The Biomechanical Effects of Rotator Cuff Taping on Muscle Activity and Throwing Velocity in Fatigued Baseball Players

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Abstract

Introduction: Due to the repetitive, high forces and torques placed on an individual during a baseball pitch, shoulder pain is present in 46-57% of pitchers. Therapeutic taping has been used in various sports including baseball as it has been proposed to have beneficial qualities in injury prevention and rehabilitation and performance enhancement via muscular facilitation. Therefore, the purpose of this study will be to investigate the effect of taping (Kinesio Tape® and no tape) on the velocity of an overhead baseball throw and muscle activation patterning of the supraspinatus, infraspinatus, teres minor, and pectoralis major muscles in baseball players after muscle fatigue has been induced.

Methods: Participants were asked to complete two, 45-minute sessions under two different taping conditions (no tape and Kinesio Tape®). Participants were asked to complete three pre-test maximum velocity overhead throws, a fatiguing protocol, followed by three post-test maximum velocity pitches while velocity and EMG activity in the infraspinatus, supraspinatus, teres minor, and pectoralis major muscles were measured.

Results: There was no statistically significant difference in throwing velocity with the application of the different taping conditions, $t(5)=.456$, $p=.668$. There was no statistically significant difference in tape conditions on the supraspinatus muscle activity in phases one ($t(6)=-1.023$, $p=.346$) , two ($t(6)=.172$, $p=.869$), or three ($t(6)=-.299$, $p=.775$) of the overhead throw. There was no statistically significant difference in tape conditions on the infraspinatus muscle activity in phases one ($t(6)=.436$, $p=.678$), two ($t(5)=1.66$, $p=.158$), or three ($t(5)=.314$, $p=.766$) of the overhead throw. There was no statistically significant difference in taping conditions on the pectoralis major muscle activity in phases one ($t(5)=.871$, $p=.424$), two ($t(4)=.520$, $p=.63$), or three ($t(5)=1.073$, $p=.332$) of the overhead baseball throw.

Conclusion: Based on the results of this study, Kinesio Tape® does not significantly change muscle activation or velocity of an overhead baseball throw when compared to a no tape condition. Future research needs to complete testing with a larger sample size to better capture the effects of taping on surface EMG in the baseball population. Clinicians, baseball players, baseball coaches, and trainers should consider the possible pros and cons of taping in deciding whether or not to apply therapeutic taping to the shoulder and the rotator cuff muscles.

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List of Abbreviations

EMG – Electromyography

mV- Millivolts

MVIC – Maximum voluntary isometric contraction

Hz – Hertz

MLB – Major League Baseball

COVID-19 - Coronavirus

Chapter One: Introduction

Baseball has become increasingly popular in recent years, with 25 million participants reported in 2017 (Sport & Fitness Industry Association, 2017). As baseball's popularity increases, more researchers are examining the critical aspects of the game such as the kinetic forces placed on the shoulder, the repetitive loading forces generated by the shoulder muscles and injuries related to baseball that result from these forces. One of the most integral parts of the sport is the overhead throw, which is an intricate and highly coordinated musculoskeletal sequence (Chalmers et al., 2017). Chalmers et al. (2017) described an overhead throw or pitch in baseball as one of the fastest known human motions with the average pitch in Major League Baseball (MLB) being 144.8 km/h (MLB, 2018). Due to the complexity of this movement, baseball players are often at a greater risk of injury. As such, baseball has been estimated to account for greater than 50,000 injuries per year (Cools, Witvrouw, Danneels, & Cambier, 2002). The significant and repetitive microtrauma placed on the shoulder during an overhead throw can cause maladaptive changes to the soft tissue or even bony structures surrounding the shoulder (Erickson, Thorsness, Hamamoto, & Verma, 2016b). The risk of injury seems to only increase with age as players participate in baseball for longer periods of time and as they age (Erickson et al., 2016).

Pitching related shoulder and elbow pain is reported in 46-57% of pitchers (Lyman et al., 2001). The large prevalence of injuries is thought to be due to the various forces and torques placed on the shoulder joint while completing an overhead throw (Bakshi & Freehill, 2018). The most common injuries related to the overhead throw in baseball include superior labrum anterior-posterior tears, rotator cuff tears, internal impingement resulting in tendinopathy related issues, and glenohumeral internal rotation deficit (Chauhan, Ahluwalia, Sharma, & Thakur, 2016). The largest risk factors described for shoulder injuries in baseball are high pitch counts during games, pitching over 100 innings per year, pitching on consecutive days, and throwing at higher velocities (Byram et al., 2010; Posner, Cameron, Wolf, Belmont, & Owens, n.d.; Spinks & McClure, 2007).

In men's college baseball in the United States, the injuries are usually severe and result in significant time loss from participation (Dick et al., 2007). Similarly, it has been reported that 50.3% of injuries in high school level baseball players in the United States resulted in greater than a week of lost participation time (Collins & Comstock, 2008). Due to the risk of injury during an overhead throw, interventions to help decrease the risk of injuries have often been introduced. The anatomy of the shoulder joint is a key factor in understanding the mechanics and forces produced during a baseball throw that may be related to the development of these injuries.

The Shoulder Joint

The shoulder region is comprised of four separate articulations including the sternoclavicular, acromioclavicular, glenohumeral, and scapulothoracic joints (Anderson, 2017). The sternoclavicular, acromioclavicular, and scapulothoracic joints make up the shoulder girdle, while the glenohumeral joint is often referred to as the shoulder joint (Anderson, 2017). The sternoclavicular and acromioclavicular joints enhance the motion of the clavicle and scapula and this allows the glenohumeral joint to move through a larger range of motion (Anderson, 2017).

Sternoclavicular joint. The sternoclavicular joint is the articulation between the manubrium and sternum and the medial aspect of the clavicle. It is surrounded by a joint capsule with four supporting ligaments including the interclavicular, costoclavicular, and anterior and posterior sternoclavicular ligaments which can be seen in Figure 1 (Anderson, 2017). The sternoclavicular joint enables motion of the lateral end of the clavicle in the superior, inferior, anterior, and posterior directions (Anderson, 2017). The sternoclavicular joint allows for elevation and depression of the shoulder. When elevating the shoulder, the clavicle rotates upward on the manubrium and produces an inferior glide at the joint surface to maintain joint contact (Anderson, 2017). The reverse of this occurs for shoulder depression (Anderson, 2017). The sternoclavicular joint allows a person to shrug his/her shoulders, reaches above his/her head, or completing a throwing motion (Anderson, 2017). This joint also allows for some anterior and posterior rotation of the clavicle to occur as well working in conjunction with other articulations in the shoulder region (Anderson, 2017).

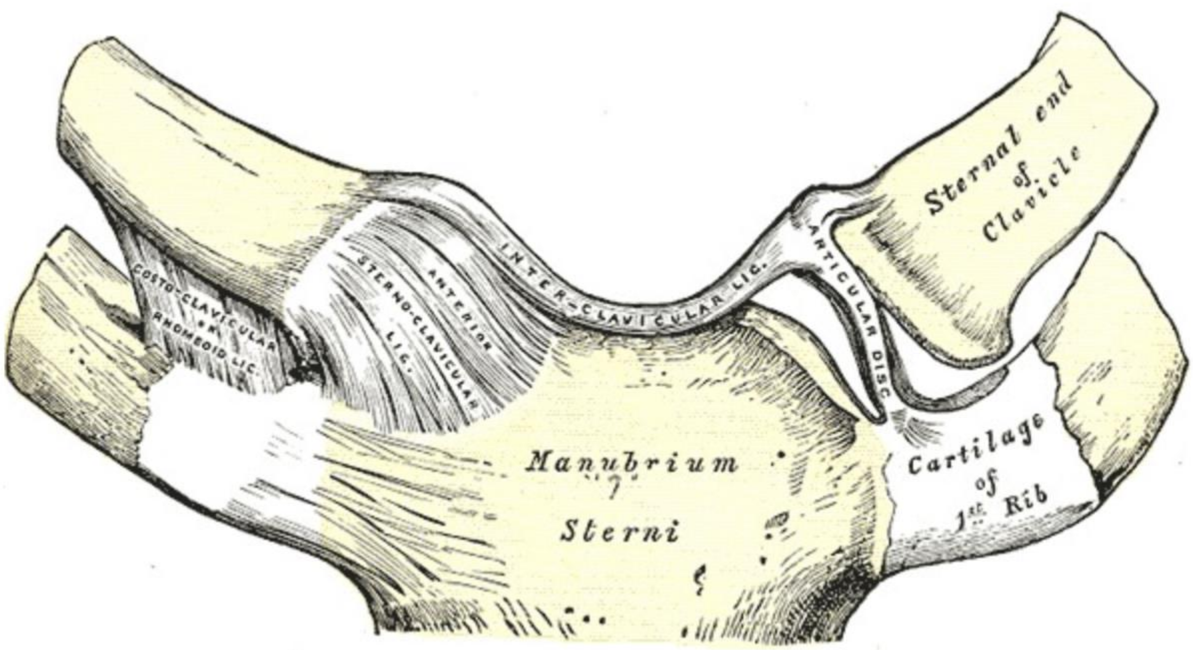

Figure 1. The anatomy of the sternoclavicular joint including the ligaments. From "Sternoclavicular Articulation" by J. Kiel & K. Kaiser, 2019, *StatPearls Publishing*.

Acromioclavicular joint. The acromioclavicular joint is comprised of the articulation between the medial facet of the acromion process of the scapula and the lateral end of the clavicle as illustrated in Figure 2 (Anderson, 2017). This joint allows for very little movement and is supported by the superior and inferior acromioclavicular ligaments and the coracoacromial ligament (Anderson, 2017). The coracoacromial ligament is divided into two parts including the conoid and trapezoid ligaments (Anderson, 2017). The conoid ligament passes superiorly and medially from to the base of coracoid process onto the conoid tubercle and the surface of the clavicle (Anderson, 2017). The trapezoid ligament passes horizontally and laterally from the superior surface of the coracoid process to the trapezoid line on the inferior side of the clavicle (Anderson, 2017). The coracoacromial ligament attaches to the inferior lip of the acromioclavicular joint and acts as a buffer between the rotator cuff muscles and the bony acromion process (Anderson, 2017). The acromioclavicular joint is highly irregular and varies from individual to individual (Anderson, 2017).

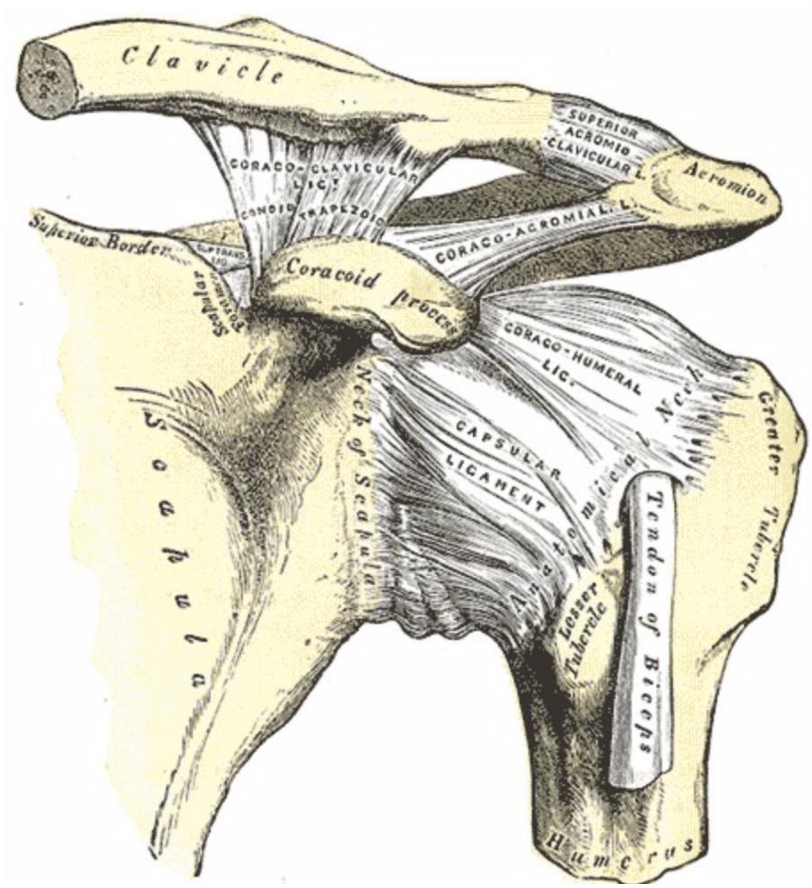

Figure 2. The anatomy of the acromioclavicular joint with labelled ligaments. From "Anatomy, Shoulder and Upper Limb, Glenohumeral Joint" by I. Chang & M. Varacallo, 2019, *StatPearls Publishing*.

Glenohumeral joint. This joint is composed of the articulation between the glenoid fossa and the head of the humerus and it lacks true bony stability (Anderson, 2017). Due to the lack of bony stability of the glenohumeral joint, there is greater total range of motion available in multiple directions than any other joint in the human body and is reliant on muscular activity to create dynamic stability (Anderson, 2017). The shallow glenoid fossa has three to four times less surface area than the head of the humerus and is less curved than the humeral head (Anderson, 2017). Due to this anatomical structure, the humerus is able to rotate and move linearly across the surface of the glenoid fossa (Anderson, 2017). The movement of the humerus across the surface of glenoid fossa is referred to as humeral head translation and it is somewhat limited by muscle tension and the joint capsule (Anderson, 2017).

The glenohumeral joint is stabilized anteriorly by the superior, middle, and inferior glenohumeral ligaments on the anterior side and the coracohumeral ligament on the superior side (see Figure 3; Anderson, 2017). The coracohumeral ligament protects the joint from superior displacement; however, inferior, posterior, and anterior displacements can still occur and are reliant on both ligamentous and dynamic structures to provide stability (Anderson, 2017). The superior glenohumeral ligament is the main static stabilizer of the abducted shoulder (Anderson, 2017). The superior, middle, and inferior glenohumeral ligaments connect the humerus to the glenoid and are the main source of stability for the glenohumeral joint (Anderson, 2017). More specifically, the middle glenohumeral ligament works to prevent anterior-posterior translation of the humerus in the mid-range of abduction (Gasbarro, Bondow, & Debski, 2017). The inferior glenohumeral ligament has three separate anatomical components including the superior band, anterior axillary pouch, and posterior axillary pouch (Gasbarro et al., 2017). Additionally, the inferior glenohumeral ligament is the most commonly injured of the three glenohumeral ligaments (Gasbarro et al., 2017). The superior glenohumeral ligament originates from the anterosuperior aspect of the glenoid labrum and attaches to the anterior aspect of the of the lesser tubercle of the humerus (Alashkham, Alraddadi, & Sames, 2018). The superior glenohumeral ligament helps to stabilize the glenohumeral joint in adduction and external rotation of the shoulder (Alashkham et al., 2018). The tendons of the supraspinatus, infraspinatus, teres minor, and subscapularis muscles also reinforce the joint capsule and these muscles are referred to as the rotator cuff muscles (Anderson, 2017). Tension of the rotator cuff muscles and the force coupling, sequencing, and timing helps to stabilize the glenohumeral joint as these muscles work to hold the head of the humerus centred on the glenoid fossa (Anderson, 2017).

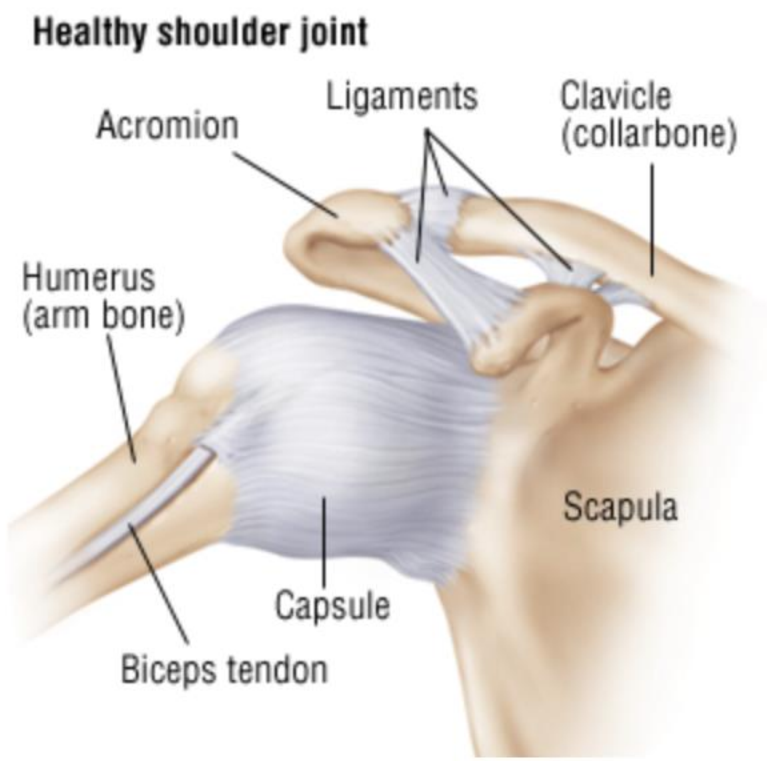

Figure 3. Glenohumeral joint including the scapula, humerus, acromion, and clavicle. From “Shoulder Sprain” by Harvard Medical School, 2019, *Harvard Health Publishing*.

Scapulothoracic joint. The scapulothoracic joint is not a true joint, rather the articulation is comprised of the concave anterior surface of the scapula moving on the convex posterolateral surface of the thoracic rib cage (Anderson, 2017). Muscles attach to the scapula and allow for its motion with respect to the trunk (Anderson, 2017). These muscles include the levator scapulae, rhomboid minor, rhomboid major, serratus anterior, pectoralis minor, deltoid, subscapularis, supraspinatus, infraspinatus, teres major, teres minor, coracobrachialis, short head of the biceps brachii, long head of the triceps brachii, and the trapezius muscles (Anderson, 2017). The scapular muscles have two main functions, the first function being to stabilize the scapulothoracic joint and the second function is to facilitate arm elevation through appropriate positioning of the scapula and scapulohumeral rhythm (Anderson, 2017).

The scapula. The role of the scapula is to create a stable base for the glenohumeral joint (Castelein, Cagnie, Parlevliet, & Cools, 2016). The scapula is very dependent on the function of the surrounding muscles as it has to move in a coordinated relationship with the humerus (Kibler, Ludewig, & McClure; 2013). The coordinated and coupled motion between the humerus and the scapula is called scapulohumeral rhythm and it is needed for efficient arm movement and stability (Kibler et al., 2013). The muscles around the scapula can be divided into two groups including the scapulohumeral muscles that act as the dynamic stabilizers of the glenohumeral joint and the scapulothoracic muscles whose primary function is to ensure the smooth movement of the scapula (Castelein et al., 2016). The scapulothoracic muscles include the trapezius, serratus anterior, levator scapulae, rhomboid major, and pectoralis minor muscles (Castelein et al., 2016). The scapulohumeral muscles include the deltoid, supraspinatus, infraspinatus, teres minors, and teres major muscles (Kibler, Sciascia, & Wilkes, 2013). These muscles have various roles during arm elevation.

