in scapular retraction. This demonstrated that any significant change in positioning of the scapula would decrease the shoulder elevation strength. These studies help to demonstrate the positioning of the shoulder can affect the strength elicited.

The scapula also plays a critical role in the force transmission during overhead movements. It is an essential part in the kinetic chain as it transfers the force generated by the lower extremity into the arm when performing overhead activities[9,11,12,21]. Scapular dyskinesis is a common disruption of the kinetic chain as the scapula has an abnormal pattern of movement that is inefficient for the transmission of forces[10,11,16,17,19,21,22,45]. Scapular dyskinesis can be seen during dynamic movement, and it can result in excessive protraction, anterior tilt, and excessive internal rotation[12,16]. The lack of retraction creates an unstable base in the cocking position of the shoulder during overhead movements[16,21]. One study performed supraspinatus manual muscle tests on those who were injured with scapular dyskinesis and a control group with no injuries[22]. They found that positioning the scapula into a more retracted position allowed the patients to produce more objective strength. This was true in the control group as well. Another study performed manual muscle tests on the trapezius (all three sections), serratus anterior, supraspinatus, and the medial and lateral rotators of the humerus on healthy individuals with and without scapular dyskinesis[25]. They found no difference in strength between the groups. However, this does not take into account how scapular dyskinesis affects the strength of injured individuals or the role it plays in the strength of the shoulder during dynamic movements.

Reliability and Validity of Manual Muscle Testing

The reliability and validity of manual muscle testing is dependent on the method of manual muscle test used and the measurement method employed. The reliability and validity are very high for the use of manual muscle testing methods using quantitative measures such as handheld dynamometry[26]. To maintain high reliability, the correct positioning needs to be used to place the shoulder girdle in the optimal position and test the correct musculature. Slight deviations from previous testing positions can change the recruitment of the muscles tested and alter the results of the manual muscle test. Therefore, if a standard positioning is not used while performing the manual muscle test, the results will not be accurate from patient to patient or clinician to clinician. The measurement used can also affect the intra- and inter-rater reliability of the manual muscle test. The subjective nature of the 6-level grading system can give different results between clinicians. This will lower the reliability of the manual muscle test. There is also the issue of clinicians not being able to tell the differences in weakness when the difference is not drastic[46]. Therefore, clinicians are not always able to detect true weakness due to an injury. Using objective measurements such as handheld dynamometry can help to increase the reliability and validity of performing manual muscle tests.

Summary

Manual muscle testing can be a practical way to test the strength of muscle groups and to gain a better understanding of the functionality of the joint and the patient. The measurement techniques of the manual muscle test are important as they can affect the reliability and accuracy of the manual muscle test. While electromyography and isokinetic testing provide reliable and objective data, it is not practical for use in the clinical setting as it is rather expensive and a lengthy process. The 6-level grading system is a cost efficient and practical method; however, it is subjective in nature and does not produce the most reliable measurements. Dynamometry appears to be the ideal means of measuring shoulder strength in the clinical setting as it is both objective and relatively cost effective. The studies have shown that handheld dynamometry can be reliable between clinicians and tests. Having an objective method of measurement is helpful with presenting goals and numbers to a patient as well as with reporting data in research studies. In regard to testing the shoulder specifically, it is critical to be aware of the positioning of the shoulder while performing the test. Small changes in rotation, flexion, extension, and scapular positioning can have an effect on the muscles activated and the strength of the shoulder. The positioning needs to be the same from test to test so the activation of muscles is not altered. The positioning of the scapula can have an effect on the force production during the manual muscle test as well. Extreme deviations in positioning or movement patterns can affect the efficiency and strength of the shoulder. The body works in a sequential manner during movement known as the kinetic chain. The scapula is a part of this chain, and the disruption of its role is known as scapular dyskinesis. Scapular dyskinesis is an alteration of the motion or positioning of the shoulder that can have an effect on the force production of the muscles. The core is also a pivotal part of the kinetic chain. The core provides much of the power produced for overhead movements. It also provides much of the stability needed during those movements. The effect of the core and scapular positioning on strength during manual muscle tests is somewhat less evident. There have been studies done on the effect of scapular positioning on strength, but they vary in their results. The effects of core and scapular positioning on shoulder manual muscle tests needs to be explored further. Apparent deficits in strength may not be due directly to the strength of the muscle, but rather the positioning of the body. This information could alter the results of injury evaluations or the progression of a rehabilitation. If the apparent strength deficit is caused by the body positioning or kinetic chain effects rather than directly by the muscles involved, this would be necessary information for a clinical diagnosis and formation of effect rehabilitation. This study needs to be done in order to further explore how body positioning can affect the strength of the shoulder and to explore further how the kinetic chain may affect the force production of manual muscle testing.

