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The initial effects of Kinesio Tape on shoulder joint position sense at increasing elevations

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Abstract

Joint position sense (JPS) is a key factor for developing and maintaining motor pathways which manage neuromuscular control of joint. This neuromuscular control is important as it helps perform specialized tasks, especially at the shoulder where stability is sacrificed for mobility. Therefore, when there is damage to the joint or the surrounding tissues the mechanoreceptors are also impaired which alters a person's proprioception. As a result of alteration in proprioception one's sense of movement and JPS is also altered which in turn diminishes his/her ability to perform specialized tasks. In the present study, shoulder JPS was assessed at increasing elevations with and without the application of Kinesio Tape (KT). Thirty healthy non-overhead athletes, who had no previous shoulder pathologies, were recruited. Subjects attempted to actively replicate three target positions with and without the KT. The absolute and variable errors were analyzed for each position. The findings of this study indicate that at 90° elevation shoulder JPS is significantly affected by the application of KT.

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Table of Contents

List of Figures

List of Appendices

Chapter I

The Problem and Its Scope

Introduction

Overhead athletes' put a great deal of stress on their shoulder joint during activity, which places them at an increased risk for developing adverse effects from their activity. Seeing that the shoulder allows for a great deal of mobility, stability is sacrificed; therefore, the shoulder is considered the most vulnerable joint in the body. However, stability is still needed to perform the precise tasks for activities of daily living and/or sporting events (Prentice, 2009). Numerous factors within the shoulder complex contribute to this lack of stability, including limited bony contour, the lack of ligamentous support and the laxity of the joint capsule. Other factors that help to provide the joint with the additional stability include: support of surrounding muscles, the intra-articular pressure of the joint and the integration of the central nervous system (CNS) via mechanoreceptors (Suprak, 2011).

Along with the muscle fibers, there are also muscle spindles located within the muscle which respond to muscle activation and play an important role in proprioception. Proprioception is a specialized sensory capability that includes both a person's sense of movement, joint position and sense of tension (Lephart, Pincivero, Giraldo, & Fu 1997). One of the elements of proprioception, joint position sense (JPS), consists of both static and dynamic abilities of detecting the position of the joint (Chapman, Suprak, & Karduna 2008). Research by Suprak, Osternig, Donkelaar and Karduna, (2006) suggests that an increase in afferent feedback, leads to an increase in muscle activation which results in enhanced JPS. JPS is afforded via the sensory feedback from peripheral receptors in sites such as skin, muscles, ligaments and tendons that are processed by the CNS. JPS is a key factor for developing and maintaining motor pathways which manage neuromuscular control of joint. Neuromuscular control is important as it helps perform specialized tasks, so when there is damage to the tissues the mechanoreceptors are impaired which alters a person's proprioception. Therefore, when a person's proprioception is affected their sense of movement and JPS is also altered which in turn diminishes his/her ability to perform specialized tasks (Lephart et al., 1997).

Due to the wide mobility of the shoulder joint there are numerous angles at which JPS can be measured. Research using constrained uniaxial rotational testing paradigms suggests that JPS changes at different points in the ROM. Research has shown that JPS is the most accurate towards the end ROM (Allegrucci, Whitney, Lephart, Irrgang, & Fu 1995; Blasier, Carpenter, & Huston 1994). Some possible explanations for this effect are: an increase in muscle tension which increases muscle activation which in turn increases the muscle spindle activity, which ultimately increases neural signals which enhance JPS. Another possibility would be the stretching of the muscle, ligament, tendon or capsule, which causes an increase in tension, in response there is an increase in mechanoreceptor (Golgi Tendon Organ (GTO) or Ruffini Endings) activity (Allegrucci et al., 1995; Blasier et al., 1994; Lephart et al., 1997). However, this effect was not supported in a more unconstrained model (Suprak, 2011). Suprak et al., (2006) have indicated that JPS is affected by elevation angle, as elevation increases beyond 90 ° repositioning error increases. However, when the elevation angle is less than 90° the repositioning error decreases. These results indicate that as elevation angle increases, the amount of gravitational torque increases, which increases muscle activation. This increase in muscle activation along with the increase in activity from the musclotendinous mechanoreceptors contributes to an improved JPS. In an adjunct study by Suprak, Osternig, Donkelaar and Karduna (2007) found that as the resistance increased the repositioning error decreased.