Normal arm elevation may be broken down into three distinct phases including the initial phase, the middle phase, and the terminal phase. The initial phase of arm elevation of the scapula is completed mostly through the movements occurring at the glenohumeral joint (Donatelli, 2011). In the initial phase the humeral head glides 3 mm and occurs between 0-80 degrees of abduction of the shoulder and is also accompanied by 30 degrees of upward scapular rotation (Donatelli, 2011). The deltoid muscle produces a superior shearing force at the glenohumeral joint and the supraspinatus, infraspinatus, teres minor, and subscapularis muscles counteract this force via a force couple (Donatelli, 2011). This force helps to stabilize the glenohumeral joint keeping it centered on the glenoid fossa and allows for painfree movement (Donatelli, 2011).

The supraspinatus muscle's primary role in arm elevation is to assist the deltoid muscle to abduct the arm (Phadke, Camargo, & Ludewig, 2009). The infraspinatus, teres minor, and subscapularis muscles offset the superior translation of the deltoid and supraspinatus muscles (Phadke et al., 2009). Additionally, the infraspinatus and teres minor muscles produce humeral external rotation that occurs during normal arm elevation (Phadke et al., 2009). When an individual has abnormal scapula movements there is often a decrease in muscle activity in the supraspinatus, infraspinatus, teres minor, and subscapularis muscles and an increase in muscle activity in the deltoid muscle (Phadke et al., 2009).

The middle phase, or critical phase, of arm elevation occurs between 80-140 degrees of shoulder abduction (Donatelli, 2011). Maximal shear forces of the deltoid muscle occur at the beginning of this phase and then the ratio of glenohumeral to scapulothoracic movement shifts and emphasizes the scapulothoracic joint (Donatelli, 2011). In the middle phase the greatest amount of scapula rotation occurs at the scapulothoracic articulation (Dontelli, 2011). The upper and lower fibers of the trapezius and lower fibers of the serratus anterior muscles are responsible for the increased scapula movement (Donatelli, 2011). The head of the humerus glides 1.5 mm inferiorly across the glenoid fossa and results in clavicular elevation to approximately 120-150 degrees (Castelein et al., 2016).

In the final and terminal phase of arm elevation, 140-180 degrees of abduction occurs at the glenohumeral joint (Kibler, Sciascia, et al., 2013). To allow for unconstrained movement of the humerus away from the scapula, the latissimus dorsi, pectoralis major, teres major, teres minor, and subscapularis muscles must have good flexibility and muscle strength (Donatelli, 2011).

Atypical patterns of scapulohumeral rhythm may predispose an individual to scapular dyskinesis (Kibler et al., 2013). The term *scapular dyskinesis* refers to a loss of control of the normal scapular physiology, mechanics, and motion (Kibler et al., 2013). The motion of the scapula, appropriate force and motion generated by each muscle in the force couple, and timing (onset of muscle contraction and when that muscle shuts down) is critical in the overhead throw as this motion predominately relies on the coordinated movement of the glenohumeral joint. The anatomy of the shoulder is key in allowing the highly coordinated movement of the overhead baseball throw.

Phases of a Baseball Throw

An overhead throw is comprised of six distinct phases including the wind-up phase, early cocking phase, late cocking phase, acceleration phase, deceleration phase, and follow through phase (Fleisig, Andrews, Dillman, & Escamilla, 1995). Figure 4 illustrates of the phases of a baseball throw.

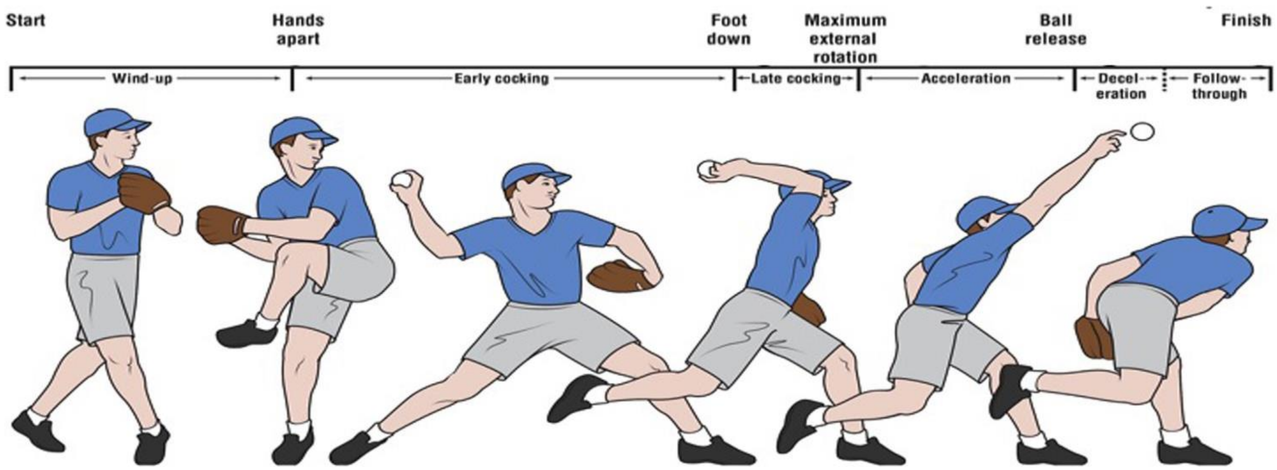

Figure 4. The six phases of a baseball pitch including the windup, early cocking, late cocking, acceleration, deceleration, and follow through phases. From "The Biomechanics of Throwing" by B. Erickson, R. Thorsness, J. Hamamoto, & N. Verma, 2016, *Operative Techniques in Sports Medicine, 24* (3), 156-161.

Wind-up phase. The wind-up phase is the beginning of the baseball throw and places the thrower in a position to generate an accurate and forceful throw (Erickson et al., 2016). This phase begins when the thrower flexes his/her lead hip and knee to a maximum height, which will be in approximately 90 degrees of knee flexion and approximately 90-110 degrees of hip flexion (Baseball Canada, 2019; Erickson et al., 2016). At this time, the throwing shoulder is slightly flexed and abducted (Erickson et al., 2016). The wind-up phase ends when the thrower achieves a balanced state; that is, with the lead hip and knee in maximum flexion before moving towards the target (Erickson et al., 2016). If the thrower's knee does move toward the target at home plate instead of upwards towards the chest, it could cause the upper and lower extremities to become uncoordinated (Erickson et al., 2016). The thrower may then rush the throw causing the potential loss of kinetic energy in the kinetic chain from the lower body to the upper body (Erickson et al., 2016). Kinetic energy is energy possessed by an object in motion and the kinetic chain describes related groups of body segments, connecting joints, and muscles working to perform movements

(Hamill & Knutzen, 2003). Furthermore, the loss of energy may increase the demand on the shoulder to generate more velocity to complete the pitch which could result in a higher risk of injury of the shoulder due to excess strain (Erickson et al., 2016; Fleisig et al., 1995).

Early cocking phase. The early cocking phase begins when the lead leg begins moving from maximal hip and knee flexion toward the target (Erickson et al., 2016). The lead hip moves into external rotation, while the stance hip moves into internal rotation; this creates kinetic energy which will be used in the later phases to generate torque and speed (Erickson et al., 2016). As the hip is moving towards home plate, the pitcher's hands begin to separate and by the end of this phase the pitching shoulder will move into approximately 90 degrees of abduction, 20 degrees of horizontal abduction, and 60 degrees of external rotation (Erickson et al., 2016). The end of this phase is signified by the lead foot making contact with the ground (Erickson et al., 2016). The risk for injury in this phase is minimal, as there in little force being placed on the shoulder (Fleisig et al., 1995).

Late cocking phase. This phase begins as the lead foot makes contact with the ground (Erickson et al., 2016). This phase marks a critical moment in the force and accuracy of the overhead baseball throw and poses a significant risk for injury of the shoulder (Fleisig et al., 1995). The shoulder reaches maximal external rotation in this phase that is typically between 160-180 degrees; however, elite baseball players often exceed this range of motion and reach maximal external rotation ranging from 175-211 degrees (Erickson et al., 2016; Miyashita et al., 2008). The prime external rotator muscles that produce this range of motion are the infraspinatus and teres minor muscles (Mcdaniel, Jackson, Gaudet, & Tonkin, 2009). Additionally, the shoulder experiences a significant amount of force transference in this phase due to the energy produced by the pelvis and torso rotating towards home plate, and the energy being transferred up the kinetic chain (Erickson et al., 2 016; Fleisig et al., 1995). This creates a significant distractive force at the glenohumeral joint that has been reported to reach an average of 750 N (Fleisig et al., 1995). In this lag, the shoulder reaches maximal external rotation at 90 degrees of abduction (Erickson et al., 2016). As the shoulder reaches maximal external rotation, it also horizontally adducts to 15 degrees (Erickson et al, 2016). At this point in the throw, the thrower's pectoralis major and anterior deltoid muscles, which are shoulder internal rotators, are eccentrically contracting to decelerate the force and motion produced by the infraspinatus and teres minor muscles (Erickson et al., 2016). A significant anterior shear force and horizontal adduction torque also occurs, which allows the shoulder to move towards home plate and the target without posterior translation of the humeral head (Erickson et al., 2016). The late cocking phase is completed when the shoulder reaches maximal external rotation (Erickson et al., 2016).

Acceleration phase. This phase begins after the throwing shoulder reaches maximal external rotation (Erickson et al., 2016). Throughout this phase, the throwing shoulder remains in approximately 90 degrees of abduction as this position allows for the greatest amount of force to be generated (Erickson et al., 2016; Fleisig et al., 1995). As the throwing shoulder moves from a position of external rotation to a position of internal rotation, the thrower's elbow extends (Erickson et al., 2016). The pectoralis major and deltoid muscles work to internally rotate the throwing shoulder producing angular velocities ranging between 6000-8000 degrees per second just before the ball is released from the throwing hand (Erickson et al., 2016). The average speed of the ball at release during a baseball pitch in MLB is 144.8 km/h and the fastest pitch recorded in MLB is 168.9 km/h (MLB, 2018). Additionally, during this phase, the throwing shoulder moves into 10 degrees of horizontal adduction when the ball is released (Erickson et al., 2016).

The end of this phase is signified by the ball being released from the throwing hand (Erickson et al., 2016).

Deceleration phase. Deceleration of the throwing shoulder begins at the release of the baseball and ends when the throwing shoulder reaches maximal internal rotation (Erickson et al., 2016). Eccentric contraction of the supraspinatus, infraspinatus, teres minor, and the long head of the biceps brachii muscles helps for quick deceleration of the throwing shoulder (Erickson et al., 2016). As the throwing shoulder is decelerating, it undergoes posterior and inferior shear forces and adduction and horizontal adduction torques (Erickson et al., 2016). To prevent anterior humeral head subluxation, the throwing shoulder must produce enough force to counter these forces. The force couple produced by the teres minor and supraspinatus muscles play a major role in producing this force and minimizing the anterior translation of the humerus (Erickson et al., 2016; Fleisig et al., 1995). Maximum tensile forces at the glenohumeral joint can reach up to 134% of a player's body weight during the deceleration phase; and this tension is placed mostly on the supraspinatus muscle as it decelerates the arm (Mazoue & Andrews, 2016). The deceleration phase is the phase in which the majority of injuries to the shoulder occur, specifically injuries to the rotator cuff muscles.

Follow through phase. This phase begins when the throwing shoulder reaches maximal internal rotation (Erickson et al., 2016). During the follow through, the kinetic energy generated to accelerate the arm to dissipates (Erickson et al., 2016). As the trunk moves forward toward home plate, the stance side foot is positioned off the ground and this helps to dissipate the energy created during the overhead throw (Calabrese, 2013; Erickson et al., 2016). Due to the kinetic energy dissipating, less stress is placed on the shoulder (Erickson et al., 2016). The throwing shoulder is also decelerated by the eccentric contraction of the posterior shoulder muscles including the infraspinatus, teres minor, and supraspinatus muscles (Erickson et al., 2016). The follow through phase is complete when the thrower is in a ready position in case the baseball is hit by the batter in his/her direction and he/she resumes a fielding position (Erickson et al., 2016).

Key Musculature in a Baseball Throw

During these phases, a few muscles play a key role in the motions that make up an overhead throw and include the pectoralis major, infraspinatus, teres minor, and the supraspinatus muscles (Erickson et al., 2016). The anatomy of these muscles can be seen in Figures 5 and 6. The pectoralis major muscle reaches peak activation during the late cocking phase of the overhead throw (Erickson et al., 2016). During this portion of the overhead throw, the shoulder reaches approximately 160-180 degrees of maximal external rotation (Erickson et al., 2016). Due to the maximal external rotation, the pectoralis major muscle, which is an internal rotator of the shoulder, is eccentrically loaded and contracts in order to control the force and decelerate the velocity generated by the shoulder external rotators (Erickson et al., 2016). Additionally, during the acceleration phase the pectoralis major, latissimus dorsi, subscapularis, and elbow extensor muscles produce velocities that exceed 7,000 degrees per second or approximately 90 km/h to generate humeral horizontal adduction, elbow extension, and rapid internal rotation of the shoulder (Anderson, 2017; Sandler, 2005).

The infraspinatus muscle also reaches peak activation during the late cocking phase, as it is one of the primary external rotators of the shoulder (Erickson et al., 2016). The teres minor muscle, on the other hand, reaches peak activation during the deceleration phase as it resists anterior humeral head translation, horizontal adduction, and internal rotation of the shoulder (Erickson et al., 2016). Additionally, the supraspinatus muscle reaches peak activation during the deceleration phase as it produces a high maximal voluntary isometric contraction to decelerate the arm as it moves forward during the throw (Erickson et al., 2016). The movement produced by the supraspinatus muscle during the overhead throw is particularly interesting as it is the most commonly torn rotator cuff muscle and is at high risk of injury during this phase (Braun, Kokmeyer, & Millett, 2009; Erickson et al., 2016b).

The rotator cuff muscles have an important role in the shoulder as they are the primary stabilizers of the glenohumeral joint (Mazoue & Andrews, 2016). Loss of stability in the glenohumeral joint has been identified as a key risk factor in injuries to the throwing shoulder (Mazoue & Andrews, 2016). In throwing athletes the majority of rotator cuff tears are a result of repetitive microtraumas; however, acute injury to the rotator cuff do still occur (Mazoue & Andrews, 2016). As the posterior rotator cuff muscles have to resist the large forces placed on them during the deceleration phase, the most common tears in the rotator cuff musculature occur in the posterior half of the supraspinatus muscle and the superior half of the infraspinatus muscle (Mazoue & Andrews, 2016). Magnetic resonance imaging (MRI) was completed on 21 asymptomatic MLB players and supported this finding as 9 of these players had partial-thickness rotator cuff tears and 2 of the players had full thickness rotator cuff tears (Lesniak et al., 2013). Since rotator cuff injuries are very common in baseball players and overhead throwing athletes, it is important to understand the neuromuscular activation that is occurring during a throw.

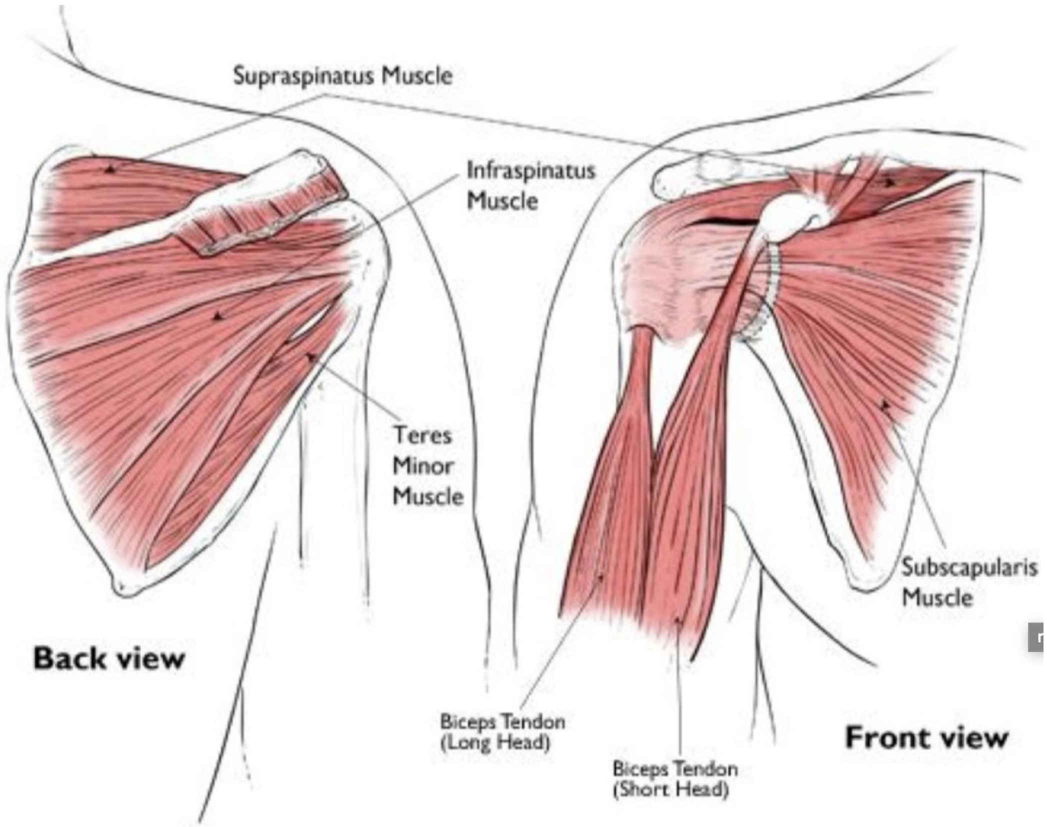

Figure 5. The rotator cuff muscles of the shoulder including the supraspinatus, infraspinatus, teres minor, and subscapularis muscles. From “Rotator Cuff Tears” by A. Armstrong & G. Athwal, 2017, *OrthoInfo*, retrieved from https://orthoinfo.aaos.org/en/diseases--conditions/rotator-cuff-tears/