III. Methods

Participants

For this study, healthy, active individuals between the ages of 18-35 were recruited to participate. To be considered active, each individual was required to participate in moderate intensity physical activity (running, jogging, bicycling, sport activity, weightlifting) for a minimum of 150 minutes each week. Subjects were excluded if they have a current shoulder injury, have had a shoulder surgery within the past 6 months, or were unable to participate in their activity completely due to injury.

Testing Protocol

Prior to performing any manual muscle tests or measurements, each subject signed an informed consent document, and was screened for any excluding factors. The screening was performed by a single certified athletic trainer for consistency. Each subject completed an orthopedic injury history form and Penn Shoulder Score to determine each subject's self-reported level of shoulder function[47]. Arm dominance was recorded and determined by which arm was used to participate in their activity or sport. The active range of motion of each subject was tested with a goniometer in flexion, extension, adduction, abduction, internal rotation, and external rotation. The goniometric alignments for the shoulder are listed in Table 1. Those subjects who were considered active, were between the ages of 18-35, and did not have a shoulder injury were included in the study. All the subjects that were included in this study were National Collegiate Athletic Association (NCAA) Division 1 athletes that participated in an overhead sport. The sports included were volleyball, softball, baseball, and track and field throwers.

Two manual muscle tests were utilized to test the general strength of the shoulder, make tests of flexion at 90° and abduction at 90°[35]. Each subject was instructed on the positioning of the arm and how to perform the manual muscle test prior to testing. The flexion at 90° test was done with the subject standing in his or her relative posture with forward flexion of the arm at 90°. The subject was standing upright without a back support, and the force was applied two inches proximal to the elbow over the biceps brachii soft tissue. This was repeated with scapular retraction and core activation and performed bilaterally. This protocol was performed twice. The next test consisted of the subject standing the with arm horizontally abducted to 90° and internally rotated so that the palm of the hand remained parallel to the floor. The examiner applied force two inches proximal to the elbow on the lateral humerus. This was repeated with scapular retraction and core activation bilaterally. This protocol was performed twice. The testing was done without randomization first in flexion in each condition bilaterally; and after a rest period, the subjects were tested again in abduction with each condition. Each make test was performed for five seconds in each position. There was a 60 second rest period after each contraction. The patient was given an additional five minutes to rest between the flexion and abduction positions. To assist the subject with maintaining the arm in the proper position during each test, an adjustable strap was placed around the arm and through the handheld dynamometer. For scapular retraction, each subject was instructed to actively place the scapula in a retracted position without shrugging the shoulder or hyperextending the trunk. For core activation, the subjects were told to use the abdominal bracing technique to support their spine as they performed the manual muscle test. This technique is an isometric contraction of the abdominal muscles to provide control and stability to the spine during loading[48]. While in a neutral spinal position, subjects were instructed to perform an isometric abdominal contraction without drawing in the abdomen. The subject's abdomen was palpated to ensure that they were performing the abdominal bracing technique correctly. Positioning was monitored with verbal cues from the researchers to correct any trunk rotation, lateral flexion, hyperextension, and shoulder shrugging. Positioning and corrections were performed with verbal cues rather than manually placing the subjects into the correct position to maintain a more realistic clinical practice. They were tested using the 6-level grading system and twice using the handheld dynamometer in each position. To provide an objective measure of strength for the manual muscle test, a Commander PowerTrack handheld dynamometer (JTech Commander PowerTrack Muscle Dynamometer, JTech Medical Industries, Salt Lake City, USA) was used to determine the amount of force that each subject was able to produce.