Some athletes rely on tape to enhance their athletic performance. Researchers believe that the application of tape may improve proprioceptive abilities by increasing stimulation of cutaneous mechanoreceptors within the skin, which increases pressure on underlying muscles; therefore having an effect on the joint proprioception (Callaghan, Selfe, Bagley, & Oldham 2002; Perlau, Frank, & Fick 1995). However, when traditional tape is applied it can impede a persons' range of motion (ROM), whereas kinesio tape (KT) stretches up to 140% of its original length, allowing for full ROM (Wilkerson, 2002; Halseth, McChesney, DeBeliso, Vaughn, & Lien 2004). Robbins, Waked and Rappel (1995) found that the application of ankle tape enhanced an individual's JPS. Athletic tape is a beneficial preventative measure, however, the integrity of the tape does not always hold up because of extraneous factors such as sweat. So, the development of more specialized tapes has been on the rise over the past couple of years; and some of these specialty tapes, can with stand these extraneous factors and last up to a couple of days.

Today's market for athletic tape is rapidly expanding, especially in the area of specialty tapes. KT is a specialized elastic tape, which closely resembles human tissue (Prentice, 2009). According to the creator of KT, Kenzo Kase, KT can strengthen an already weakened muscle by correcting the muscle function, improves circulation of blood and lymph, decrease pain, reposition subluxed joints and improve joint position and kinesthetic awareness. These effects allow the fascia and muscle to return to normal function by relieving the buildup of abnormal muscle tension and it can improve joint function by increasing sensory mechanisms (Halseth et al., 2004; Briem, Eythorsdottir, Magnusdottir, Palmarsson, Runarsdottir, & Sveinsson 2011; http://www.kinesiotaping.co.uk/tapingmethod.jsp).

Some common applications for KT include but are not limited to the following: the neck, back, shoulder, wrist and knee. There is also a wide array of conditions in which KT may be beneficial in using, which include: carpel tunnel syndrome, lymphedema, tendonitis, etc. Many of the application techniques use one or more strips of tape that vary in the amount of tension and direction of pull. (Kinesio USA, LCC, 2010)

Purpose of Study

The purpose of this study is to assess the effects of the application of KT has on shoulder JPS at increasing shoulder elevations in athletes.

Hypothesis

The application of KT will not have an effect on JPS of the shoulder when compared to no tape. Further, it is hypothesized that KT will not change the effect of elevation angle on shoulder JPS.

Significance of Study

Injuries are common in athletics and sometimes modalities and exercises are helpful for rehabilitation of the injured structure. In order for an athlete to return to his/her sport, he/she may need some extra support for their injured extremity and tape can provide the extra support. One of the most widely used tapes by athletes of all ages on the market today is KT (Kinesio USA, LCC, 2010). Although KT was developed in the 1980's in more recent years it has gained popularity among professional athletes and physical therapist worldwide. KT is seen in the eyes of many as a fix all tape, however, KT is suppose to be a form of tape that has therapeutic benefits, so if used in the right context (therapeutic purposes) KT can have lasting effects (Briem et al., 2011).

According to Halseth et al., (2004), KT is unlike any other athletic tape as it can be stretched prior to application (up to 140% of its original length), and this provides a constant shear force to the skin. This shear force leads to increased stimulation of the cutaneous mechanoreceptors, which may lead to an increase in JPS acuity. Research conducted by (Garcia, 2010) supports these claims that the application of KT to the ankle can significantly improve a persons' balance when compared to no tape. It is from studies like this, that claims are made which state that KT can have a positive impact on a persons' proprioception. There is little to no scientific research that supports the claims brought forth by the creator of KT; it should be noted that the creator of KT does not specifically claim that the application of KT may be beneficial to a person's proprioception. However, it is from claims within the research community that have stated that the application of tape or brace provides can enhance JPS that has researchers testing what effects specialty tapes like KT may have on JPS (Wilkerson, 2002; Perlau et al., 1995). Currently there are no studies that look at what effects KT has on JPS.

Limitations of Study

The following were recognized as limitations for this study:

1. This study only assessed the short-term effects of KT; therefore, the results cannot be applied to the long term effects of KT.
2. Subjects used for this study were healthy non-overhead division II athletes' who had no injury to their shoulder in the past six months. Caution should be used be applying results to injured populations or overhead athletes.
3. The subjects' may not be familiar with the test device, so there may be a learning effect as the subjects becomes more familiar with the testing apparatus.
4. The subjects' may have bias towards KT and once the tape is applied they may try and perform the task better.

Definition of Terms

Proprioception: The ability to determine the location of a joint in space (Allegrucci et al., 1995).

Kinesthesia: The ability to sense the position and movement of our limbs and trunk. (Proske & Gandevia, 2009).