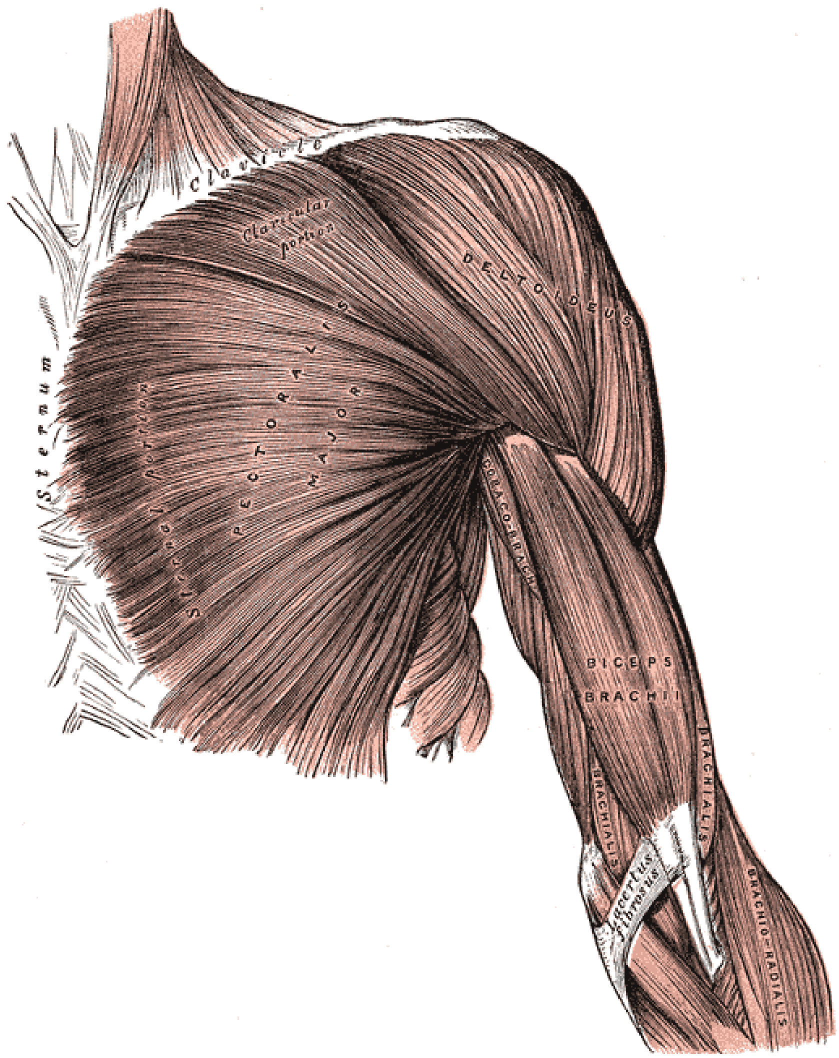

Figure 6. Pectoralis major, deltoid, biceps brachii, brachioradialis, and bachials muscles. From "Anatomy of the Human Body" by H. Gray & W. Lewis, 1918, retrieved from https://archive.org/stream/anatomyofhumanbo1918gray#page/n7/mode/2up

Electromyography

Electromyography (EMG) is the measurement of neuromuscular activity of the human body and it can used to examine the biomechanics and motor control of the muscles (Mogk & Keir, 2003). Electromyography signals are affected by changes in a muscle's force and length, as well as torques or moments produced by muscle around the joint and may be used to measure the intensity and timing of muscle contraction (Criswell, 2011; Mogk & Keir, 2003). Surface EMG provides a non-invasive and easy method of objectively quantifying the amount of activity in a muscle (Criswell, 2011). Surface EMG is measured in microvolts or 10^{-6} volts which ensures even the smallest amount of muscle activity generated is measured (Criswell, 2011). Surface EMG is a valid and reliable tool to measure muscle activity and fatigue (Christova, Kossev, Kristev, & Chichov, 1999; Merletti & Lo Conte, 1997; Moritani, Muro, & Nagata, 1986). Mathur, Eng, and Macintyre (2005) reported moderate to high reliability (intraclass correlation [ICC] = .58-.99) when using surface EMG in the lower extremities. They measured the muscle activity of the rectus femoris, vastus lateralis, and vastus medialis muscles of 20, healthy participants during two fatiguing contractions of 80% and 20% of their maximum voluntary contraction (Mathur et al., 2005). Similarly, in another study which surface EMG was measured on the muscle activity in the quadriceps and hamstring muscles, it was found to have an ICC of greater than .80 while 24 participants performed jumps and cutting tasks (Fauth et al., 2010). Meskers, Groot, Arwert, Rozendaal, and Rozing (2004) reported excellent reliability (ICC= .89-.96) when measuring mean EMG activity of the pectoralis major, deltoid, teres major, serratus anterior, trapezius, latissimus dorsi, supraspinatus, infraspinatus, and subscapularis muscles. The EMG activity was measured while 12 participants performed a force measuring task using a 2D force transducer (Meskers et al., 2004).

The relationship between muscle strength and muscle endurance of the supraspinatus, infraspinatus, and teres minor muscles was examined by Motabar, Nimbarte, and Raub (2019). They measured the strength, endurance, and fatigue response using maximum voluntary contractions and EMG in a sample of 10 healthy, male participants (Motabar et al., 2019). It was reported that although the infraspinatus muscle had more muscle strength than the supraspinatus and teres minor muscles, the muscles all had relatively similar muscular endurance (Motabar et al., 2019). This is believed to be due to the fact that the three muscles have approximately the same percentage of type I muscle fibers (Motabar et al., 2019).

DiGiovine et al. (1992) described a comprehensive, integrated, and quantified database of EMG activity in 29 muscles of the upper extremity in a sample of 56 healthy, skilled baseball pitchers during the fastball pitching motion. A 16mm motion picture camera was used to film each pitch at a rate of 400 or 450 frames per second to correlate EMG activity with specific movements in the overhead throw (DiGiovine et al., 1992). They divided the EMG data into six phases (wind-up, early cocking, late cocking, acceleration, deceleration, and follow through) and EMG data were collected while the pitcher completed fast pitch overhead throws (DiGiovine et al., 1992). They normalized EMG data for each participant by making it a percent of the participant's maximal manual muscle test (0-20% was considered low activity, 21-40% was considered moderate activity, 41-60% was considered high activity, and above 60% was considered very high activity). They found high activity in the upper trapezius during the early cocking phase and very high activity in all portions of the trapezius in the late cocking phase (DiGiovine et al., 1992). In the serratus anterior muscle, they found very high activity in the late cocking phase, high activity during the acceleration phase, and high during the follow through phase (DiGiovine et al., 1992). In the rhomboid muscles, they found muscle activity was very high activity during the acceleration phase (DiGiovine et al., 1992). In the late cocking and acceleration phase the levator scapulae muscle had very high activity (DiGiovine et al., 1992). The deltoid muscle presented with very high muscle activity in the early cocking and deceleration phase and decreased to moderate levels of activity in the late cocking and acceleration phases (DiGiovine et al., 1992). As a whole, the rotator cuff muscles presented moderate activity in the early cocking phase, very high activity during the acceleration phase, moderate activity during the deceleration phase, and low activity during the follow through phase (DiGiovine et al., 1992). They found high activity in the supraspinatus muscle during the early cocking phase (DiGiovine et al., 1992).

DiGiovine et al. (1992) concluded the supraspinatus muscle functioned with the deltoid to position the humeral head against the glenoid. The infraspinatus and teres minor muscles both externally rotated the humerus in the late cocking phase (DiGiovine et al., 1992). During the acceleration and deceleration phase, the teres minor muscle maintained a high level of muscle activity in order to limit humeral head translation (DiGiovine et al., 1992). The pectoralis major muscle provided anterior stability during maximal external rotation (DiGiovine et al., 1992). Although surface EMG has been well researched in the rotator cuff muscles, research remains controversial when analyzing the effect different types of therapeutic has on muscle recruitment patterns in the rotator cuff.

Kinesio Tape®. Kinesio Tape® is an elastic acrylic tape, designed to mimic the thickness and stretch of human skin (Kase, Wallis, & Kase, 2013). It is proposed that Kinesio Tape® supports and stabilizes muscles and joints without restricting the joint's range of motion (Kase et al., 2013). The theory behind Kinesio Tape® is that when it is manually stretched over structures, the tape forms convolutions that lift the skin (Kase et al., 2013). These convolutions or coils may help by increasing the interstitial space, allowing for increased lymphatic and venous fluid flow (Figure 7; Kase et al., 2013). As a result, Kinesio Tape®'s proposed benefits include decreasing pain, increasing joint function, increasing sensory function, and increasing muscle facilitation (Ujino, Eberman, Kahanov, Renner, & Demchak, 2013). The proposed benefit that would help a baseball player most when completing an overhead throw would be muscle facilitation.

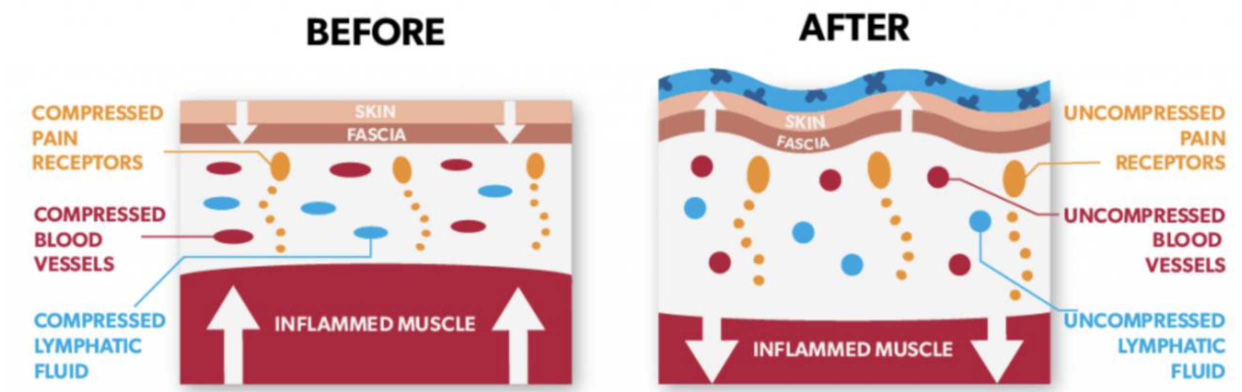

Figure 7. The effect of skin convolutions formed with the application of Kinesio Tape®. From "Clinical Therapeutic Applications of the Kinesio Taping Method" by K. Kase, J. Wallis, & T. Kase, 2013, Tokoyo, Japan: Ken Ikai Co. Ltd.

Kinesio Tape® is proposed to affect muscle facilitation by modifying the recruitment activity patterns of the underlying muscles and by increasing the force the muscle generates (Kase et al., 2013). In baseball, the precise motor acquisition and muscle activation is important in maximizing the performance of the movement (e.g. accuracy, speed, distance, and type of pitch thrown) and in preventing injuries to the shoulder joint (Bruan et al., 2009). Alterations in activation in the rotator cuff muscles may predispose a baseball player to an increased risk of injury (Bruan et al., 2009). Many researchers have used EMG in order to examine the effects of Kinesio Tape® on muscle recruitment during different functional and sport specific tasks (Hsu, Chen, Lin, Wang, & Shih, 2009; Janwantanakul & Gaogasigam, 2005; Reynard, Vuistiner, Léger, & Konzelmann, 2018; Slupik, Dwornik, Bialoszewski, & Zych, 2007; Vithoulk et al., n.d.; Zanca, Grüninger, & Mattiello, 2016).

The research relating to muscle recruitment changes with the use of Kinesio Tape® remains controversial, with many studies having contradictory results. Some studies found that Kinesio Tape® had little to no effect on muscle recruitment (Janwantanakul & Gaogasigam, 2005; Zanca et al., 2016). Janwatanakul and Gaogasigam (2005) evaluated the effect of inhibition and facilitation taping techniques on the activity of the vastus lateralis and vastus medialis muscles in 30 healthy females. The EMG activity was measured for both muscles during a stair descent task. They found no significant change in EMG muscle activity between the types of technique when compared to the no tape condition (Janwatanakul & Gaigasigam, 2005). Zanca et al. (2016) investigated the effects of Kinesio Tape® on shoulder joint position sense after inducing muscle fatigue in 24 healthy participants. Shoulder joint position was assessed in three sessions and under three taping conditions (no tape, Kinesio Tape®, and sham tape) at 50, 70, and 90 degrees of arm elevation in the scapular plane (Zanca et al., 2016). Scapular 3D kinematics and EMG of the clavicular and acromial portions of the upper trapezius, lower trapezius, and serratus anterior muscles were analyzed during arm elevation and lowering, before and after the fatigue protocol (Zanca et al., 2016). There were no significant differences or effect reported between the different types of tape and position during each session (Zanca et al., 2016).

In contrast, many studies reported that Kinesio Tape® had a significant effect when evaluating muscle recruitment in different segments of the body (Slupik et al., 2007; Vithoulka et al., 2010). Slupik et al. (2007) examined the effect of Kinesio Tape® on changes in the tone of the vastus medialis muscle while completing isometric contractions in 27 healthy individuals. The EMG muscle activity was collected with the patients positioned in sitting, with their knee bent to 15 degrees and resistance applied over the upper ankle joint (Slupik et al., 2007). Statistically significant results were reported for both increased recruitment of the muscle's motor units and bioelectrical activity of the muscle in the Kinesio Tape® session when compared to the no tape condition (Slupik et al., 2007). Vithoulka et al. (2010), investigated the effect of taping (Kinesio Tape®, no tape, and placebo tape) on the quadriceps muscle. They measured the strength of the quadriceps muscle at maximum concentric and eccentric isokinetic exercise in healthy non-athlete participants (Vithoulka et al., 2010). No significant differences in maximum concentric activation were found between taping conditions; however, significant differences were found between the three taping conditions in maximum eccentric torque (Vithoulka et al., 2010).

Hsu et al. (2009) investigated the effects of Kinesio Tape® on scapular kinematics, muscle strength, and EMG activity in baseball players with shoulder impingement problems. In this study, they applied Kinesio Tape® to the lower fibres of the trapezius muscle and looked at scaptions (Hsu et al., 2009). Scaption is defined as the elevation of the humerus in the scapular plane (30 degrees anterior to the frontal plane) and participants were asked to move in this plane paced to a metronome guided by a wooden pole (Hsu et al., 2009). Once participants were coordinated to the pace of the metronome, they were given a 2 kg weight and asked to perform three repetitions of this motion with the weight in their hand while EMG data was collected from the lower trapezius and serratus anterior muscles. Hsu et al., (2009) reported that with the application of Kinesio Tape® to the lower fibres of the trapezius muscle, there was increased muscle activity during 60-30 degrees of the lowering phase of the scaption movement. There was also increased scapula posterior tilt at 30 and 60 degrees of arm scaption.

Reynard et al. (2018) investigated the immediate effects of Kinesio Tape® on shoulder muscle activity, mobility, strength, and pain in a population of participants who underwent a surgical repair of the rotator cuff. Participants were assessed using a quick Disabilities of the Arm, Shoulder, and Hand questionnaire and a visual analog scale while needle EMG data was simultaneously collected (Reynard et al., 2018). The EMG data was collected while the participants were asked to lift their arms through full range into flexion while in the sagittal plane as high as possible and held for 5 seconds (Reynard et al., 2018). A maximum isometric contraction (MVIC) was also completed, and force was measured using a dynamometer while the participant positioned his/her arm in 90 degrees of shoulder flexion. The arm was simultaneously held in neutral rotation with the elbow extended, the forearm pronated, and the fist closed (Reynard et al., 2018). Participants were asked to complete this procedure under three difference taping conditions including no tape, placebo tape, and Kinesio Tape® (Reynard et al., 2018). The results revealed that there was no change in mobility and muscular strength; however, they did find a decrease in muscle activation in the upper fibres of the trapezius muscle which is often over-activated during maximal isometric contractions (Renyard et al., 2018).

Zhang et al. (2016) examined the immediate effect of Kinesio Tape® applied over the wrist extensor and flexor muscles on muscle strength and endurance during isometric and isokinetic muscle testing at both low (60 degrees per second) and high (210 degrees per second) angular speeds (Zhang et al., 2016). Participants completed the tasks under three different taping conditions including no tape, placebo tape, and Kinesio Tape® (Zhang et al., 2016). Isometric maximal voluntary contractions and isokinetic wrist extension and flexion forces were measured using a dynamometer (Zhang et al., 2016). The application of Kinesio Tape® resulted in no change in normalized peak moment, peak power, average power, and total work in the wrist flexor and extensor muscles (Zhang et al., 2016). The application of Kinesio Tape® applied to the wrist flexors; however, reduced work fatigue and resulted in a lower rate of decline in moment compared to the no taping condition (Zhang et al., 2016). This suggests that Kinesio Tape® may have a positive effect on muscle fatigue resistance during repeated concentric muscle actions (Zhang et al., 2016).

Muscle Fatigue

When muscles become fatigued there is a reduction in contractile function and muscle activation patterns can change (Bowman et al., 2006; Jacko et al., 2018). As muscle recruitment patterns change with fatigue, the EMG muscle activity is often decreased in some muscles and more active in others (Bowman et al., 2006; Jacko et al., 2018). In competitive sports such as baseball, the loss of physical work capacity due to muscle fatigue can greatly affect the outcome of a game (Jackso et al., 2018). Therefore, interventions that are able to decrease the amount of stress on the rotator cuff muscles caused by fatigue could potentially contribute to improved performance and shoulder injury prevention in overhead throwing athletes (Bruan et al., 2006; Jacko et al., 2018). Due to supraspinatus, infraspinatus, pectoralis major, and teres minor muscles being highly active during the overhead throw, these muscles are more susceptible to fatigue caused by strenuous physical activity and skeletal muscle activation (Bowman, Hart, McGuire, Palmieri, & Ingersoll, 2006; Jacko et al., 2018). Due to muscle fatigue being inevitable during strenuous physical activity, modalities are being sought out to reduce the change in muscle recruitment that is often induced by fatigue.

As Kinesio Tape® is proposed to increase blood and lymphatic flow, the effects of muscle fatigue could perhaps be mitigated by the application of this intervention (Kase et al., 2013). It has been proposed that Kinesio Tape® increases circulation and lymphatic flow by lifting the skin in the area it is applied to allowing more blood and lymph flow to the region; this in turn improves and increases the function of the muscles underlying the tape (Kase et al., 2013). This is an important proposed benefit of Kinesio Tape® as less fatigue in muscles in the overhead throwing athlete could result in an improved and increased performance and a decrease in the risk of injury.

Several studies have analyzed subjective arm fatigue while throwing as a risk factor for injuries (Lyman et al., 2001; Makhni et al., 2015; Olsen, Fleisig, Dun, Loftice, & Andrews, 2006; Petty, Andrews, Fleisig, & Cain, 2004; Yang et al., 2014). Arm fatigue was found to pose a significant risk of injury in four studies (Lyman et al., 2001; Makhni et al., 2015; Olsen et al., 2006; Petty et al., 2004; Register-Mihalik, Oyama, Marshall, & Mueller, 2012; Yang et al., 2014). Makhni et al. (2015) investigated the frequency quality, and effect of arm pain in 203 healthy youth baseball players. Participants completed a survey and it was found that players with prior overuse injuries were more likely to have arm pain while throwing, to have arm fatigue during a game or practice, and to be encouraged to keep playing despite their pain (Makhni et al., 2015). It was concluded that a majority of healthy youth baseball players report at least some baseline arm pain and fatigue (Makhni et al., 2015).

Olsen et al. (2006) had 95 adolescent pitchers who had shoulder or elbow surgery and 45 adolescent pitchers who had never had a significant pitching-related injury complete a survey to identify risk factors related to injury in baseball. The results demonstrated that the injured group reported significantly more months per year, games per year, innings per game, pitches per game, pitches per year, and warm-up pitches before a game than the uninjured group (Olsen et al., 2006). The previously injured pitchers reported pitching at a higher velocity and pitching with more arm pain and fatigue than the uninjured group (Olsen et al., 2006). Olsen et al. (2006) concluded that there may be a strong association between injury, muscle overuse, and fatigue in youth baseball players.