Table 1. Goniometric Alignments for Shoulder Range of Motion

Motion	Axis	Stationary Arm	Moving Arm
Flexion	Center of humeral head near acromion	Mid-axillary line	Midline of humerus
Extension	Center of humeral head near acromion	Mid-axillary line	Midline of humerus
Abduction	Center of humeral head near acromion	Parallel to sternum at side of body	Midline of humerus
Adduction	Center of humeral head near acromion	Parallel to sternum at side of body	Midline of humerus
Internal Rotation	Olecranon process of ulna	Aligned vertically perpendicular to table	Aligned with ulna
External Rotation	Olecranon process of ulna	Aligned vertically perpendicular to table	Aligned with ulna

Source: Starkey C, Brown SD. *Examination of Orthopedic Injuries.* 4 ed. Daryaganj, New Delhi: Jaypee Brothers Medical Publishers Ltd; 2015.

Data Analysis

Summary statistics for demographic items were calculated and reported as means and standard deviations as all variables were continuous. Univariate comparisons were made between sexes using independent t-tests or Mann-Whitney U rank sum procedures based on normality of each variable distribution. The distribution of data for each variable was assessed for normality using the Shapiro-Wilk test. To compare the 3 manual muscle testing conditions for all subjects, separate repeated measures analyses of variance (ANOVA) were performed for flexion and abduction. Within and between comparisons were performed for dominant arm compared to non-dominant arm across the 3 manual muscle testing conditions. These same comparisons were performed for each sex individually. Mauchly's test was utilized to assess sphericity. In the event sphericity had been violated, a Greenhouse-Geisser correction was employed. The Bonferroni method was used for post hoc analysis as appropriate. Statistical significance was set at $p \leq 0.05$. In addition, pairwise Cohen d calculations were performed to determine the relative effect size of any differences between or within testing positions[49]. The effect size is often used to determine if mean differences are large enough to be considered clinically meaningful; Cohen defined effect sizes as small (≤0.4), medium (0.41-0.79), and large (≥0.8)[49]. All analyses were performed on SPSS (v26, IBM, Armonk, NY).

To ensure the consistency of measurement obtained by the examiner, a reliability assessment for each of the muscle testing positions was performed. A sample of ten subjects who were not included in the actual study was obtained for this purpose. Using a two-way random design (2,1), intraclass correlation coefficients (ICC) were calculated from the two trials of each position obtained for a single examiner. This same examiner also gathered all of the study data for all trials. Intrasession test/retest reliability was calculated. Once the ICC's were determined, standard error of measurement (SEM) and minimal detectable change (MDC) at the 90% confidence level were calculated (Table 2). An ICC greater than 0.75 was interpreted as excellent while values between 0.40–0.75 were considered fair to good and <0.40 was considered poor (Cicchetti 1994).

Using previously published data[22] as a guide, a sample size of 40 subjects would have 80% power to detect a difference in means of 4kg (the difference between a mean of 18kg in a normal posture testing position and 14kg in a scapula retracted testing position), assuming that the common standard deviation is 4.5kg, using a two group t-test with a two-sided significance level of 0.05.

Table 2. Reliability Assessment

	Dom Norm	Non-dom Norm	Dom Scap	Non-dom Scap	Dom Core	Non-dom Core
Flexion						
ICC	0.86	0.80	0.90	0.90	0.95	0.98
95% CI Lower	0.54	0.39	0.66	0.64	0.82	0.94
95% CI Upper	0.96	0.95	0.97	0.97	0.99	0.99
Mean	39	44	36	35	36	38
SD	10	17	14	12	12	16
SEM	3.74	7.63	4.35	3.74	2.59	2.32
MDC	3.96	8.07	4.50	3.96	2.74	2.45
Abduction						
ICC	0.93	0.91	0.80	0.83	0.95	0.96
95% CI Lower	0.76	0.70	0.39	0.46	0.80	0.86
95% CI Upper	0.98	0.98	0.95	0.95	0.98	0.99
Mean	35	36	33	32	35	35
SD	15	14	13	12	15	13
SEM	3.98	4.17	5.84	4.91	3.29	2.65
MDC	4.20	4.42	6.18	5.19	3.48	2.80