Joint Position Sense: The ability to consciously identify the position of limb in space. (Aydin, Yildiz, Yanmis, Yildiz, & Kalyon, 2001).

Cutaneous Mechanoreceptors: Sensory endings which are found in periarticular tissues (skin, muscle, ligament, tendon) which respond to mechanical forces. (Rowinski, 1990).

Range of Motion (ROM): The amount of movement within joint. (Houglum, 2005)

Static Stability: The state of remaining unchanged, even in the presence of forces that would normally change the state. (Riemann & Lephart, 2002)

Dynamic Stability: Stability of joint during every phase of movement. (Saha, 1971)

Intra-articular Pressure: Pressure within a joint. (Kelly, Weiland, Schenker & Philippon, 2005)

Muscle spindle: An intramuscular sensory receptor arranged in parallel with skeletal muscle fibers that monitors changes in muscle length. (Enoka, 1988)

Intrafusal fibers: Spindle receptors found within the muscle are composed of small bundle of modified muscle fibers, which the endings of several sensory nerves are attached and they are inervated by gamma-motor neurons. (Lephart et al., 1997)

Extrafusal fibers: Form the bulk of muscle and are responsible for generating force and are innervated by the alpha-motor neurons. (Lephart et al., 1997)

Golgi tendon organ (GTO): Is a high threshold, slow adapting mechanoreceptor, which is stimulated by increased tension within the tendon. (Riemann & Lephart, 2002)

Gamma motor neuron: A neuron whose axon innervates fusimotor muscle fibers. (Enoka, 1988)

Pacinian corpuscles: Are low threshold mechanoreceptors, fast adapting mechanoreceptors which are stimulated by tissue deformation. (Riemann & Lephart, 2002)

Ruffini endings: Are lowthreshold, slow adapting mechanoreceptors which are stimulated by stretch. (Riemann & Lephart, 2002)

Pain receptors: Exteroreceptor that detects external stimuli that impinge on the system. (Enoka, 1988)

Central nervous system (CNS): Portion of the nervous system which is comprised of the brain, spinal cord and cranial nerves. (Enoka, 1988)

Chapter II

Review of Literature

Introduction

This chapter presents a review of the anatomy of the shoulder, along with its role in stability of the shoulder. Since the shoulder is such a mobile joint, there is a lack of stability. When stability is lacking, there is an enhanced need for proprioception in order to try and prevent injury to the joint. Proprioception has previously been described as a combination of JPS and kinesthesia. JPS is a key component to the maintenance of muscle stiffness, coordination and the ability to produce smooth movements that are required for the task at hand (Suprak, 2011). In recent research, it has been suggested that one can enhance their proprioception by increasing the stimulation of cutaneous mechanoreceptors (Lephart et al., 1997; Perlau et al., 1995). It is believed that the application of tape could increase this stimulation (Halseth et al 2004). The purpose of this literature review is to compile research related to proprioception, JPS, the application of tape and KT and determines what effects these components have on the shoulder.

Anatomy of Shoulder

The shoulder is not only the joint with the greatest amount of mobility, but it is also the most complex joint in the human body. Boney architecture, together with soft tissue structures, provides stability and functionality to the shoulder. This instability of the shoulder predisposes this joint to inconsistencies in functionality, proprioceptive abilities and ultimately, acute and overuse injury.

The shoulder complex, which is comprised of three bones (clavicle, humerus and scapula) acts like a series of pulleys, levers and hinges to provide ample motion in all planes (Starkey, Brown & Ryan, 2010). These bones, along with other soft tissues (muscles, ligaments, tendons and joint capsule) form four joint articulations (glenohumeral, sternoclavicular, acromioclavicular and scapularthoracic) (Prentice, 2008). The clavicle is a slender s-shaped bone, which provides the only attachment connecting the trunk to the upper extremity. The clavicle serves as an attachment site for muscles and ligaments, but it also helps maintain the alignment of the scapula (Starkey et al., 2010). The humerus is the longest bone in the upper extremity. The head of the humerus articulates with the glenoid fossa and serves as an attachment site for the rotator cuff muscles (supraspinatus, infraspinatus, subscapularis and teres minor). The scapula is a relatively flat, triangle shaped bone, which primarily serves as a muscle attachment and an articulation for the head of the humerus (Prentice, 2009). The scapula is also considered the foundation of the shoulder girdle as it serves as the primary attachment site for several ligaments and muscles (Terry & Chopp, 2000).