Register-Mihalik et al. (2012) described pitching practices among youth baseball pitchers and associations among these practices and self-reported throwing injuries in 702 little league and high school pitchers. It was found that upper extremity fatigue was a risk factor for shoulder injuries; however, not for elbow injuries (Register-Mihalik et al., 2012). Baseball Canada has set out a recommendation on the exact number of pitches a player is allowed to throw before they are considered fatigued and must take a day's rest to recover. Players aged 21 years of age or older are recommended to complete 45 pitches per day and then they should stop and not be allowed to continue pitching until they have had a day of rest (Baseball Canada, 2019). Due to the large amount of strain placed on the rotator cuff muscles during an overhead baseball throw, the rotator cuff muscles may become fatigued when performing a high number of throws over a short period of time. This fatigue could lead to a higher risk of injury; therefore, the application of therapeutic taping to the shoulder may be a solution to this problem as it may alter the muscle activity in the rotator cuff muscles, allowing players to perform better and decrease his/her risk of injury.

Purpose of the Research

Due to the effects of Kinesio Tape® being unclear, more research is needed in order to determine if it does have a significant effect and clinical utility on muscle activation and the velocity of an overhead throw in fatigued throwing athletes and in order to try to understand how taping of the rotator cuff muscles affects this sport specific task. It has been proposed that Kinesio Tape® could be effective at reducing the risk of injury in baseball players by changing the muscle recruitment patterning and relieving stress off the key musculature such as the rotator cuff muscles. By altering the recruitment of key muscles and relieving some of the stresses on the muscles associated with the overhead baseball throw, baseball players may also be able to improve the velocity of their throws leading to a better performance. Therefore, the purpose of this study was to investigate the effect of taping (Kinesio Tape® and no tape) on the velocity of an overhead baseball throw and muscle activation patterning of the supraspinatus, infraspinatus, and pectoralis major muscles in baseball players after muscle fatigue was induced.

Research Questions

The following research questions were used to guide this study:

1. Is there a difference between tape condition (Kinesio Tape® and no tape) on the velocity of an overhead baseball throw?
2. Is there an association between the supraspinatus, infraspinatus, and pectoralis major muscles on percent MVIC in the Kinesio Tape® condition during phases one, two, and three of an overhead baseball throw?
3. Is there an association between the supraspinatus, infraspinatus, and pectoralis major muscles on percent MVIC in the no tape condition during phases one, two, and three of an overhead baseball throw?
4. Is there a difference between tape condition (Kinesio Tape® and no tape) on the percent MVIC in the supraspinatus muscle in phases one, two, and three of an overhead baseball throw?
5. Is there a difference between tape condition (Kinesio Tape® and no tape) on the percent MVIC in the infraspinatus muscle in phases one, two, and three of an overhead baseball throw?
6. Is there a difference between tape condition (Kinesio Tape® and no tape) on the percent MVIC in the pectoralis major muscle in phases one, two, and three of an overhead baseball throw?

Chapter 2: Methodology

Participants

To be included in this research study participants had to be between the ages of 15 and 35 years and be considered healthy based on self-report from the Get Active Questionnaire from the Canadian Society for Exercise Physiology (CSEP; Appendix A). To be included in this research study participants had to have at least one-year experience playing baseball and had to be comfortable completing an overhead baseball throw. Participants were excluded if they had a history of fracture, dislocation, strain, or sprain in the upper extremity that affected their ability to complete an overhead throw, or if they had a known allergy to tape or adhesives/glue. The student researcher asked the participant if he/she had a history of fracture, dislocation, strain, or sprain in the upper extremity that affected their ability to complete an overhead throw, or if they had a known allergy to tape or adhesives/glue and were excluded if he/she answered ‘yes’.

Participant Recruitment Procedures

After obtaining ethical approval from the Lakehead University Research Ethics Board, the process of purposive sampling was used to recruit prospective participants. Participants were recruited from Lakehead University and the baseball community of Thunder Bay, Ontario. Posters (Appendix B) were distributed throughout the university and a letter (Appendix C) was given to travelling baseball leagues in Thunder Bay as well as little league coaches and players. This study aimed to have a total of 45 participants as based on pilot data and a priori analysis; this number would have been sufficient to detect a medium to large effect size with 80% power at α=.05 (two-tailed) in EMG muscle activity. However, due to the coronavirus (COVID-19) testing in this study was ended early as Lakehead University facilities were closed.

Screening Measures

Get Active Questionnaire. The Get Active Questionnaire was developed by CSEP to easily screen an individual's ability to safely participate in physical activity (CSEP, 2019). This is an evidence-based pre-screening tool which replaced all other previous CSEP tools. This questionnaire can be completed by all ages and helps users make an informed decision whether they should seek further advice from a health care professional before becoming physically active (CSEP, 2019).

Instrumentation

Surface electromyography. Surface EMG is a non-invasive procedure to measure muscle activity (Criswell, 2011). A Trigno™ Wireless Delsys© EMG system and Trigno™ IM sensors were used for this study. The Trigno™ Wirelesss Delsys© system and sensors are capable of collecting 16 EMG channels simultaneously and are able to transmit within a range of 20 metres (Delsys Inc. 2012). This system was used collect and read the raw EMG signals for each targeted muscle. The EMG activity of the infraspinatus, supraspinatus, teres minor, and pectoralis major muscles were collected on the side of the body participants indicated as his/her dominant hand and measured in millivolts (mV). One wireless electrode was also used to collect the acceleration of the elbow. The wireless electrode placed on the elbow was used to distinguish between the phases of the overhead baseball throw which will be described in the data processing section.

Hypafix® was used to hold the five wireless EMG electrodes in place while the participant completed the warmup, fatiguing protocol, and testing protocol. The Hypafix® was cut into 5.08 cm wide by 7.62 cm long strips. The Hypafix® pieces were then placed over the five wireless EMG electrodes to ensure the electrodes remain properly positioned and maintain good contact with the skin throughout each session.

LabChart software™. LabChart™ software is an Analogue to Digital (AD)™ Instruments software program used to acquire and analyse EMG activity. The software was used to interface with the Trigno™ Wirelesss Delsys© EMG system. This study used LabChart™ 8 to collect EMG data in real time. For this study, four Wirelesss Delsys© EMG sensors attached to the muscles (infraspinatus, supraspinatus, teres minor, and pectoralis major muscles) and one elbow acceleration sensor were interfaced with the LabChart™ program. LabChart™ software was then be used to acquire, amplify, rectify, and filter all of the EMG data.

Radar gun. The Sports Radar SR3600 was used in this study to measure the velocity of the ball at release of the participant's overhead throws. The Sports Radar SR3600 has an accuracy within 1 km/h and is capable of measuring speeds between 16 km/h and 322 km/h (Sports Radar, n.d.).

Kinesio Tape®. Kinesio Tape® was used in this research for the Kinesio Tape® condition. Kinesio Tape® is a high-quality cotton tape with wave-like coating. The Kinesio Tape® that was applied to participants in this research study was 5.08 cm wide and was applied to the participant's throwing shoulder in accordance with the rotator cuff impingement taping procedure as described by Kase et al. (2013).

Procedures

There were two taping conditions including 1) no tape and 2) Kinesio Tape®. Each participant was asked to attend two 45-minute testing sessions, with a minimum of at least 24-hours of rest in between sessions and no more than a maximum of 1 week between the sessions. The two taping conditions were randomized between sessions one and two by alternating the session participants started with. The first participant completed the Kinesio Tape® condition in session one and the no tape condition in session two. Following the first participant, the subsequent participants were alternated between completing the Kinesio Tape® and no tape conditions in session one.

Session one. In session one, the participant was asked to report to the Lakehead University Hangar field, where he/she met the student researcher. The participant received an informed consent form (Appendix D) prior to her/his first session. Prior to the start of session one the student researcher read through the informed consent with the participant to ensure he/she fully understood what this research entailed and if he/she had any further questions. The participant was then asked to complete the Get Active Questionnaire and anthropometric measures and demographic information obtained (height, mass, age, level of baseball competition, and the number of years he/she have played baseball; Appendix E). Once the participant provided informed consent, his/her skin was prepared for the EMG wireless electrode placement. To prepare the skin for electrode placement, all hair surrounding the electrode placements was shaved by the student researcher with a razor, as required. The participant's skin was then cleaned using an alcohol wipe and then wiped with a textile towel in order to remove any residue or dead skin in the area. The student researcher then proceeded to place the wireless electrodes on the participant as described in the electrode placement section below. All electrodes were placed on the side of the body that the participant indicated as his/her throwing arm.

Electrode placement. Once the participant's skin was been prepared for electrode placement, the first wireless electrode was placed was on the supraspinatus muscle. To isolate this muscle, the participant was asked to lay on an examination bed in a prone position with his/her arm abducted to 90 degrees and his/her elbow flexed over the edge of the table (Konrad, 2005). The student researcher then palpated the midpoint and two finger-breadths anterior to the scapular spine and placed the electrode on this location (Figure 9; Konrad, 2005). The participant was asked to remain in this position. The student researcher located the position of the electrode for the infraspinatus muscle by palpating approximately 4 cm below and parallel to the spine of the scapula and placed the electrode over the infrascapular fossa (Figure 8; Konrad, 2005). While in prone lying, the teres minor wireless electrode position was located by palpating one-third of the way between the acromion process and inferior angle of the scapula, along the lateral boarder of the scapula (Figure 9; Konrad, 2005). For the wireless electrode placement of the pectoralis major muscle, the participant was asked to sit on the examination bed, faced the student researcher with his/her elbow flexed to 90 degrees and his/her shoulder abducted to 75 degrees (Figure 10; Konrad, 2005). The student researcher then placed the wireless electrode four finger breadths inferior to the medial clavicle and medial to the anterior axillary border (Konrad, 2005). The student researcher then asked the participant to flex his/her shoulder to 90 degrees with the elbow extended and with the dorsum of his/her hand positioned upwards and his/her wrist in fully extended position. For placement of the final electrode, the participant was asked to sit facing the student researcher with his/her shoulder flexed to 90 degrees and his/her elbow fully extended. The electrode was placed 2.4 cm distal to the medial epicondyle (Figure 11). The student researcher then secured all of the wireless electrodes with a piece of the Hypafix™ to ensure the wireless electrodes stay in place throughout the testing session.

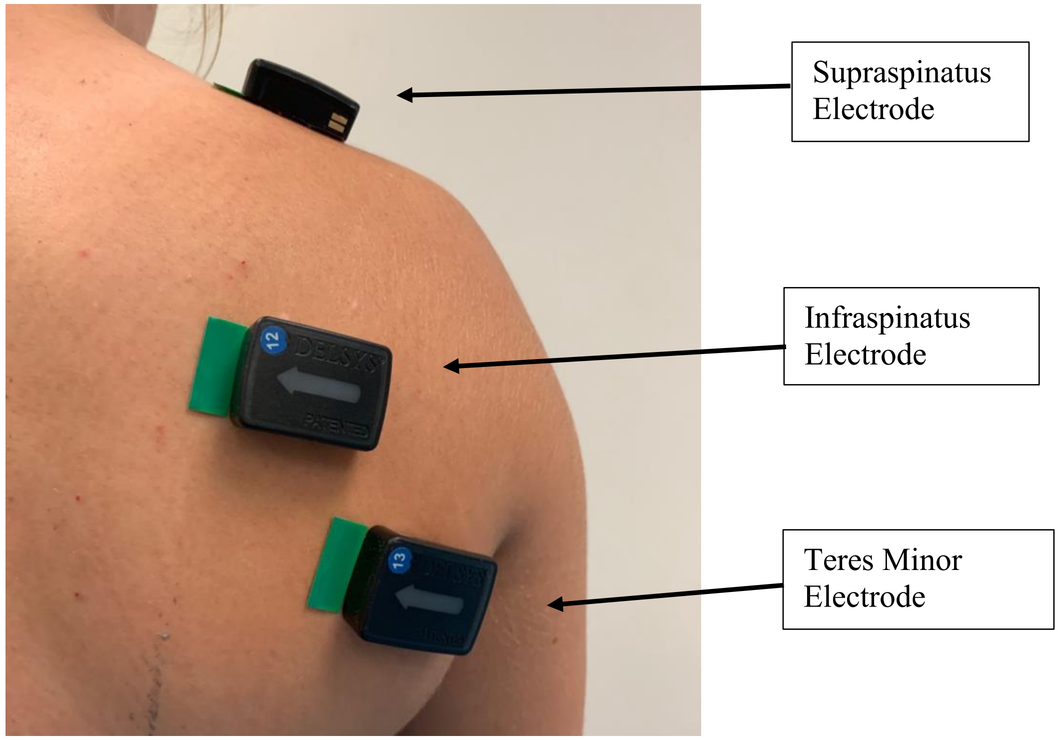

Figure 8. Posterior view of wireless electrode placement.

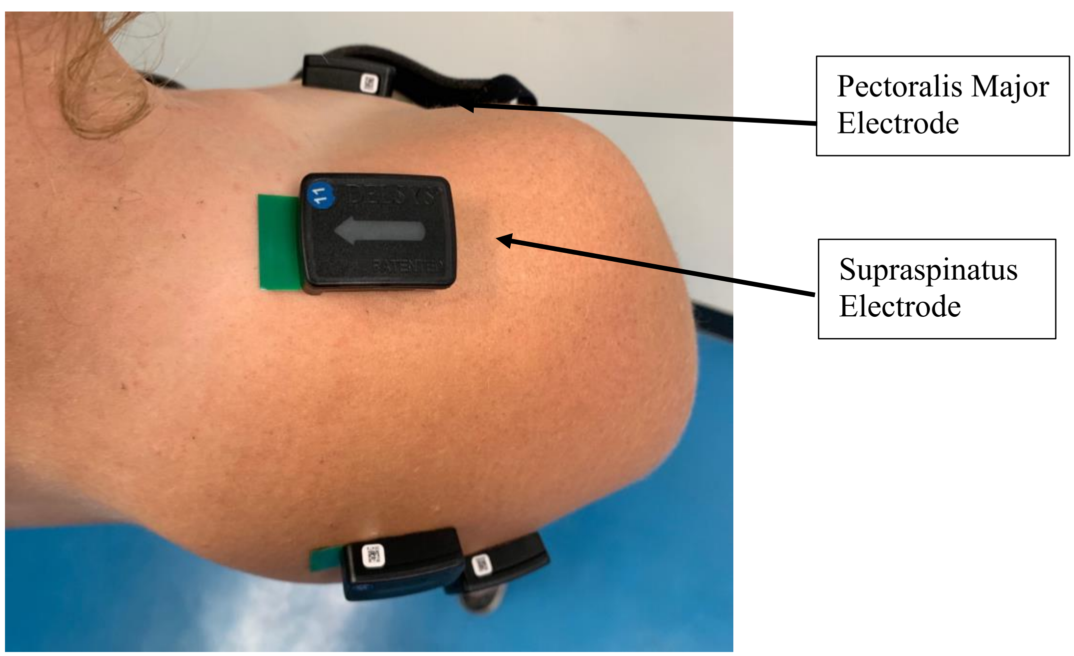

Figure 9. Superior view of wireless electrode placement.

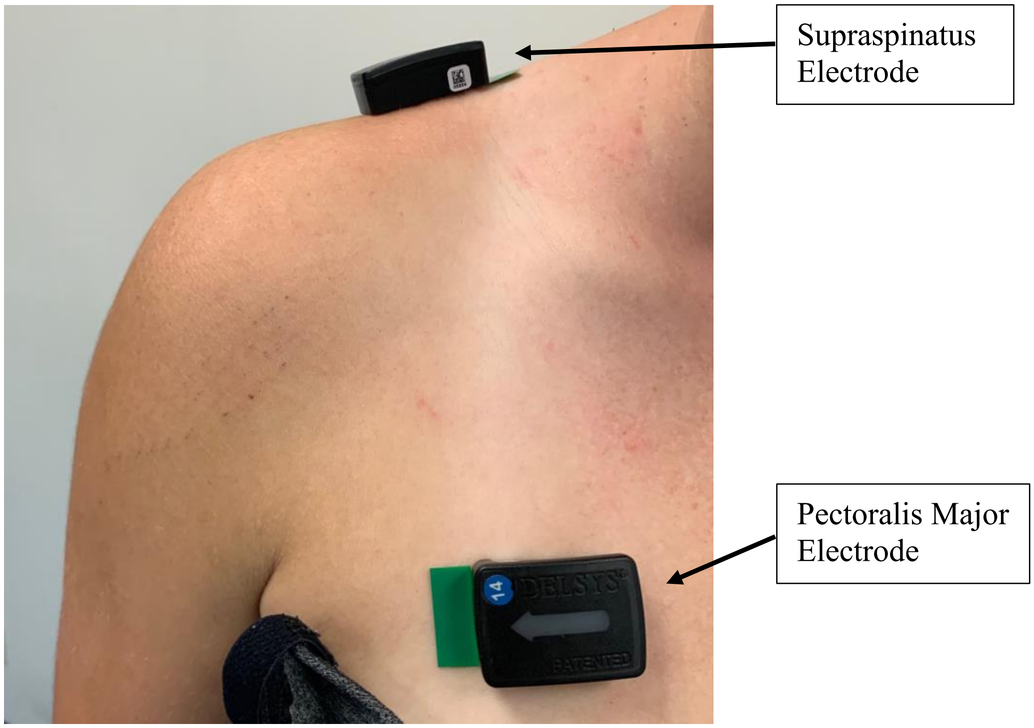

Figure 10. Anterior view of the wireless electrode placement.

Figure 11. Wireless EMG electrode placed on the elbow to measure acceleration.

Once all wireless EMG electrodes were positioned and secured on the skin, the student researcher then turned on the wireless EMG electrodes and asked the participant to complete three forward and three backward rotation arm circles while the student researcher recorded the wireless EMG data. This ensured all wireless EMG electrodes were working properly and that they were not impeding the participant's range of motion. The student researcher then completed the MVIC testing protocol for each muscle.

Maximum isometric voluntary contraction protocol. The MVIC protocol was used for normalization purposes for the EMG data of the infraspinatus, supraspinatus, teres minor, and pectoralis major muscles. While data was being recorded, participants were asked to hold an isometric contraction for a length of 3 seconds each and one trial was completed per MVIC for each muscle (Castelein, Cagie, Parlevliet, Danneels, & Cools, 2015). As the participant performed the resisted isometric contraction, the student researcher encouraged him/her by repeating the phase 'push hard' three times. All MVIC testing was completed with the participant in a seated position with a supported high back chair to help ensure an upright and neutral spine posture. The first MVIC was completed for the supraspinatus muscle. The participant was asked to sit on the examination table while the student researcher applied resistance against the participant's unsupported forearm while the participant generated a maximal isometric contraction into abduction (Figure 11; Kendall, McCreary, Provance, Rodgers, & Romani, 2005). The next MVIC was for the infraspinatus muscle and it was completed with the participant's arm resting on the table (Kendall et al., 2005). The student researcher placed one hand under the upper arm, near the elbow to stabilize the humerus (Figure 12; Kendall et al., 2005). This position ensured that the participant's arm was stabilized, and he/she could not adduct or abduct his/her arm. The participant was encouraged to externally rotate the shoulder maximally against resistance (Kendall et al., 2005).