Dom=dominant; Non-dom=non-dominant; Scap=scapula retracted; ICC=intraclass correlation coefficient; 95%CI=95% confidence interval; SD=standard deviation; SEM=standard error of measurement; MDC=minimal detectable change

IV. Results

The demographic data for the subjects (n=40) is presented in Table 3. There were demographic variable differences in both the height and weight of the subjects, with males having significantly greater height and weight compared to females ($p \leq 0.001$). No other statistically significant differences existed amongst the demographic variables.

When examining the results for all subjects for shoulder flexion, there were no significant differences within or between the 3 manual muscle testing conditions. However, relative posture (15.8±5.0kg) and core activation (15.6±5.2kg) resulted in significantly greater force generation compared to the scapula retracted position (14.7±4.5kg) on the dominant arm for abduction ($p \leq 0.05$). The resultant effect sizes were small for relative posture (d=0.242, 95%CI: -0.20, 0.68) and for core activation (d=0.192, 95%CI: -0.25, 0.63). Relative posture (16.6±5.8kg) and core activation (16.0±5.8kg) for abduction on the non-dominant arm resulted in significantly greater force generation than scapular retraction (14.7±4.7kg) for the dominant arm and scapular retraction (15.0±5.0kg) for the non-dominant arm ($p \leq 0.045$). The resultant effect sizes were small for relative posture for the dominant arm (d=0.379, 95%CI: -0.06, 0.82) and for the non-dominant arm (d=0.310, 95%CI: -0.13, 0.75). The effect sizes for core activation were small for the dominant arm (d=0.250, 95%CI: -0.19, 0.69) and for the non-dominant arm (d=0.184, 95%CI: -0.26, 0.62).

When examining the results of the subjects concerning sex, males generated significantly greater force compared to female subjects for all measures ($p \leq 0.001$). For the female subjects, relative posture (13.8±2.8kg) resulted in significantly greater force generation compared to the scapula retracted position (12.6±2.6kg) on the dominant arm for abduction ($p = 0.038$). The resultant effect size was medium (d=0.474, 95%CI: -0.11, 1.1). For male subjects, relative posture (20.5±6.7kg) and core activation (19.8±6.7kg) for abduction on the non-dominant arm resulted in significantly greater force generation than scapular retraction

(17.4±5.5kg) for the dominant arm and scapular retraction (17.9±6.0kg) for the non-dominant arm (p≤0.018). The resultant effect sizes for relative posture were medium for both the dominant arm (d=0.496, 95%CI: -0.19, 1.2) and non-dominant arm (d=0.408, 95%CI: -0.27, 1.1). The effect sizes for core activation were small for the dominant arm (d=0.385, 95%CI: -0.30, 1.1) and for the non-dominant arm (d=0.301, 95%CI: -0.38, 0.97).

Table 3. Descriptive Statistics for Demographic Variables (Reported as Mean Standard Deviation)