Soft tissues provide dynamic and static stability for the shoulder joint. Static stabilizers include the labrum, capsule and the ligaments. Muscles are the sole dynamic stabilizers. The primary dynamic stabilizers for the shoulder are the four rotator cuff muscles along with the deltoid and long head of biceps brachii. The four rotator cuff muscles attach and reinforce the glenohumeral joint capsule. These four muscle work both individually and collectively to provide stability to the joint capsule during shoulder motion. Therefore, when one structure is injured the whole joint can be affected (Andrews, Harrelson & Wilk, 2004).

Acromioclavicular Joint. The articulation between the acromion process of the scapula and the distal portion of the clavicle make up the acromioclavicular (AC) joint. The AC joint is a commonly injured joint in the shoulder due to its weak connection between articulating structures, which are separated by fibrocartilaginous disks (Terry & Chopp, 2000). Surrounding the AC joint is a thin fibrous capsule, which can provide support when it is reinforced by the anterior, posterior, inferior and superior acromioclavicular ligaments. However, most of the stability at the AC joint comes from two complexes of surrounding ligaments, consisting of the acromioclavicular ligaments (anterior, posterior, inferior and superior) and the coracoclavicular and coracohumeral ligaments (Prentice, 2009). The AC joint allows for motion to occur in all three anatomical planes; and has two primary functions: to maintain the appropriate relationship between the clavicle and scapula during the early phase of shoulder elevation and to allow for more motion of the scapula on the thorax during the later phases of limb elevation (Andrews et al., 2004).

The acromioclavicular joint is reinforced by two ligaments: the acromioclavicular ligament and the coracoclavicular ligament. These two ligaments together form the coracoacromial arch or subacromial space of the AC joint (Prentice, 2009). The primary purpose of the ligaments is to provide protection for the AC joint against posterior dislocation of the humeral head. The subacromial space is common place for soft tissues to become inflamed and cause impingement (Andrews et al., 2004). The acromioclavicular ligament has four portions: anterior, posterior, inferior and superior. These ligaments function to prevent posterior translation of the acromioclavicular joint (Prentice, 2009). The coracoclavicular ligaments are divided into the conoid and the trapezoid ligaments, which function together as the primary joint stabilizers and prevent vertical displacement of the clavicle (Andrews et al., 2004).

Sternoclavicular Joint. The sternoclavicular (SC) joint is formed as the medial portion of the clavicle meets the manubrium of the sternum; because of the articulation where the clavicle is larger than the articulating surface of the sternum, there is a fibrocartilaginous disk which helps improve the articulation. This fibrocartilaginous disk acts as a shock absorber and also prevents upward displacement of the clavicle. The SC joint provides the only direct connection between the upper extremity and the axial skeleton (Prentice, 2009).

Due to the bony make-up of SC joint, it is a rather weak joint, but there is strong reinforcement from the ligaments. The ligaments which help anchor the SC joint are the anterior and posterior sternoclavicular ligaments, the interclavicular ligament, and the costoclavicular ligament. The primary function of the anterior and posterior sternoclavicular ligament is to anchor the sternal end of the clavicle to the sternum, preventing upward displacement of the clavicle on the sternum. Lateral displacement of the clavicle is prevented by the interclavicular ligament. Finally, the costoclavicular ligament prevents superior and lateral displacement of the clavicle (Prentice, 2009).

Scapulothoracic Joint (articulation). The scapulothoracic joint is not classified as a true joint because it lacks joint characteristic like joint capsule and ligamentous stability. The main source of stability for this joint is atmospheric pressure. However, its articulation between the thoracic cage and the scapula is a vital component of shoulder motion (Andrews et al., 2004). Numerous muscles originate from the scapula and these muscles function to provide it with some stability. These structures allow it the shoulder to move through the range of motion smoothly (elevation, depression, protraction, retraction, abduction & adduction) (Prentice, 2009).

Glenohumeral Joint. The glenohumeral joint (GH), also known as the shoulder joint, is very unstable due to the shallowness of the articulation of the humeral head with the glenoid fossa, the lack of ligamentous support, and the laxity of the joint capsule. For this reason, there is more mobility than stability at the shoulder joint (Prentice, 2009). It is for this reason that the GH joint is the most commonly dislocated joint in the shoulder complex.

Within the glenoid there are two important structures: the glenoid fossa and the glenoid labrum. The glenoid labrum is dense fibrocartilage within the glenoid. The labrum functions like the meniscus in the knee, in that it helps diffuse the compressive forces of the joint. The labrum is a dense, fibrous structure that deepens the GH joint cavity. This increase in depth of the cavity allows for there to be increased stability of the humeral head on the glenoid fossa. Without the labrum, stability of the shoulder decreases while the risk for injury increases (Halder, Itoi & An 2000).