Next, the MVIC for the teres minor muscle was completed with the participant's shoulder positioned in external rotation and with the elbow held at a right angle unsupported (Kendall et al., 2005). The participant then was asked to externally rotate the shoulder maximally against resistance (Figure 13; Kendall et al., 2005). The final MVIC was completed for the pectoralis major muscle. The student researcher stabilized the participant's opposite shoulder firmly to prevent rotation of the trunk (Kendall et al., 2005). The participant was asked to position his/her shoulder in a position of 90 degrees of flexion and slight medial rotation with the elbow extended (Kendall et al., 2005). The participant was asked to horizontally adduct his/her shoulder maximally against resistance (Figure 14; Kendall et al., 2005). Each resisted isometric contraction for the respective muscles was held for 3 seconds. Once the MVIC protocol was completed the student researcher then either began applying the Kinesio Tape® or the no tape condition depending on the taping condition that the participant had been allocated to.

Figure 12. The position for the MVIC of the supraspinatus muscle.

Figure 13. The position for the MVIC of the infraspinatus muscle.

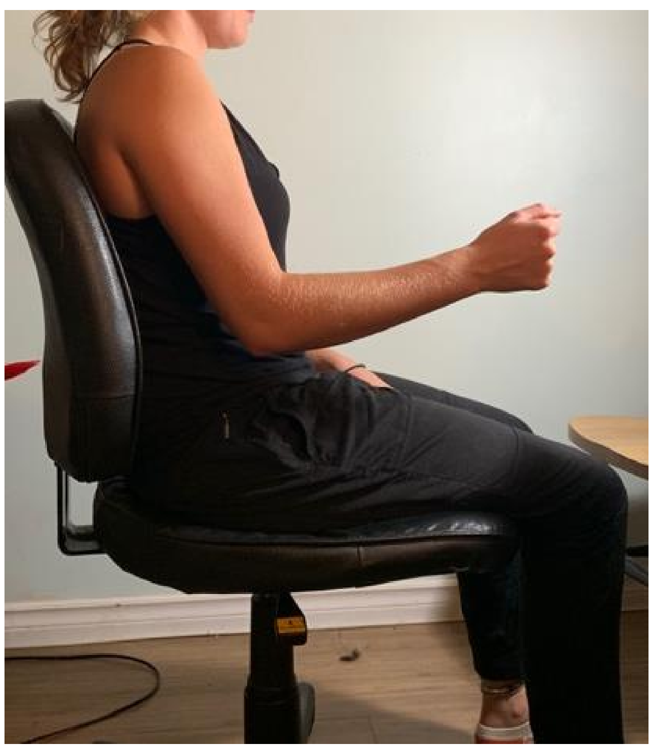

Figure 14. The position for the MVIC of the teres minor muscle.

Figure 15. The position for the MVIC of the pectoralis major muscle.

Taping procedure. In this taping technique, the first piece of Kinesio Tape® was applied to the supraspinatus muscle, as this was the primary muscle being treated in many throwing athletes such as baseball players (Kase et al., 2013). The length of the Kinesio Tape® was determined by measuring between the anatomical landmarks described below for each piece of tape. The corners of each piece of Kinesio Tape® were rounded, to ensure that the tape did not pull away from the skin. The anchor of the Kinesio Tape® Y-strip was placed approximately 2 inches below the greater tuberosity of the humerus and applied with no tension (Kase et al., 2013). The participant was then asked to move his/her shoulder into an adducted position with his/her forearm behind his/her back (Kase et al., 2013). The superior tail of the Y-strip was then anchored superior to the spine of the scapula at the junction between the upper and middle fibres of the trapezius muscle and ended at the supraspinous fossa on the superior medial border of the scapula (Kase et al., 2013). The inferior tail of the Kinesio Tape® Y-strip was applied superior to the spine of the scapula and anchored on the medial spine of the scapula (Kase et al., 2013). The two Kinesio Tape® Y-strip tails were applied initially with light, 15-25% of the available tension and then reduced so that the distal 1-2 inches of tape was anchored with no tension (Kase et al., 2013).

The second piece of Kinesio Tape® was applied to the deltoid muscle. The anchor of the Kinesio Tape® Y-strip was applied with no tension and started approximately 2 inches below the deltoid tuberosity of the humerus (Kase et al., 2013). The participant was then asked to move his/her arm into approximately 45 degrees of shoulder abduction with slight external rotation (Kase et al., 2013). The anterior tail of the Kinesio Tape® Y-strip was applied by following the curvature of the anterior deltoid muscle (Kase et al., 2013). The Kinesio Tape® anterior tail was initially applied with light, 15-25% of the available tension and then reduced so that the distal 1-2 inches was anchored with no tension (Kase et al., 2013). The participant was then asked to move into shoulder horizontal adduction (Kase et al., 2013). The Kinesio Tape® posterior tail of the Y-strip followed the curvature of the posterior deltoid muscle and anchored on the acromioclavicular joint with no tension (Kase et al., 2013).

The third piece of Kinesio Tape® was applied to limit anterior translation of the humeral head (Kase et al., 2013). This piece of tape was an I-strip and was anchored on the anterior aspect of the shoulder medial to the coracoid process with no tension (Kase et al., 2013). The participant's shoulder was positioned in internal rotation (Kase et al., 2013). Th Kinesio Tape® was then applied with moderate to high, 50-75% of the available tension (Kase et al., 2013). The proximal anchor of the Kinesio Tape® I-strip was stabilized to ensure that no tension was added to the distal anchor of the tape as it was laid down (Kase et al., 2013). This portion of the Kinesio Tape® was applied with downward and inward pressure to the middle of the lateral aspect of the humeral head (Kase et al., 2013). Once the Kinesio Tape® was attached to the middle of the humeral head on the lateral aspect of the shoulder, the anchor was tensioned to the desired point of tension (Kase et al., 2013). The participant was then asked to move his/her shoulder into horizontal adduction and the remaining portion of the Kinesio Tape® I-strip was anchored with light, 15-25% of the available tension (Kase et al., 2013). These steps are illustrated in Figure 16-18.

Figure 16. Lateral view of taping protocol with Kinesio Tape®.

Figure 17. Anterior view of taping protocol with Kinesio Tape®.

Figure 18. Posterior view of taping protocol with Kinesio Tape®.

The participant was then asked to complete a supervised warmup which consisted of a dynamic stretching session. The dynamic stretching included 10 repetitions per leg of high knees, butt kicks, lunges, and skipping with the arms swinging forward and backwards. This dynamic stretching warmup took approximately 5 minutes to complete, was standardized between participants, and was supervised by the student researcher. The participant then completed three maximal overhead baseball throws while wireless EMG and velocity of the ball at release were being collected. The participant then began the fatiguing throwing protocol.

Fatiguing throwing protocol. To induce fatigue in the participant's throwing arm, the participant was asked to complete 30 consecutive overhead throws with a baseball of standard size and weight into a net positioned 10 metres in front of them. The first 10 throws were performed at a low intensity. The next 10 throws were completed at a medium intensity, and the final 10 throws were completed at the participant's maximum velocity. The participant rated the intensity of his/her own throws with the use of the Borg Scale of Perceived Exertion (Borg, 1982). A score from 6-11 was considered a low intensity throw; a score from 12-14 was considered a medium intensity throw; and a score of above 15 was considered a maximum intensity throw (Borg, 1982). The student researcher counted the number of overhead throws that the participant completed to ensure it was accurate. The participant was asked to throw into a net positioned 10 metres in front of them. When the participant completed 30 consecutive overhead throws he/she was considered fatigued as per the Official Rules of Baseball-Canadian Content (Baseball Canada, n.d.). The participant was asked to complete a total of 33 overhead baseball throws that included the fatiguing protocol and maximal throws for the testing protocol and the number of throws fell below the maximum recommendation set out by Baseball Canada to reduce the risk of injury. After the fatiguing protocol was completed, the participant began the testing protocol immediately so that no time was allowed for the participant to recover from the fatigue.

Testing protocol. For the maximal overhead throw testing protocol, the participant was asked to complete three maximal overhead throws into a net positioned 10 meters away while surface EMG and velocity of the ball at release were recorded. The participant was asked to stand as still as possible until the student researcher indicated to begin. The participant then completed one overhead baseball throw at his/her maximum velocity and returned to his/her starting position. This process was repeated for all three trials of the testing protocol. The mean EMG value for each muscle and recorded throwing velocity of the three trials was used for data analysis. Once the data collection was completed, the electrodes and tape were removed from the participant and the session was concluded.

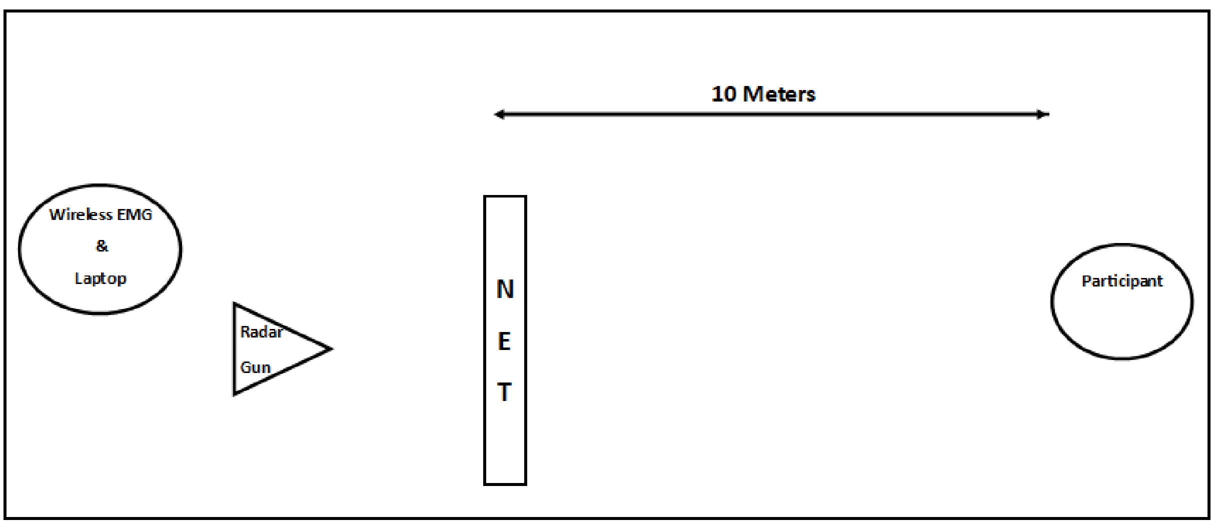

Figure 19. Equipment set-up. The participant threw the baseball into a net placed 10 meters away. The radar gun, wireless EMG base, and laptop were positioned behind the net.

Session two. In session two, participants completed the same preparation and data collection as described for session one. The procedure for session two differed in that it was completed under the opposite taping condition.

Data Processing

Electromyography. All data was analyzed with custom written analysis software (MATLAB, MathWorks, Inc., Natick, MA, USA). Background EMG data was full-wave rectified and low pass filtered at a cut-off frequency of 10 Hz with a 4th order Butterworth filter. For MVIC trials, EMG was quantified by calculating the mean EMG activity (mV) for the 3 seconds. Mean EMG activity for each muscle during the overhead baseball throw was calculated and averaged within each of the three phases and across the three testing trials after being checked for reliability using an ICC. For normalization between participants and experimental sessions EMG data was converted into a percentile based on the MVIC he/she performed that day for each muscle. Phase one (wind-up phase) was defined as the point from the time the participant began movement to the lowest point of acceleration in the negative direction. Phase two (acceleration phase) was defined as the time from the lowest point of acceleration in the negative direction to the highest peak of acceleration in the positive direction. Phase three (follow through phase) was defined as the time from the highest peak of acceleration in the positive direction to when acceleration stopped. The three phases are illustrated in Figure 20.

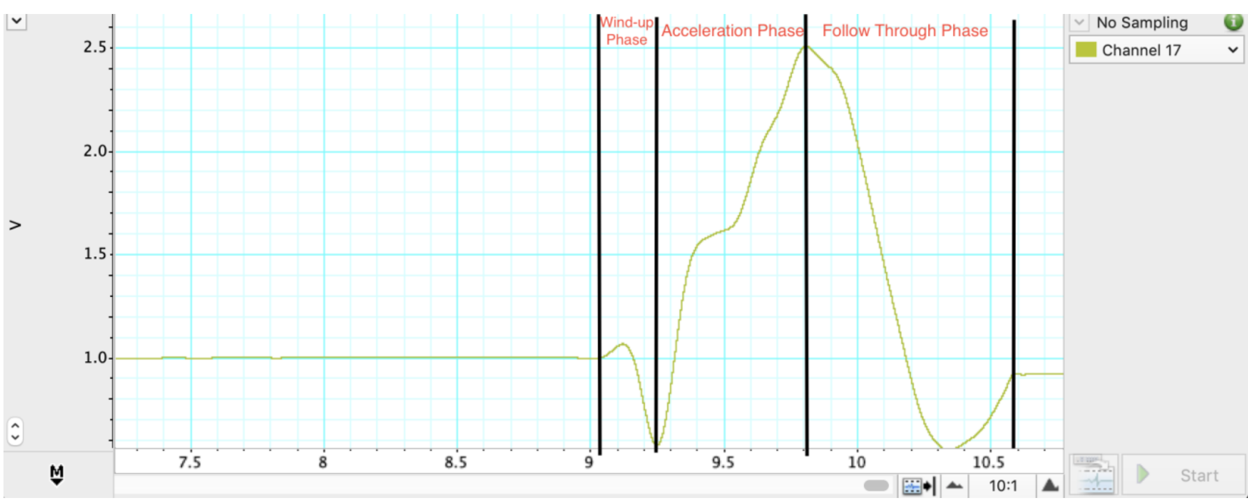

Figure 20. The three phases of an overhead throw the EMG data will be broken into.

Throwing velocity data. Throwing velocity of the ball at release data was collected throughout the fatiguing and testing protocols. Data collected during the fatiguing throwing protocol was used to verify the intensity of the overhead baseball throws and this data was not analyzed. If the participant threw too fast he/she was asked to throw a softer and if he/she threw too slow the student researcher asked the participant to throw harder. The velocity of the final three maximal effort throwing trials was used for the analysis. Since the radar gun was positioned on a tripod, it was used in continuous mode setting so that the tracking of the pitch velocity was ongoing. The data was then recorded every time the Sports Radar SR3600 beeped. The radar gun was set to measure the velocity of participant's throws in km/h.

Statistical Analysis

Following data collection, filtering, and processing procedures, the EMG and throwing velocity data were transferred into an IBM® SPSS Version 24 data file for further analysis. Descriptive statistics were completed based on the anthropometric data collected from participants. There were seven independent variables in this study including the supraspinatus muscle, infraspinatus muscle, pectoralis major muscle, phase one, phase two, phase three, and tape condition. The independent variable tape condition had two levels including no tape and Kinesio Tape®. There were two dependent variables including EMG muscle activity and velocity of throw. Pre-test muscle activity was also measured with the wireless EMG system. ICC were conducted on the EMG data of the three muscles to evaluate the relationship the muscles had with one another. Nine paired samples t-tests were conducted to test the hypothesis that there was a difference between tape conditions (Kinesio Tape® and no tape) on percent MVIC in the supraspinatus, infraspinatus, pectoralis major muscle in phases one, two, and three of the overhead baseball throws. A paired samples t-test was conducted to test the hypothesis that there was a difference between tape conditions (Kinesio Tape® and no tape) on the velocity of an overhead throw. All statistical tests were 2-tailed, and significance level set at $p<.05$.

Chapter Three: Results

Demographics

A total of 7 participants completed this study. The demographic information of all participants is presented in Table 1.

Table 1.
Participant demographic information.

Sex	7 males, 1 female
Height (cm)	179.76 +/- 4.52
Mass (kg)	79.5 +/- 18.29
Age (years)	22.5 +/- 6.92
Number of years playing baseball (years)	15.33 +/- 7.76
Position in baseball	3 pitchers, 2 infielders, and 2 outfielders
Level of baseball competition	3 club, 2 high school, and 2 recreational
Amount of physical activity per week (minutes)	410 +/- 342.4

Missing Data

Due to equipment malfunction (electrode failure or loss of electrode adherence), usable data for each variable from trials varies from n=7 to n=5. In cases where equipment malfunction occurred, and only two out of three trials were considered usable, the mean of the two trials was used in place of the three-trial average.

Throwing Velocity Inferential Statistics

Is there a difference between tape conditions (Kinesio Tape® and no tape) on the velocity of an overhead baseball throw? A paired samples t-test was used to determine whether there was a statistically significant difference between the velocity of an overhead baseball throw at release when Kinesio Tape® was applied to the participant compared to no tape. There were no outliers in these data, as assessed by inspection of a boxplot. The difference in throwing velocity scores for the Kinesio Tape® and no tape conditions were normally distributed, as assessed by the Shapiro-Wilk's test ($p=.148$). There was no statistically significant difference in throwing velocity with the application of the different taping conditions, $t(5)=.456$, $p=.668$. Participants performed an overhead baseball throw slightly faster when Kinesio Tape® was applied (*M*=3.82 km/h, *SD*=2.97) compared to the no tape condition (*M*=2.99 km/h, *SD*=2.74). The Kinesio Tape® condition resulted in a slightly faster overhead throw by .83 km/h, 95% CI [-3.85, 5.51] compared to the no tape condition, as seen in Figure 21.

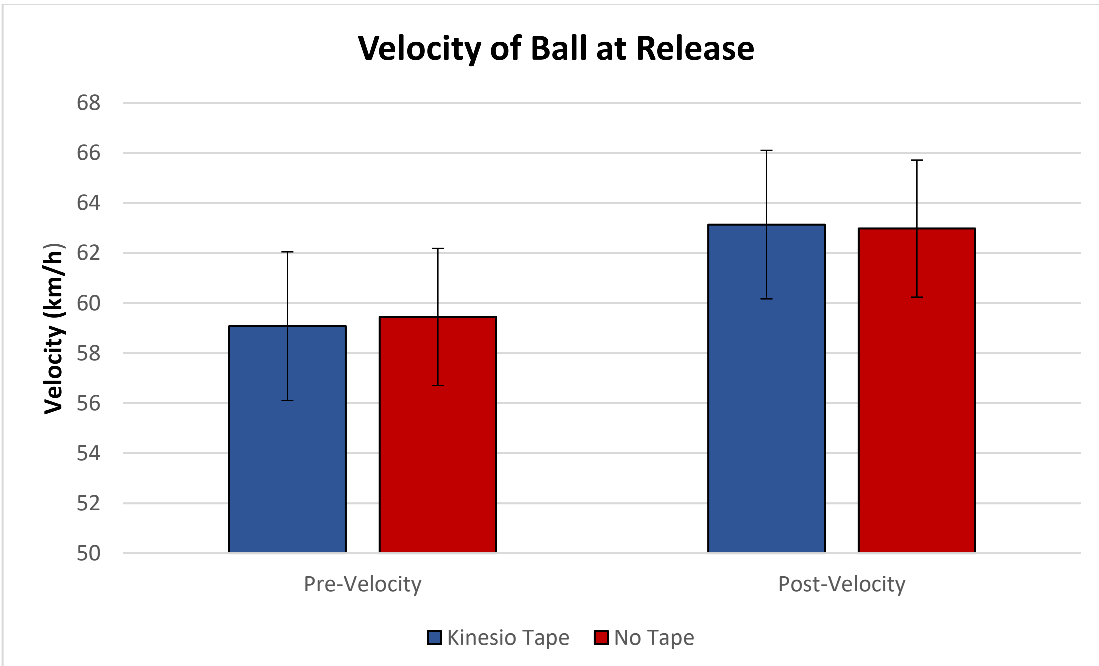

Figure 21. Mean differences in velocity of the ball at release across taping conditions.