	Overall (n=40)	Female (n=23)	Male (n=17)	P-value
Age (years)	20.0 ± 1.4	19.7 ± 1.3	20.4 ± 1.5	0.166
Height (centimeters)	175.5 ± 13.9	168.6 ± 13.4	184.7 ± 8.1	***<0.001***
Weight (kilograms)	80.3 ± 16.3	73.4 ± 11.6	89.5 ± 17.6	***0.001***
Years Playing Sport	12.4 ± 3.6	11.8 ± 2.0	13.1 ± 5.0	0.324
Penn Shoulder Score Total	94.6 ± 7.2	94.6 ± 7.0	94.5 ± 7.7	0.988
Penn Shoulder Score Pain	28.3 ± 2.7	28.2 ± 2.8	28.4 ± 2.6	0.825
Penn Shoulder Score Satisfaction	8.5 ± 2.4	8.8 ± 2.1	8.2 ± 2.8	0.442
Penn Shoulder Score Function	57.7 ± 2.8	57.6 ± 2.5	57.9 ± 3.3	0.685
Flexion (degrees)				
Dominant Arm	167.2 ± 10.6	164.7 ± 11.9	169.2 ± 6.9	0.140
Non-Dominant Arm	169.6 ± 10.1	168.8 ± 11.2	171.9 ± 9.1	0.354
Abduction (degrees)				
Dominant Arm	168.0 ± 8.8	169.6 ± 9.3	165.3 ± 6.8	0.110
Non-Dominant Arm	170.0 ± 9.2	170.7 ± 9.2	169.5 ± 9.9	0.700
Dominant Arm	55.5 ± 22.1	53.7 ± 25.4	57.2 ± 15.1	0.587
Non-Dominant Arm	66.7 ± 20.6	64.9 ± 25.3	70.1 ± 13.8	0.411
External Rotation (degrees)				
Dominant Arm	114.9 ± 14.9	116.8 ± 13.5	111.4 ± 15.5	0.244
Non-Dominant Arm	111.2 ± 12.3	115.0 ± 11.5	107.1 ± 14.0	0.057

Table 4. Manual Muscle Testing All Subjects (reported in kilograms) (n=40)

	Flexion Dominant	Flexion Non-Dominant	P-Value	Abduction Dominant	Abduction Non-Dominant	P-Value
Relative Posture	18.5 ± 6.2	18.8 ± 6.4	0.254	15.8 ± 5.0[a]	16.6 ± 5.8[b]	***0.024***
Scapular Retraction	17.6 ± 6.3	17.5 ± 6.2	0.510	14.7 ± 4.7	15.0 ± 5.0	0.387
Core Activated	18.3 ± 6.4	18.3 ± 6.6	0.907	15.6 ± 5.2[a]	16.0 ± 5.8[b]	0.304

a=significantly greater vs. dominant arm scapular retraction ($p \leq 0.05$)
b=significantly greater vs. dominant and non-dominant arm scapular retraction ($p \leq 0.045$)

Table 5. Manual Muscle Testing by Sex (reported in kilograms)

Female (n=23)	Flexion Dominant	Flexion Non-Dominant	P-Value	Abduction Dominant	Abduction Non-Dominant	P-Value
Relative Posture	15.0 ± 3.7	15.3 ± 3.8	0.382	13.8 ± 2.8[a]	13.8 ± 2.7	0.989
Scapular Retraction	13.9 ± 2.9	14.0 ± 2.8	0.719	12.6 ± 2.6	12.8 ± 2.8	0.438
Core Activated	14.6 ± 2.9	14.6 ± 7.4	0.988	13.3 ± 2.6	13.2 ± 2.7	0.573
Male (n=17)	Flexion Dominant	Flexion Non-Dominant	P-Value	Abduction Dominant	Abduction Non-Dominant	P-Value
Relative Posture	23.1 ± 5.9	23.6 ± 6.2	0.455	18.5 ± 6.1	20.5 ± 6.7[b]	***0.006***
Scapular Retraction	22.7 ± 6.0	22.1 ± 6.5	0.234	17.4 ± 5.5	17.9 ± 6.0	0.578
Core Activated	23.4 ± 6.2	23.4 ± 6.6	0.876	18.7 ± 6.3	19.8 ± 6.7[b]	0.191

Note: Male subjects generated significantly greater force compared to female subjects for all measures $p \leq 0.001$
a=significantly greater vs. dominant arm scapular retraction ($p=0.038$)
b=significantly greater vs. dominant and non-dominant arm scapular retraction ($p \leq 0.018$)

Table 6. Percent Changes

All subjects	Flexion Dominant	Flexion Non-Dominant	Abduction Dominant	Abduction Non-Dominant
Relative to Scapular retraction	4.9%	7.0%	7.0%	9.6%
Scapular retraction to core activation	4.0%	4.6%	6.1%	6.3%
Core activation to relative	1.0%	2.7%	1.4%	3.6%
Females				
Relative to Scapular retraction	7.3%	8.5%	8.7%	9.6%
Scapular retraction to core activation	5.0%	4.3%	5.6%	6.7%
Core activation to relative	2.7%	4.6%	1.3%	3.6%
Males				
Relative to Scapular retraction	1.7%	6.4%	5.9%	12.7%
Scapular retraction to core activation	3.1%	5.9%	7.5%	10.6%
Core activation to relative	1.3%	0.8%	1.1%	3.4%