Surface Electromyography Interclass Correlations Analysis

Is there an association between the supraspinatus, infraspinatus, and pectoralis major muscles on percent MVIC in the no tape condition during phases one, two, and three of an overhead baseball throw?

An interclass correlation (ICC) was completed to determine if there was an association between the supraspinatus, infraspinatus, and pectoralis major muscles in phase one of the overhead baseball throw in the no tape condition. If a strong relationship was found between muscles, those muscles would have been transformed into one variable to increase the power of the statistical tests completed. A low degree of association was found between the supraspinatus, infraspinatus, and pectoralis major muscles in phase one of the overhead baseball throw in the no tape condition, $F(5,10)=1.44$, $p=.291$. The average measure ICC was .30 with a 95% confidence interval from -1.70 to .893. Due to there being a low degree of association, statistical tests were completed for each muscle individually.

An ICC was completed to determine if there was an association between the supraspinatus, infraspinatus, and pectoralis major muscles in phase two of the overhead baseball throw in the no tape condition. A low degree of association was found between the supraspinatus, infraspinatus, and pectoralis major muscles in phase two of the overhead baseball throw in the no tape condition, $F(4,8)=1.52$, $p=.284$. The average measure ICC was .24 with a 95% confidence interval from -.658 to .882.

An ICC was completed to determine if there was an association between the supraspinatus, infraspinatus, and pectoralis major muscles in phase three of the overhead baseball throw in the no tape condition. A low degree of association was found between the supraspinatus, infraspinatus, and pectoralis major muscles in phase three of the overhead baseball throw in the no tape condition, $F(4,8)=1.38$, $p=.324$. The average measure ICC was .24 with a 95% confidence interval from -1.4 to .903.

Is there an association between the supraspinatus, infraspinatus, and pectoralis major muscles on percent MVIC in the Kinesio Tape® condition during phases one, two, and three of an overhead baseball throw?

An ICC was completed to determine if there was an association between the supraspinatus, infraspinatus, and pectoralis major muscles in phase one of the overhead baseball throw in the Kinesio Tape® condition. A low degree of association was found between the supraspinatus, infraspinatus, and pectoralis major muscles in phase one of the overhead baseball throw in the Kinesio Tape® condition, $F(4,8)=.595$, $p=.705$. The average measure ICC was -.68 with a 95% confidence interval from -6.1 to .746.

An ICC was completed to determine if there was an association between the supraspinatus, infraspinatus, and pectoralis major muscles in phase two of the overhead baseball throw in the Kinesio Tape® condition. A low degree of association was found between the supraspinatus, infraspinatus, and pectoralis major muscles in phase two of the overhead baseball throw in the Kinesio Tape® condition, $F(4,8)=1.1$, $p=.419$. The average measure ICC was .09 with a 95% confidence interval from -5.1 to .905.

An ICC was completed to determine if there was an association between the supraspinatus, infraspinatus, and pectoralis major muscles in phase three of the overhead baseball throw in the Kinesio Tape® condition. A low degree of association was found between the supraspinatus, infraspinatus, and pectoralis major muscles in phase three of the overhead baseball throw in the Kinesio Tape® condition, $F(5,10)=1.29$, $p=.339$. The average measure ICC was .25 with a 95% confidence interval from -3.69 to .896.

Surface Electromyography Inferential Statistics

Is there a difference between tape conditions (Kinesio Tape® and no tape) on the percent MVIC in the supraspinatus muscle in phases one, two, and three of an overhead baseball throw?

A paired samples t-test was used to determine whether there was a statistically significant difference between the taping conditions (Kinesio Tape® and no tape) on percent MVIC in the supraspinatus muscle in phase one. Due to the small sample size, parametric and non-parametric tests were performed and both tests produced similar results; therefore, the parametric paired sample t-test results are presented in the analysis of the results. There were no outliers in the data, as assessed by inspection of a boxplot for values greater than 1.5 box-lengths from the edge of the box. The difference in surface EMG scores for the Kinesio Tape® and no tape conditions were normally distributed, as assessed by Shapiro-Wilk's test (*p*=.902). Participants had a higher percent of muscle activity during the no tape condition (*M*=-.004%, *SD*=.027) as opposed to the Kinesio Tape® condition (*M*=-.085%, *SD*=.072) when completing an overhead baseball throw and as illustrated Figure 22. There was a mean increase of -8%, 95% CI [-.274, .112]. There was, however, no statistically significant difference in muscle activity under the different taping conditions in the supraspinatus muscle in phase one of the overhead throw, *t*(6)=-1.023, *p*=.346.

A paired samples t-test was used to determine whether there was a statistically significant difference between the taping conditions (Kinesio Tape® and no tape) on percent MVIC in the supraspinatus muscle in phase two. Due to the small sample size, parametric and non-parametric tests were once again performed and both tests produced similar results; therefore, the parametric paired sample t-test results are presented in the analysis of the results. There were no outliers in the data, as assessed by inspection of a boxplot for values greater than 1.5 box-lengths from the edge of the box. The difference in surface EMG scores for the Kinesio Tape® and no tape conditions were normally distributed, as assessed by the Shapiro-Wilk's test (*p*=.823). Participants had a higher percent of muscle activity with the application of Kinesio Tape® condition (*M*=-2.2%, *SD*=.187) as opposed to the no tape condition (*M*=-3.4 %, *SD*=.150) when completing an overhead baseball throw and as illustrated Figure 22. There was a mean increase of 1.3%, 95% CI [-.167, .193]. There was no statistically significant difference muscle activity under different taping conditions in the supraspinatus muscle in phase two of the overhead throw, *t*(6)=.172, *p*=.869.

A paired samples t-test was used to determine whether there was a statistically significant difference between the taping conditions (Kinesio Tape® and no tape) on percent MVIC in the supraspinatus muscle in phase three. Due to the small sample size, parametric and non-parametric tests were performed and both tests produced similar results; therefore, the parametric paired sample t-test results are presented in the analysis of the results. There were no outliers in the data, as assessed by inspection of a boxplot for values greater than 1.5 box-lengths from the edge of the box. The difference in surface EMG scores for the Kinesio Tape® and no tape conditions were normally distributed, as assessed by Shapiro-Wilk's test (p=.892). Participants had a higher percent of muscle activity during the no tape condition (M=10.3 %, SD=.096) as opposed to the Kinesio Tape® condition (M=7.2%, SD=.027) when completing an overhead baseball throw and as illustrated Figure 22. There was a mean increase of 3.2%, 95% CI [-.293, .223]. There was no statistically significant difference in muscle activity under different taping conditions in the supraspinatus muscle in phase three of the overhead throw, $t(6)$=-.299, p=.775.

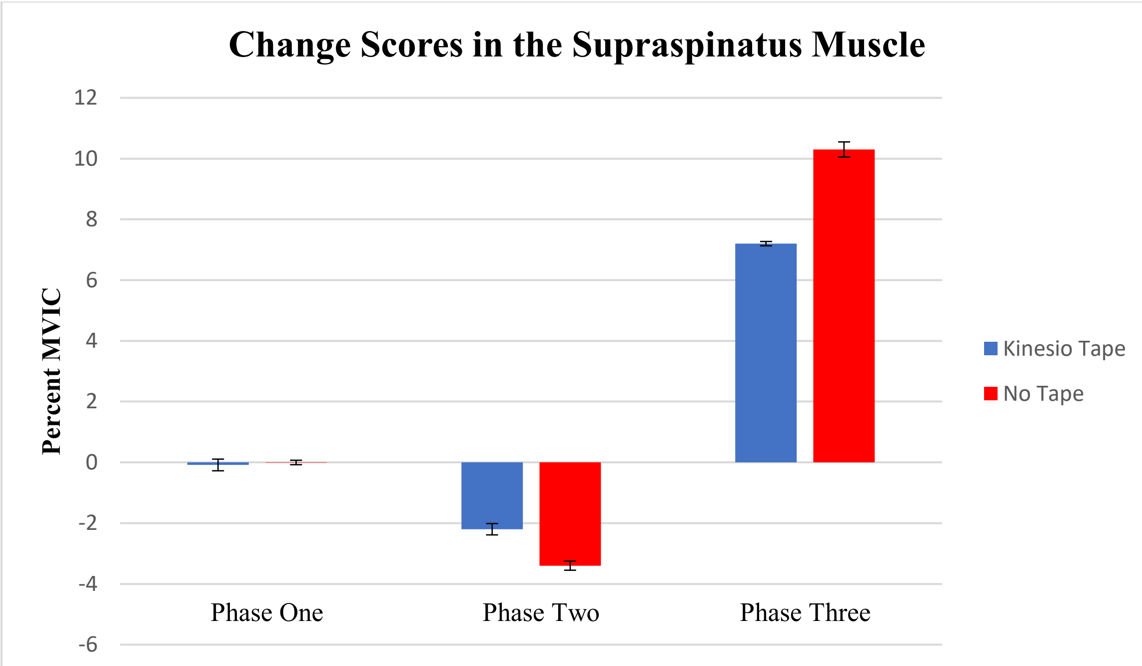

Figure 22. Change scores differences in surface EMG (percent MVIC) in the supraspinatus muscle in phases one, two, and three.

Is there a difference between tape conditions (Kinesio Tape® and no tape) on the percent MVIC in the infraspinatus muscle in phases one, two, and three of an overhead baseball throw?

A paired samples t-test was used to determine whether there was a statistically significant difference between the taping conditions (Kinesio Tape® and no tape) on percent MVIC in the infraspinatus muscle in phase one. Due to the small sample size, parametric and non-parametric tests were once again performed and both tests produced similar results; therefore, the parametric paired sample t-test results will be presented in the analysis of the results. One outlier was detected that was more than 1.5 box-lengths rom the edge of the box in a boxplot. The analysis was completed with and without the outlier included in the analysis and produced similar results; therefore, it was included in the final analysis and reporting. The difference in surface EMG scores for the Kinesio Tape® and no tape conditions were normally distributed, as assessed by the Shapiro-Wilk's test (p=.100). Participants had a higher percent of muscle activity during the Kinesio Tape® condition (M=1.5%, SD=.131) as opposed to the no tape condition (M=-8.2 %, SD=.216) when completing an overhead baseball throw and as illustrated Figure 23. There was a mean increase of 9.6%, 95% CI [-.444, .638]. There was no statistically significant difference in muscle activity under different taping conditions in the infraspinatus muscle in phase one, $t(6)$=.436, p=.678.

A paired samples t-test was used to determine whether there was a statistically significant difference between the taping conditions (Kinesio Tape® and no tape) on percent MVIC in the infraspinatus muscle in phase two. Due to the small sample size, parametric and non-parametric tests were performed and both tests produced similar results; therefore, the parametric paired sample t-test results are once again presented in the analysis of the results. There were no outliers in the data, as assessed by inspection of a boxplot for values greater than 1.5 box-lengths from the edge of the box. The difference in surface EMG scores for the Kinesio Tape® and no tape conditions were not normally distributed, as assessed by the Shapiro-Wilk's test (p=.045). Participants had a higher percent of muscle activity during the Kinesio Tape® condition (M=64.5%, SD=.82) as opposed to the no tape condition (M=6.5%, SD=.06) when completing an overhead baseball throw as seen in Figure 23. There was a mean increase of 57.9%, 95% CI [-.318, 1.477]. There was no statistically significant mean difference in muscle activity under different taping conditions in the infraspinatus muscle in phase two, $t(5)$=1.66, p=.158.

A paired samples t-test was used to determine whether there was a statistically significant difference between the taping conditions (Kinesio Tape® and no tape) on percent MVIC in the infraspinatus muscle in phase three. Due to the small sample size, parametric and non-parametric tests were performed and both tests produced similar results; therefore, the parametric paired sample t-test results are presented in the analysis of the results. There were no outliers in the data, as assessed by inspection of a boxplot for values greater than 1.5 box-lengths from the edge of the box. The difference in surface EMG scores for the Kinesio Tape® and no tape conditions were normally distributed, as assessed by the Shapiro-Wilk's test (p=.675). Participants had a higher percent of muscle activity during the Kinesio Tape® condition (M=-34.8%, SD=.296) as opposed to the no tape condition (M=21.6%, SD=.161) when completing an overhead baseball throw and is illustrated in Figure 23. There was a mean increase of 13.3%, 95% CI [-.953, 1.22]. There was no statistically significant mean difference in muscle activity under different taping conditions in the infraspinatus muscle in phase three, $t(5)$=.314, p=.766.

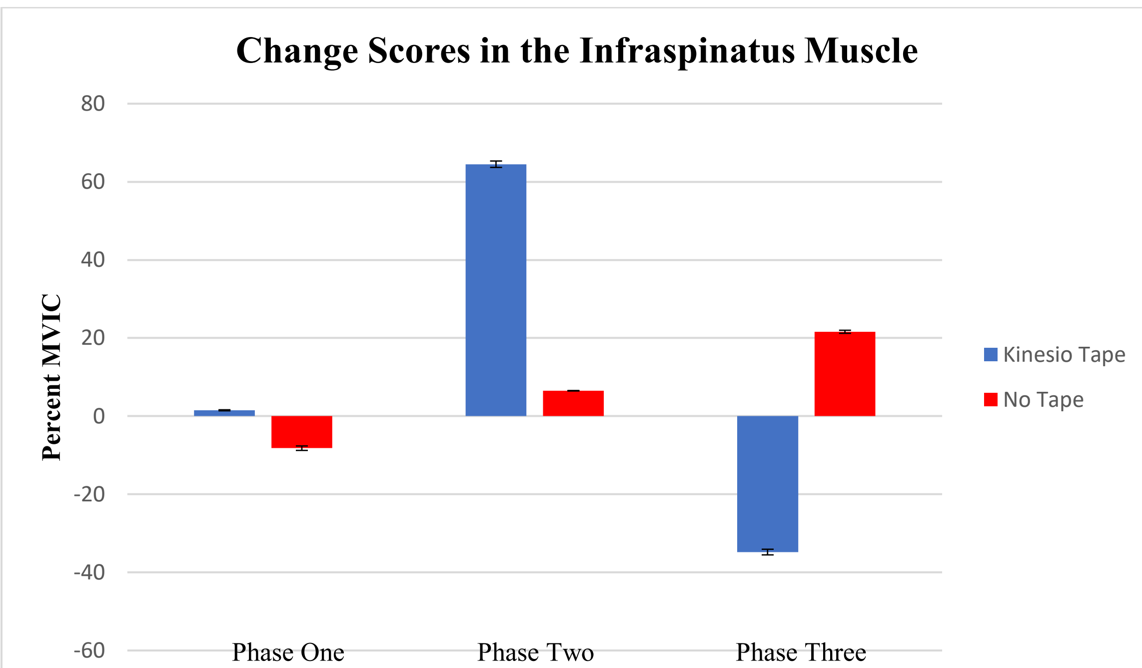

Figure 23. Change scores differences in surface EMG (percent MVIC) in the infraspinatus muscle in phases one, two, and three.

Is there a difference between tape condition (Kinesio Tape® and no tape) on the percent MVIC in the supraspinatus muscle in phases one, two, and three of an overhead baseball throw?

A paired samples t-test was used to determine whether there was a statistically significant difference between the taping conditions (Kinesio Tape® and no tape) on percent MVIC in the pectoralis major muscle in phase one. Due to the small sample size, parametric and non-parametric tests were performed and both tests produced similar results; therefore, the parametric paired sample t-test results are presented in the analysis of the results. Two outliers were detected that was more than 1.5 box-lengths rom the edge of the box in a boxplot. The analysis was completed with and without the outliers and produced similar results; therefore, they were included in the final analysis and reporting. The difference in surface EMG scores for the Kinesio Tape® and no tape conditions were normally distributed, as assessed by the Shapiro-Wilk's test (p=.748). Participants had a higher percent of muscle activity during the Kinesio Tape® condition (M=3.1%, SD=.497) as opposed to the no tape condition (M=-11.1%, SD=.153) when completing an overhead baseball throw and as illustrated in Figure 24. There was a mean increase of 14.2%, 95% CI [-.278, .563]. There was no statistically significant difference in muscle activity under different taping conditions in the pectoralis major muscle in phase one, $t(5)$=.871, p=.424.

A paired samples t-test was used to determine whether there was a statistically significant difference between the taping conditions (Kinesio Tape® and no tape) on percent MVIC in the pectoralis major muscle in phase two. Due to the small sample size, parametric and non-parametric tests were performed and both tests produced similar results; therefore, the parametric paired sample t-test results are presented in the analysis of the results. There were no outliers in the data, as assessed by inspection of a boxplot for values greater than 1.5 box-lengths from the edge of the box. The difference in surface EMG scores for the Kinesio Tape® and no tape conditions were normally distributed, as assessed by the Shapiro-Wilk's test (p=.762). Participants had a higher percent of muscle activity during the Kinesio Tape® condition (M=-16.9%, SD=.253) as opposed to the no tape condition (M=-22 %, SD=.177) when completing an overhead baseball throw and illustrated in Figure 24. There was a mean increase of 5.1%, 95% CI [-.221, .323]. There was no statistically significant difference in muscle activity under different taping conditions in the pectoralis major muscle in phase two, $t(4)$=.520, p=.63.

A paired samples t-test was used to determine whether there was a statistically significant difference between the taping conditions (Kinesio Tape® and no tape) on percent MVIC in the pectoralis major muscle in phase three. Due to the small sample size, parametric and non-parametric tests were performed and both tests produced similar results; therefore, the parametric paired sample t-test results are presented in the analysis of the results. There were no outliers in the data, as assessed by inspection of a boxplot for values greater than 1.5 box-lengths from the edge of the box. The difference in surface EMG scores for the Kinesio Tape® and no tape conditions were normally distributed, as assessed by the Shapiro-Wilk's test (p=.363). Participants had a higher percent of muscle activity during the Kinesio Tape® condition (M=-19.7%, SD=.639) as opposed to the no tape condition (M=-46.5 %, SD=.147) when completing an overhead baseball throw and illustrated in Figure 24. There was a mean increase of 26.8%, 95% CI [-.374, .911]. There was no statistically significant difference in muscle activity under different taping conditions in the pectoralis major muscle in phase three, $t(5)$=1.073, p=.332.

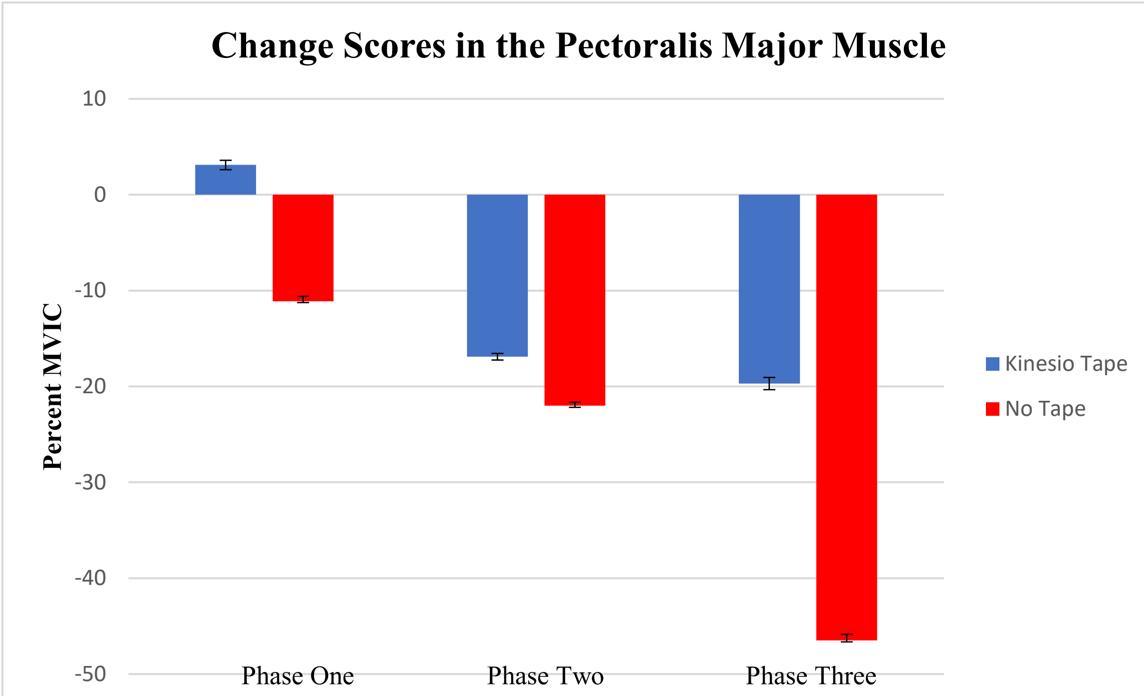

Figure 24. Change scores differences in surface EMG (percent MVIC) in the pectoralis major muscle in phases one, two, and three.

Chapter Four: Discussion

The purpose of this study was to investigate the effect of taping (Kinesio Tape® and no tape) on the velocity of an overhead baseball throw and muscle activation of the supraspinatus, infraspinatus, and pectoralis major muscles in baseball players after muscle fatigue was induced. Previous literature examining the effects of taping on muscle activation patterning in the rotator cuff muscles is conflicting, and the results of this study may support that the application of Kinesio Tape® does not significantly alter muscle change muscle activity in these muscles. Additionally, while the research examining the effect of taping on the velocity of an overhead baseball throw is limited, the results of this study may indicate that the application of Kinesio Tape® does not significantly affect the velocity of an overhead baseball throw. The following sections will discuss the results, implications, and limitations of this study in greater detail.

Throwing Velocity

When completing an overhead baseball throw, there was no significant difference in throwing velocity when comparing the Kinesio Tape® and no tape conditions. Measuring the velocity of the overhead baseball throw was an exploratory piece of this study, as there was limited previous research examining the effects of different taping techniques (Kinesio Tape® and no tape) on the velocity of an overhead baseball throw. This finding is aligned with the findings from Van der Lingen (2016) as no statistically significant differences were found in the velocity in service for tennis players. Van der Lingen (2016) studied a population of 30 collegiate tennis players while they completed serves with and without Kinesio Tape®. The velocity of overhead baseball throws was measured to examine if the Kinesio Tape® condition resulted in sustained or increased velocity of the baseball at release after the fatiguing protocol was completed. If there was a significant difference in percent MVIC between the Kinesio Tape®

and no tape conditions, this might have also affected the participant's velocity of the baseball at release. Therefore, if a participant's percent MVIC muscle activity had changed in the rotator cuff muscles with the application of Kinesio Tape®, then their throwing velocity of the baseball at release may have been sustained at the pre-test throwing velocity or increased from the pre-trial. It was hypothesized, in the current study, that if Kinesio Tape® was able to change percent MIVC in the rotator cuff muscles when completing an overhead baseball throw then this may have sustained the velocity of the overhead baseball throw at release after fatigue had been induced. If the application of Kinesio Tape® was able to significantly change the percent MIVC or activation of the rotator cuff muscles after fatigue had been induced then the rotator cuff muscles may have been able to produce a more energy efficient overhead baseball throw; therefore, having a sustained or greater velocity than pre-trial velocities displayed. The implication and practical application of sustaining or increasing the throwing velocity of the ball at release with the application of Kinesio Tape® from pre-trial to post-trial would be that Kinesio Tape® could be used in game situations. In game situations Kinesio Tape® could be applied to the shoulder of pitchers in later inning or towards the upper limit of their pitch count, for example, and be used to sustain a baseball player's velocity to counter the muscle fatigue. Due to there being no significant differences changes in the muscle activity between the taping conditions in the current study this aligns with the findings that there were also no statistically significant differences in throwing velocity of the baseball at release (Van de Lingen, 2016).

Surface Electromyography Interclass Correlations

When completing an overhead baseball throw, there was no relationship between the supraspinatus, infraspinatus, and pectoralis major muscles under different taping conditions (Kinesio Tape® and no tape) in phase one of the overhead baseball throw. No relationship between the supraspinatus, infraspinatus, and pectoralis major muscles may have been due to the muscles all being activated at different parts of the overhead throw from a timing perspective and also in that at times the role that the muscle played (e.g., primary mover, secondary mover, or stabilizer function) and the type of contraction (i.e., concentric versus eccentric) was different. DiGiovine et al. (1992) split the overhead baseball throw into six phases (windup, early cocking, late cocking, acceleration, deceleration, and follow through phases) during their research.

The current study divided the overhead baseball throw into three phases (phase one, two, and three). Phase one of the current study accounts for the windup, early cocking, and late cocking phases described by DiGiovine et al. (1992). Phase one of the current study began with the start of movement from the participant and ended when the participant's shoulder reached maximal external rotation. In phase one, the participant's shoulder moved into maximal external rotation and the prime external rotator of the shoulder are the infraspinatus and teres minor muscles (DiGiovine et al., 1992; Erickson et al., 2013). The pectoralis major and anterior deltoid muscles are the primary internal rotators of the shoulder and in phase one of the overhead throw these muscles are working and contracting eccentrically (DiGiovine et al., 1992; Erickson et al., 2013). Phase two of the current study was equivalent to the acceleration phase described by DiGiovine et al. (1992) and this phase started after maximal external rotation of the shoulder was reached. During phase two, the pectoralis major and anterior deltoid muscles were used to internally rotate the participant's shoulder as the ball was released; phase two ended when the baseball was released from the participant's hand (DiGiovine et al., 1992; Erickson et al., 2013). Phase three of the current study was comprised of the deceleration and follow through phases described by DiGiovine et al. (1992). Phase three began after the release of the baseball and ended when the participant returned to a still position. In phase three the supraspinatus, infraspinatus, and teres minor muscles were eccentrically contracted to decelerate the arm (DiGiovine et al., 1992; Erickson et al., 2013). The supraspinatus and teres minor muscles produce force to stop anterior humeral head translation caused by the posterior and inferior shear forces placed on the shoulder during deceleration (DiGiovine et al., 1992; Erickson et al., 2013). Due to the pectoralis major, infraspinatus, and supraspinatus muscles all playing different roles in the overhead baseball throw, it is aligned with the current study because there was no association found between these muscles during the phases of an overhead throw. During phase one of the overhead throw, DiGiovine et al. (1992) found that the supraspinatus reaches 13-60% of the participant's MVIC in an overhead baseball throw. They also reported that the infraspinatus muscle reaches 11-30% and the pectoralis major muscle only reaches 6-13% of a participants MVIC in phase one of an overhead baseball throw (DiGiovine et al., 1992). Due to the muscles being activated at different times and durations throughout phase one of the overhead baseball throw, this may have caused there not to be a correlation between muscles in the current study.

When completing an overhead baseball throw, there was no relationship between the supraspinatus, infraspinatus, and pectoralis major muscles when no tape was applied in phase two of the overhead baseball throw. Erickson et al. (2013) found that the pectoralis major and infraspinatus muscles are in peak activation during phase two. During this phase, the pectoralis major muscle is eccentrically loaded and contracts to control the force and decelerate the velocity generated by the shoulder external rotators (Erickson et al., 2013). During phase two, the infraspinatus muscle is in peak activation as it is one of the primary external rotators of the shoulder (Erickson et al., 2013). DiGiovine et al. (1992) found that during phase two of the overhead throw the supraspinatus muscle reaches 49-51% of the participant's MVIC, and the infraspinatus muscle reaches 34-74%, and the pectoralis major muscle reaches 54-56% of the participant's MVIC (DiGiovine et al., 1992). Therefore, due to the supraspinatus, infraspinatus, and pectoralis major muscles being activated differing amounts during phase two of the overhead baseball throw, this may once again explain why there is no association found between the different muscles in the current study. Due to the supraspinatus, infraspinatus, and pectoralis major muscles having no association within the phases of the overhead throw, the muscles could not be clustered together to utilize and complete a different statistical analysis; therefore, multiple paired sample t-tests were completed on the data with a Bonferroni adjustment. There may not have been an association between the different muscles in phases one, two, and three of the overhead throw due to the fact that the muscles having different temporal and functional roles, such as acting as a primary mover, secondary mover, or stabiliser throughout the action.

When completing an overhead baseball throw, there was no relationship between the supraspinatus, infraspinatus, and pectoralis major muscles when no tape was applied in phase three of the overhead baseball throw. The supraspinatus muscle reaches peak activation in the phase three as it produces a high maximal voluntary isometric contraction to decelerate the arm as it moves forward during the throw (Erickson et al., 2013). DiGiovine et al. (1992) found in phase three, the infraspinatus muscle reaches 20-37% of a participant's MVIC and the pectoralis major muscle reaches 29-31% of a participant's MVIC in an overhead baseball throw. Therefore, there may not have been an association between muscles in the current study due to some muscles being more active in phase three than others and the different roles that they play within that complex movement pattern.

The overhead baseball throw is not only an intricate and highly coordinated musculoskeletal sequence but also one of the fastest known human movements (Chalmers et al., 2017). Due to the complexity and speed of the overhead baseball throw, it is difficult to capture the relationships between the muscles involved as every muscle has a slightly different role in the movement. The muscles involved in the overhead throw are coupled and work in unison to perform the motion of the overhead throw; however, each muscle produces a very specific movement and serve a specific function within the overhead throw sequence. Therefore, this may be why the current study did not find a relationship between the supraspinatus, infraspinatus, and pectoralis major muscles in phases one, two, or three of the overhead baseball throwing task. Due to there being no relationship between the muscles in the three phases of the overhead throw, muscles were considered an independent variable.

Surface Electromyography

Supraspinatus muscle. When completing an overhead baseball throw, there was no statistically significant difference in percent MVIC when comparing the Kinesio Tape® condition to the no tape condition. This finding is aligned with Janwatanakul and Gaogasigam (2005) as they found no significant change in EMG activity of the vastus lateralis and vastus medialis muscles when comparing Kinesio Tape® to a no tape condition. Although these findings are in the lower extremity, an inhibitory taping technique using Kinesio Tape® was used, similar to the current study. The Kinesio Tape® technique used in this study for the rotator cuff muscles was proposed to inhibit and reduce the muscle activity in the supraspinatus muscle; therefore, the findings by Janwatanakul and Gaogasigam (2005) are aligned with the current study (Kase et al., 2013). An inhibitory Kinesio Tape® technique was used in the current study because the first piece of tape was applied to the supraspinatus muscle and this muscle has an increased risk of injury during phase three of the overhead baseball throw. If the Kinesio Tape® could have changed the muscle activation of this muscle or the muscle activation pattern than it may have been able to decrease the risk of injury to the supraspinatus muscle but this would require more of a longitudinal type of follow up and analysis. The application of Kinesio Tape® produced a lower percent MVIC mean in phases two and three when compared to the no tape condition (as illustrated in Figure 22) but was not significantly different. If the application of Kinesio Tape® was able to decease the muscle activity in phase two and three then this could indicate Kinesio Tape® may be able to decrease the risk of a rotator cuff tear occurring in the supraspinatus muscle. During phase three of the overhead baseball throw, the supraspinatus muscle, along with the teres minor muscle, prevent anterior humeral head subluxation by producing counter forces to decelerate the arm; therefore, in this phase the supraspinatus muscle is at an increased risk of injury (Erickson et al., 2016; Fleisig et al., 1995; Mazoue & Andrews, 2016).

By using another example of taping applied to a different region of the body, Kuciel et al. (2020) found that Kinesio Tape® applied to the lumbar spine region of 17 pregnant women delayed and altered the activation of the gluteus maximus muscle and increased the activation of the ipsilateral erector spinae muscle while completing a hip extension movement in a four-point kneeling position. Although the current study did not have statistically significant results, by looking at the descriptive statistics, this study may have followed this trend. During the Kinesio Tape® trials, it appeared that the supraspinatus muscle's percent MVIC decreased and the infraspinatus muscle's percent MVIC increased. The implication of this result would mean that there could be a decreased risk of injury to the supraspinatus muscle as some of the force placed on it during phases two and three may be shifted to the infraspinatus muscle. As mentioned previously, the supraspinatus muscle produces a high MIVC in phase three as its primary role is to decelerate the arm and resist anterior humeral head translation and due to its primary roles, the supraspinatus muscle is at an increased risk of injury (Erickson et al., 2016). Therefore, if the application of Kinesio Tape® decreases the muscle activity in the supraspinatus muscle then it may reduce the impacts of overuse, inflammation, or injury. Glousman, Jobe, and Tibone (1988) found that when comparing muscle activity between healthy pitchers with no shoulder pathologies to pitchers with chronic anterior shoulder instability, the pitchers with chronic anterior shoulder instability exhibited greater muscle activity in the supraspinatus muscle and lower muscle activity in the infraspinatus muscle in the acceleration phase of the overhead throw. In the current study, while there was no statistically significant difference, with application of Kinesio Tape® there was a slight decrease in muscle activity in the supraspinatus muscle and a slight increase in infraspinatus muscle activity and this could mean that if Kinesio Tape® were applied to a player with shoulder pathologies it may help decrease the risk of injury in the rotator cuff muscles. The application of Kinesio Tape® may have a similar impact in baseball players without anterior shoulder instability; however, this would require a longitudinal study perhaps over the course of a baseball season.

The supraspinatus muscle is the most commonly torn rotator cuff muscle and it is at high risk of injury during the deceleration phase of throwing due to the high maximal voluntary eccentric contraction it produces to decelerate the arm (Bruan et al., 2009; Erickson et al., 2016). Therefore, the decrease found in percent MVIC in phases two and three of an overhead baseball throw in the Kinesio Tape® condition could have been caused by the Kinesio Tape® being applied to inhibit and reduce the muscle activity of the supraspinatus muscle. If Kinesio Tape® can cause a decrease in the percent MVIC in the supraspinatus muscle during phases two and three of the overhead baseball throw, then this could lead to a decreased risk of injuries to the supraspinatus muscle in the deceleration phase. Lesniak et al. (2013) found that when an MRI was completed on 21 asymptomatic MLB players, 9 of these players had partial rotator cuff tears and 2 of the players had full-thickness rotator cuff tears. The slight decrease in muscle activity in the supraspinatus muscle as seen in the current study, although not statistically significant, could result in a decreased risk of injury over time counteracting this finding on MRI imaging and be supported by the increased muscle activity seen in the infraspinatus muscle supporting the clinical utility of the application of Kinesio Tape® to the shoulder.

Infraspinatus muscle. When completing an overhead baseball throw, there was no statistically significant difference in percent MVIC when comparing the Kinesio Tape® condition to the no tape condition in the infraspinatus muscle. These results are aligned with the findings of Slevin, Arnold, Wang, and Abboud (2020) in a sample of 27 participants. Slevin et al. (2020) induced sudden ankle inversion with and without the application of Kinesio Tape® while the EMG muscle activity was measured in the peroneus longus and tibialis anterior muscles. It was found that there was no statistically significant difference with the application of Kinesio Tape® on EMG muscle activity. Although these findings are in the lower extremity, an inhibitory taping technique with Kinesio Tape® was used, similar to the current study. The Kinesio Tape® technique used in this study for the rotator cuff muscles was proposed to inhibit and reduce the muscle activity in the supraspinatus muscle (Kase et al., 2013). Therefore, the research finding by Slevin et al. (2020) are aligned with that of the current study as both studies used inhibitory taping applications.

The infraspinatus muscle had an increased mean percent MVIC with the application of Kinesio Tape® compared to the no tape condition in phase two of the overhead baseball throw as illustrated in Figure 23. Phase two of the overhead baseball throw began after maximal external rotation of the shoulder was reached. During phase two the pectoralis major and anterior deltoid muscles contract to internally rotate the participant’s shoulder as the ball is released (DiGiovine et al., 1992; Erickson et al., 2013). Kase et al. (2013) proposed that the taping technique used in this study would inhibit and reduce the muscle activity of the supraspinatus muscle. As previously mentioned, although not statistically significant, there was a decrease in the percent MVIC found in phase two and three in the Kinesio Tape® condition compared to the no tape condition. The infraspinatus is a primary external rotator of the shoulder and is in peak activation during phases two and three of the overhead baseball throw (Erickson et al., 2016; Fleisig et al., 1995; Mazoue & Andrews, 2016). The slight decrease observed in the percent MVIC found in the supraspinatus muscle with the application of Kinesio Tape® to the shoulder may have resulted in the increased recruitment of muscle fibers for the infraspinatus muscle to use more muscle activity; therefore, causing the increase in percent MVIC found in the infraspinatus muscle in phase two with the application of Kinesio Tape®. As previously mentioned, Glousman et al. (1988) found that in phase two of the overhead baseball throw, baseball players with anterior instability of the shoulder had lower muscle activation in the infraspinatus muscle and higher muscle activation in the supraspinatus muscle when compared to asymptomatic players. As previously described, the findings in the current study could mean that with the application of Kinesio Tape® may alter the muscle activation patterning in baseball players with anterior instability of the shoulder but further study is definitely warranted. If Kinesio Tape® is able to decrease risk of injury in the supraspinatus muscle and increase muscle activity in the infraspinatus muscle, then the application of Kinesio Tape® could be used in a population of baseball players who present with anterior instability or decreased muscle activation in the infraspinatus muscle. The application of Kinesio Tape® could help this population to better perform an overhead baseball throw and decrease their risk of further injury while playing baseball.