V. Discussion

It was hypothesized that the scapular retracted position would produce more force compared to the relative position in both the flexion and abduction position. However, the data do not support this hypothesis. It was also hypothesized that the core activation position would produce more force compared to scapular retraction and the relative position in flexion and abduction. The results showed that the core activation position resulted in significantly greater force production on the non-dominant arm compared to scapular retraction on both arms. However, the data do not support the hypothesis that core activation would produce more force than the subjects' relative positioning. Furthermore, the effect sizes of the significant differences were all in the small to medium range. This would suggest that positioning, whether relative, scapular retracted or core activated, do not represent as significant of a difference compared to the minimal detectable change from the pilot testing. To see the same difference and find the actual affect, another 142 subjects would need to be tested.

The findings were consistent with other literature in that with excessive deviation from the neutral scapular positioning, force production decreased.[20,44] The study by Smith resulted in a 30% decrease in strength in the scapular retracted position and a 23% decrease in strength in the scapular protracted position[20]. However, the results did not agree with another study from Kibler et al[22] that showed that the scapular retracted position provided a 24% increase in force production in those with scapular dyskinesis and a 13% force production increase in the control group. Tate et al[23] reported similar results to the study done by Kibler. However, the results in that study only reported that about one-third of the subjects showed a 4% increase in strength in the scapular retracted position. This included both the symptomatic and the asymptomatic subjects. The current study found no significant change in strength with scapular retraction when testing flexion. However, when looking at the significant results for abduction, for the dominant arm there was a 7% decrease in force production in the scapular retracted position compared to the relative position and a 6.1% decrease between the scapular retracted and the core activated positions. On the non-dominant arm there was a 9.6% decrease in the scapular retracted position compared to the relative position and a 6.3% decrease in the scapular retracted position compared to the core activated position. Additionally, there was an 8.7% decrease in force production for the scapular retracted position compared to the relative position on the dominant arm for the females. Males had a 12.7% decrease in force production in scapular retracted compared to the relative positioning and a 10.6% decrease in scapular retraction compared to the core activation position. The lack of significant change could be explained by methodological differences. In the previous studies, researchers manually stabilized the scapula while the subjects performed the manual muscle test. In the current study researchers did not provide stabilization throughout the contraction. Without the provided stabilization it could have been more difficult for the subjects to maintain that scapular retracted position throughout the contraction. Kibler et al[22] suggested that keeping the scapula in the scapular retracted position helped to provide a stable base for the rotator cuff muscles. If individuals have weak scapular muscles, it is possible they may not have been able to maintain the scapula in a retracted position to fully provide that stable base for the rotator cuff. Kibler et al[22] also utilized subjects who had a medical diagnosis of a shoulder injury and a control group, and Tate et al[23] included subjects that had positive impingement tests as well as a group that did not have positive tests. The current study only included those who were healthy and able to participate in their sport. While the other two studies did have a control group, it is possible that the effects of scapular retraction are seen less in a healthy population. In addition to only including healthy and active individuals, every participant was an NCAA Division I overhead athlete. Compared to a non-athletic population, NCAA Division I athletes could have higher baseline of strength which could result in a lesser noticeable change in strength when changing positioning. They also train to optimize their performance in their relative positioning and moving them out of their relative positioning could have resulted in a decrease of force production. These differences could help to explain why this study found no significant changes in strength.