Pectoralis major muscle. When completing an overhead baseball throw, there was no statistically significant difference in percent MVIC when comparing the Kinesio Tape® condition to the no tape condition in the pectoralis major muscle. Zanca et al. (2016) found no statistically significant difference in EMG muscle activity when comparing the effects of Kinesio Tape® to a no tape condition applied to the upper trapezius, lower trapezius, and serratus anterior muscles. Zanca et al. (2016) investigated the effects of Kinesio Tape® on the shoulder joint after muscle fatigue had been induced in a sample of 24 participants while the participants completed arm elevation to 50, 70, and 90 degrees. Like the current study, Zanca et al. (2016) also measured muscle activity before and after implementing a fatiguing protocol and reported no statistically significant difference in muscle activity with the application of Kinesio Tape®. However, the pectoralis major muscle had a slightly lower mean percent MVIC in the Kinesio Tape® condition than in the no tape condition in phases one, two, and three. This may indicate the application of Kinesio Tape® to the shoulder changed the muscle activation patterning for the pectoralis major muscle in the overhead baseball throw. Unfortunately, there is no known research on the effect of tape application on the pectoralis major muscle and this muscle was included in the current study to explore if the application of tape to the shoulder would affect the shoulder internal rotators. Due to the small sample size of this study, there was no statistically significant difference between taping conditions in the pectoralis major muscle.

Limitations

Some limitations must be taken into consideration concerning the interpretation and generalizability of the results of this study. The largest limitation to the current study was the sample size. Unfortunately, due to the onset of the COVID-19 pandemic no further participants could be recruited to complete testing as Lakehead University facilities were closed and all research using human participants halted. The researchers decided to move forward with the analysis of the data using the small sample size due to time limitations for completing this study and because of the unknown long-term consequences and timing delays associated with the COVID-19 pandemic. Additionally, a univariate analysis was selected over a multivariate analysis because of the small sample size and this could potentially increase the chance of type I error occurring. The analysis of this study did not control for other independent variables such as sex, taping experience, or playing position of the baseball players and this could influence the dependent variables that were collected in this study. Again, this may have been addressed with being able to complete testing of participant's that had already consented to participate but were impacted by the pandemic.

As each participant was asked to complete three trials for each taping condition, the mean of each participant's surface EMG and velocity was used for the final analysis. Using the mean of the three trials may have improved the variability of these values as it may have limited extreme values present in the data. The variability may have also been increased in this study as the participant's throwing technique was not controlled for. Although all participants were instructed that he/she had to perform an overhead baseball throw, each participant's form may have been slightly different and this could have affected the muscle activation patterning and external validity of this study being generalized to all throwing athletes (e.g., overhead throw versus side arm technique). As the overhead baseball throw is an extremely rapid movement, with front foot contact to ball release occurring in 0.145 seconds, it is very difficult to control for differing mechanics of the overhead throw between individuals and nor might this be a realistic thing to attempt to modify and standardize (Stodden, Campbell, & Moyer, 2008). Additionally, during the current study, participants were instructed to complete their overhead throws as he/she would in a game as this would increase the external validity of this study. This means participants were allowed to complete the overhead baseball throw using their preferred arm (left versus right) and this was not controlled for as it represents a more externally valid scenario.

Delimitations

Delimitations of the study must also be taken into consideration. A heterogeneous population of baseball players was incorporated and included in this study in order to maximize the sample size. All baseball positions were included in this study as youth baseball players tend to play multiple positions until the players reach a higher level of competition. The results of this study; however, are not entirely representative of a single position in baseball and the results are broader to the sport of baseball and the throwing movement rather than to a specific position.

For the analysis, multiple paired sample t-tests were selected over a three-way ANCOVA due to the small sample size and the inability to recruit further participants as a result of the onset of the pandemic. A paired sample t-test was used as it is a broader test and the addition of a Bonferroni adjustment was used to control for type 1 error. A three-way ANCOVA would have allowed for just one inferential statistic test to be run further decreasing the chance of type I error from occurring.

Future Research

This study was the first to analyze the surface EMG muscle activity of the supraspinatus, infraspinatus, and pectoralis major muscles during the execution of an overhead baseball throw while assessing the effects of taping (Kinesio Tape® and no tape). More research; however, is needed to gain a full understanding of the effects of tape applied to the shoulder on throwing and build on the results of the current study. Additionally, future research should use a larger sample size of baseball players to further examine the effect of tape on muscle activation and velocity in the population. A larger sample size would reduce the potential for type I error to occur as well as to allow for more appropriate interferential statistics to be completed and to further analyze the effects on different sexes, positions of play, and/or throwing techniques (i.e., overhead versus side arm or left versus right handed).

Furthermore, as this study was the first to incorporate the velocity of an overhead baseball throw when assessing the effects of taping, more research is needed to explore how tape impacts on this movement. Future research should also incorporate the use of kinematic and kinetic analysis and motion capture as this may improve the interpretation of the surface EMG as well as it may be used to further break down the surface EMG data into the phases of an overhead baseball throw and understand how this affects the mechanics of throwing. Additionally, future research should limit recruitment to a specific baseball position, such as pitchers, as this will make the results more position-specific and may be better used in game scenarios.

Chapter Six: Conclusion

The purpose of this study was to investigate the effect of taping (Kinesio Tape® and no tape) on the velocity of an overhead baseball throw and muscle activation of the supraspinatus, infraspinatus, and pectoralis major muscles in baseball players after muscle fatigue had been induced. The current study builds on and supports previous research examining the effects of taping on muscle activation patterning and adds to the limited research on the effects of taping on the velocity of an overhead throw, more specifically.

The results of this study are aligned with previous research that was completed examining the effects of Kinesio Tape® applied on muscles in the lower extremities that found that tape did not have an effect. The muscle activation measured using surface EMG findings in the current study was not significantly different between taping conditions (Kinesio Tape® and no tape) in the supraspinatus, infraspinatus, and pectoralis major muscles in the three phases on an overhead baseball throw. The results of this study found the application of tape to the shoulder did not have a statistically significant difference in throwing velocity when completing an overhead baseball throw. More research is required, however, due to the limited sample size and challenges with recruitment due to the onset of the COVID-19 pandemic during the data collection and recruitment phase of the current study.

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Appendix A

Get Active Questionnaire

Get Active Questionnaire

ASSESS YOUR CURRENT PHYSICAL ACTIVITY

Answer the following questions to assess how active you are now.

1 During a typical week, on how many days do you do moderate- to vigorous-intensity aerobic physical activity (such as brisk walking, cycling or jogging)? ☐ DAYS/WEEK

2 On days that you do at least moderate-intensity aerobic physical activity (e.g., brisk walking), for how many minutes do you do this activity? ☐ MINUTES/DAY

For adults, please multiply your average number of days/week by the average number of minutes/day: ☐ MINUTES/WEEK

Canadian Physical Activity Guidelines recommend that adults accumulate at least 150 minutes of moderate- to vigorous-intensity physical activity per week. For children and youth, at least 60 minutes daily is recommended. Strengthening muscles and bones at least two times per week for adults, and three times per week for children and youth, is also recommended (see csep.ca/guidelines).

GENERAL ADVICE FOR BECOMING MORE ACTIVE

Increase your physical activity gradually so that you have a positive experience. Build physical activities that you enjoy into your day (e.g., take a walk with a friend, ride your bike to school or work) and reduce your sedentary behaviour (e.g., prolonged sitting).

If you want to do **vigorous-intensity physical activity** (i.e., physical activity at an intensity that makes it hard to carry on a conversation), and you do not meet minimum physical activity recommendations noted above, consult a Qualified Exercise Professional (QEP) beforehand. This can help ensure that your physical activity is safe and suitable for your circumstances.

Physical activity is also an important part of a healthy pregnancy.

Delay becoming more active if you are not feeling well because of a temporary illness.

DECLARATION

To the best of my knowledge, all of the information I have supplied on this questionnaire is correct.
If my health changes, I will complete this questionnaire again.

I answered NO to all questions on Page 1

Sign and date the Declaration below

I answered YES to any question on Page 1

Check the box below that applies to you:

- ☐ I have consulted a health care provider or Qualified Exercise Professional (QEP) who has recommended that I become more physically active.
- ☐ I am comfortable with becoming more physically active on my own without consulting a health care provider or QEP.

Name (+ Name of Parent/Guardian if applicable) [Please print]	Signature (or Signature of Parent/Guardian if applicable)	Date of Birth

Date	Email (optional)	Telephone (optional)

With planning and support you can enjoy the benefits of becoming more physically active. A QEP can help.

☐ Check this box if you would like to consult a QEP about becoming more physically active.
(This completed questionnaire will help the QEP get to know you and understand your needs.)

Appendix B

Recruitment Poster

Lakehead UNIVERSITY

Research Participants Needed!

The Biomechanical Effects of Rotator Cuff Taping on Muscle Recruitment and Throwing Velocity in Fatigued Baseball Players

Who:

- Healthy baseball players
- Between ages 15-35 years old

This Pilot Study will include:

- Two, 45-minute sessions
- Completing 30 overhead throws
- Throwing a baseball with your maximum effort
- Taping of your throwing shoulder

Purpose of this Pilot Study:

- To investigate the effect of taping on the velocity of an overhead baseball throw and muscle recruitment using surface electromyography and a radar gun in fatigued baseball players

If you are interested in participating or would like more information please e-mail:

Kara Harrison
krharris@lakeheadu.ca

Appendix C

Letter to Coaches

Appendix D

Informed Consent Form

Lakehead UNIVERSITY

School of Kinesiology

Dear Coach,

I hope you are doing well! My name is Kara-Lyn Harrison and I am currently completely my Master of Science in Kinesiology at Lakehead University under the supervision of Dr. Paolo Sanzo. The purpose of my current research is to investigate the effect of taping (Kinesio Tape and no tape) on the velocity of an overhead baseball throw and muscle recruitment patterning in baseball players after muscle fatigue has been induced. I am contacting you in hopes that you might pass some information about my research along to your players.

If players are willing to participate, they will be asked to complete two, 45-minute testing sessions, with at least 24 hours of rest between sessions. During each testing session, they will be asked to complete a different taping method. On the day of testing they will be asked to report the Lakehead University Hangar field, where they will meet the research team. They will then be asked to complete the Get Active Questionnaire and give information about their height, weight, age, level of baseball they have competed in, and the number of years they have played baseball. The researcher will then apply four electrodes to the back and front of their shoulder and one electrode to their elbow. Then the student researcher will ask them to perform four maximal muscle contractions for the four muscles activity is being collected for. The student researcher will then apply the tape, if it is the Kinesio taping session. Next, they will be asked to complete a dynamic warm up. They will then be asked to complete 30 overhead throws: 10 at a slow velocity, 10 at a moderate velocity, and 10 at a fast velocity. For all overhead throws, they will be asked to aim at a net placed 10 meters away from them. For the testing protocol, they will be asked to complete 3 overhead throws into a net positioned 10 meters away while surface electrodes measure muscle activity of the shoulder and velocity of their throws is collected.

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The electrodes and tape will then be removed, and the testing session will be completed. The second session will follow this design, with the only difference between testing sessions being after the first testing session they will not have to complete the Get Active Questionnaire and the tape being applied will change.

I have attached a poster to this letter for your review as well. Thank you for your consideration and I look forward to hearing from you soon.

Sincerely,

Kara-Lyn Harrison

School of Kinesiology

Letter of Information and Consent for Potential Participants

Dear Potential Participant,

You are invited to take part in a research study entitled ***The Biomechanical Effects of Rotator Cuff Taping on Muscle Recruitment and Throwing Velocity in Fatigued Baseball Players***. You have been invited because you have been identified as a baseball player and throwing athlete.

It is your choice if you would like to participate in this study. Please read this information letter outlining the details of participation before you decide if you would like to be a part of this study. This letter has information about why we are doing the study and what will happen during the study. This letter should help you decide if you would like to participate in the study. After you have read the letter, please ask the research team if you do not understand something or if you have any questions that require further clarification.

PURPOSE

The purpose of this study is to get a better understanding of the biomechanical effect taping has on the velocity of an overhead baseball throw and the muscle activity of the rotator cuff muscles in fatigued baseball players. The student researcher completing this study is Kara-Lyn Harrison, a Master of Science in Kinesiology candidate. The student researcher will be supervised by Dr. Paolo Sanzo, Associate Professor in the School of Kinesiology at Lakehead University.

WHAT INFORMATION WILL BE COLLECTED?

As a prospective participant, you will be asked to provide information about your height, weight, age, level of baseball competition you have competed in, and the number of years that you have played baseball. You will also be asked to complete a Get Active Questionnaire that will be used to make sure you are a good candidate to participate in physical activity in this study. During the testing procedure, the muscle activity in the shoulder muscles and acceleration of the elbow will be measured using electrodes placed on your skin and the velocity of your throws will be measured with a radar gun.

WHAT IS REQUESTED OF ME AS A PARTICIPANT?

You will be asked to complete two, 45-minute testing sessions, with at least 24 hours of rest between sessions. During each testing session, you will be asked to complete a different taping method. On the day of testing you will be asked to report the Lakehead University Hangar field, where you will meet the research team. You will then be asked to complete the Get Active

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Questionnaire and give information about your height, weight, age, level of baseball you have competed in, and the number of years you have played baseball. You will then have the skin around your shoulder and upper back of your throwing arm cleaned using an alcohol wipe to prepare for electrode placement. If there is hair in the region, this area will require to be shaved so the electrodes will adhere to the area. The researcher will then apply four electrodes to the back and front of your shoulder and one electrode to your elbow. Then the student researcher will ask you to perform four maximal muscle contractions for the four muscles activity is being collected for. The student researcher will then apply the tape, if it is the Kinesio taping session. Next, you will be asked to complete a warmup of 10 high knees per leg, 10 butt kicks per leg, 10 lunges per leg, skipping with arms swinging forward, and skipping with arms swinging backwards. This dynamic stretching warm up will take place on the track and should take approximately 5 minutes to complete. You will then be asked to complete 30 overhead throws: 10 at a slow velocity, 10 at a moderate velocity, and 10 at a fast velocity. For all overhead throws, you will be asked to aim at a net placed 10 meters away from you. For the testing protocol, you will be asked to complete 3 overhead throws into a net positioned 10 meters away while surface electrodes measure muscle activity of the shoulder and velocity of your throws is collected. The electrodes and tape will then be removed, and the testing session will be completed. The second session will follow this design, with the only difference between testing sessions being after the first testing session you will not have to complete the Get Active Questionnaire and the tape being applied may change. You will be responsible for arriving at your agreed upon testing session and time and the same testing and throwing protocol will be used during each of the remaining testing sessions.

WHAT ARE MY RIGHTS AS A PARTICIPANT?

You are free to withdraw from this study at any time without any consequences. Your decision to participate or not participate in this study will not affect your academics at Lakehead University in any way. If you wish to withdraw after some data collection has taken place, you will be able to withdraw your data from the study as well. You will be given updates on the study and any changes to the research study that may affect your decision to participate in the study, in a timely manner.

WHAT ARE THE RISKS AND BENEFITS?

By participating in this study, you may experience muscle fatigue, muscle soreness, or a muscle strain. The risk to you as a participant in experiencing these potential harms is minimal and will be reduced by having you complete a proper warmup and ensuring you are healthy enough to participate in the study as identified by the screening questionnaire. There are no direct benefits to participating in this study, but you may learn about the effect of taping on muscle recruitment and throwing velocity.

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HOW WILL MY CONFIDENTIALITY BE MAINTAINED?

Your identity will remain anonymous and confidential throughout the study. Your name will be assigned a unique and randomized code and the code will be what you will be referred to as in the study. The legend with names of the participants and their corresponding code will be sealed under lock and key and will remain sealed in a separate location than the results to maintain confidentiality. Only the student researcher and supervisor will have access to the information collected of the participants.

WHAT WILL MY DATA BE USED FOR:

The results of this study will be analyzed, and the data will be looked at as a whole; it will not be individualized. The results of this study will be used as part of the requirements to complete master's thesis as part of the student researcher's graduate studies and may be presented at conferences and possibly submitted for publication in a peer reviewed journal. This raw data will only be accessible to the student researcher and the supervisor.

WHERE WILL MY DATA BE STORED?

While this study is being conducted, data will be stored on the student researcher personal computer in an encrypted file. Once this study has been completed all data, including all results and information related to the study, will be moved to a USB drive and deleted from the student researcher's computer. The USB drive will then be kept in a locked filing cabinet for five years in Dr. Paolo Sanzo's office, in accordance with the Lakehead University storage of data protocol and policy. In addition, the results will only be accessible to the student researcher involved in the study, and the advisor. If Dr. Sanzo retires the data will still be stored at Lakehead University for the remainder of the five years.

HOW CAN I RECEIVE A COPY OF THE RESEARCH RESULTS?

If you wish to receive a copy of the results of this study, you can request this by checking the box on the consent form and by supplying your e-mail or other contact information.

RESEARCH ETHICS BOARD REVIEW AND APPROVAL:

This research study has been reviewed and approved by the Lakehead University Research Ethics Board. If you have any questions related to the ethics of the research and would like to speak to someone outside of the research team, please contact Sue Wright at the Research Ethics Board at 807-343-8283 or research@lakeheadu.ca

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WHAT IF I WANT TO WITHDRAW FROM THE STUDY?

If you wish to withdraw from this research study, you can do this at any time. To withdraw, you should e-mail the student researcher at krharris@lakeheadu.ca. In this e-mail you may state that you wish to withdraw from the study and whether you wish to withdraw your data from the study. Once the student researcher receives this e-mail, she will remove you from the study. If you indicate that you wish to have your data withdrawn, she will remove your data from the study at this time as well. You will be thanked for your consideration and should you have any other questions then please do not hesitate to contact any members of the research team.

RESEARCHER CONTACT INFORMATION:

Student researcher: Kara-Lyn Harrison E-mail: krharris@lakeheadu.ca

Research supervisor: Dr. Paolo Sanzo E-mail: paolo.sanzo@lakeheadu.ca

Lakehead UNIVERSITY

School of Kinesiology

Consent Form for Potential Participants

MY CONSENT:

I agree to the following:

- ✓ I have read and understand the information contained in the Information Letter
- ✓ I agree to participate
- ✓ I understand the risks and benefits to the study
- ✓ That I am a volunteer and can withdraw from the study at any time and may choose not to answer any question
- ✓ That the data will be securely stored at Lakehead University for a minimum period of 5 years following completion of the research project
- ✓ I understand that the research findings will be made available to me upon request
- ✓ I will remain anonymous
- ✓ All of my questions have been answered

By consenting to participate, I have not waived any rights to legal recourse in the event of research-related harm.

Name (print): ____

Signature: ____

Date: __________________________________

☐ I want to receive a copy of the result of this research study once it has been completed.

E-mail: ____

Appendix E

Anthropometric Measures

Anthropometric Measures

Participant:___________________

1. Gender (Circle one): Male Female Other Prefer not to say
2. Mass: _____________kg
3. Height: ________________cm
4. Age: _______years
5. How many years have you played baseball? _____________years
6. What level of baseball competition have you participated in (example: high school or recreational)? ____