One unique aspect of this study was that subjects were not tested in flexion only but also in abduction. While there was no significance found when testing flexion, there was a significant difference when testing abduction. The relative position and core activated position were significantly stronger than the scapular retracted position. One consideration as to why there was less force production in the scapular retracted position is that the subjects could have retract their scapula too far. By changing this positioning, it would alter the length tension relationship of the muscles and could have resulted in less force production. However, the amount of scapular retraction was not measured to verify this possibility. Research performed by Smith et al[20] resulted in strength that was decreased in both protraction and retraction and the most force production in scapular neutral supporting the idea that moving the subjects from their relative positionings into scapular retraction would not result in an increase of force production. Anecdotally, one potential cause for the lack of force production in the abducted scapular retracted position, is that it limited the use of the lower trapezius muscle. It was observed that the subjects relied on their upper trapezius to produce force as demonstrated by noticeable shrugging of the shoulder during testing. Even when cued to not shrug while performing the manual muscle test, subjects noticeably recruited the upper trapezius muscles to produce force. When subjects retracted their scapula, there was an observable decrease in upper trapezius utilization. Subjects were not able to shrug their shoulder in the scapular retracted position similar to the relative and core activated stances. It is unknown if the utilization of the upper trapezius was a compensation or a natural phenomenon.

Another unique aspect to this study was the incorporation of conscious core activation. A study by Radwan et al[41] found that collegiate athletes with shoulder dysfunction performed worse on balance tests and some core stability tests showing that there is a relationship between the core musculature activation and shoulder function. Another study by Reeser et al[42] found a correlation between core instability and athletes with shoulder problems. There was a higher incidence of core instability in athletes with shoulder problems than those did not report shoulder pain. Similarly, a study by Tate et al[43] showed a that there was a correlation with swimmers with symptomatic shoulders and a decrease in core endurance. These three studies highlight the role that the core plays in the kinetic chain and shoulder functionality. In the current study, when testing abduction, the core activated position did result in significantly more force than the scapular retracted position. However, there was no significant change between the relative position and the core activated position. While core activation results in more strength than scapular retraction, when compared to traditional manual muscle testing, core activation does not necessarily influence strength in healthy individuals. The previous studies showed that core instability was found more in individuals with shoulder dysfunction. Healthy individuals in their study did not present with core instability at the same rate as those with shoulder issues. This study focused on healthy individuals, and that may be the reason that activating the core did not show in increase in force production compared to the relative positioning. Additionally, while the abdominal bracing technique was confirmed while they were tested in the core activation position, it was not considered in the other positions. The subjects could have been activating their core while in the other testing positions causing a crossover effect. One other factor to consider is that the kinetic chain is the corporation of the segments through motion. These tests were performed isometrically, and the effect of the core in the kinetic chain may be seen less without that aspect of movement.

Future research could explore whether providing manual stabilization of the scapula in the scapular retracted position provides more force production than in their relative position when testing abduction. Research could also explore the actual effect of the upper trapezius involvement in the force production in the relative and core activated positions. Lastly, this could be applied to individuals with diagnosed shoulder injuries to see if there is significant change in the injured versus healthy population when adding in scapular retraction and core activation to manual muscle testing.

Some limitations of this study are a small sample size and patient motivation while performing manual muscle tests. A much larger sample size would be needed to see the same difference from the pilot testing. Patient motivation is very important when performing multiple manual muscles tests. If subjects did not provide maximum effort it could affect the results of the study. Another limitation is that testing order was not randomized. The relative position was tested first for every subject. This could have caused them to experience fatigue when performing the other testing positions. This could have affected the results that were found. Additionally, some of these subjects may have come into the testing already fatigued. All the male subjects participated in a throwing sport, and many of the males were baseball pitchers. They were not required to refrain from overhead activity prior to performing the testing. Their dominant arm may have been fatigued from practices thus decreasing its ability to produce maximum force. Lastly, there could have been a possible crossover in the testing positions. While the subject's core was palpated for bracing in the core activation position, it was not palpated in the other two positionings. They could have been activating their core while in the other positions.

Conclusion

This study found that relative scapular positioning and core activation resulted in significantly more strength than the scapular retracted positioning when testing in abduction. Positioning in abduction is a more important factor for clinicians to consider when manual muscle testing their patients. However, while the differences were statistically significant, the effect sizes were so small that the results may not be clinically significant. Further research is needed to explore the relationship between the scapula and manual muscle testing as well as how the core activation could contribute to the results.

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