The joint capsule consists of multiple layers (outer, middle, inner) of collagen that have varying degrees of thickness and strength. The inner portion of the joint capsule is composed of synovium, whereas the outer portion is comprised of the rotator cuff tendons (Halder et al., 2000). The structure of the joint capsule allows for the greatest amount of motion of the shoulder, as it is double the size of the humeral head. Capsular ligaments reinforce the strength and stability of the capsule. Generally speaking, the GH joint capsule is usually relatively stable because the amount of fluid within the joint is limited. This feature allows for a vacuum like seal to occur between the glenoid fossa and the humeral head, referred to as intra-articular pressure. When there is a disruption of this intra-articular pressure, there is instability within the joint, which can cause a disruption of the normal function of the shoulder and predispose a person to injury (Andrews et al., 2004).

The GH joint and capsule is reinforced by the glenohumeral superior, middle and inferior ligaments, the transverse humeral ligament and the coracohumeral ligament. These ligaments function together to help prevent excess motion, which can result in injury (Prentice, 2009). Each ligament can provide specific function; the superior and middle glenohumeral ligaments act together to resist anterior translation of the humeral head. The inferior glenohumeral ligament is divided into two distinct bands: the anterior and superior. They function together to act as a checkrein for anterior and posterior dislocation of humeral head. The anterior portion resists inferior displacement of the clavicle, while the posterior band resists posterior displacement of the clavicle (Andrews et al., 2004). The coracohumeral ligament acts in conjunction with the superior glenohumeral ligament to prevent the humeral head from translating inferiorly or posteriorly. By itself, the anterior portion of the coracohumeral ligament functions as the primary restraint against extension action of the GH joint; while the posterior fibers are a primary restraint against flexion action of the GH joint (Terry & Chopp 2000). The transverse humeral ligament's sole function is to contain the long head of the biceps tendon in the bicipital groove (Prentice, 2009).

Muscles are the primary structures which provide dynamic stability to the GH joint. There are a variety of muscles in and around the shoulder that function together, which are classified by the bony structures with which they articulate. The scapulohumeral muscles originate from the scapula and act on the humerus. They include: rotator cuff muscles (infraspitatus, supraspinatus, subscapularis and teres minor) along with the deltoid (anterior, middle, posterior), teres major, biceps brachii, triceps brachii and coracobrachialis muscles. The scapulothoracic muscles connect the scapula and the thoracic spine and include: trapezius (upper, middle, lower fibers), rhomboids (major and minor), serratus anterior (superior, middle, inferior), levator scapulae, pectoralis minor and subclavius muscles. The thoracohumeral muscles originate from the thoracic spine and act on the humerus and include: latissimus dorsi and the pectoralis major muscles (Terry & Chopp, 2000). Together these muscles function to produce muscle contraction which helps produce motion and in some circumstances enhance the stability of the humeral head within the glenoid fossa. The rotator cuff muscles increase the GH joint stability by blending with the capsular ligaments to produce tension which causes the joint capsule to tighten. Finally, the muscles function in neuromuscular control. This relating to one's owns awareness of JPS and their ability to produce muscle contraction to stabilize the GH in that position (Andrews et al., 2004).

Neuromuscular control

Within in a joint there are numerous neural components (afferent and efferent) that must function properly. In order to produce the desired motion of a joint the muscle and joint mechanoreceptors must work in conjunction with each other to transmit sensory information to the central nervous system (CNS) (Myers, Guskiewicz, Schneider, & Prentice 1999). These mechanoreceptors include Pacinian corpuscles (rapid adapting receptors), Ruffini endings (slow adapting receptors) and pain receptors. These mechanoreceptors are responsible for providing proprioceptive feedback to the CNS, so that the CNS can process the information and send a proper signal which will allow the joint to move properly (Lephart et al., 1997).

Along with the mechanoreceptors, the muscle also contains muscle spindles. Muscle spindles are specialized cells located in skeletal muscle that respond to changes in muscle length. They are composed of extrafusal fibers are the main force-generating fibers, and are innervated by the alpha motor neurons (Lephart et al., 1997). Intrafusal fibers are the proprioceptive fibers that detect the amount and rate of change within the muscle, and are innervated by gamma motor neurons (Kirkpatrick, Allouh, Nighingale, Devon, Yablonka-Reuveni & Rosser, 2008). Both the intrafusal and extrafusal fibers respond to changes within the muscle and muscle spindle, this allows for the muscle spindle to function all the time during muscle contraction. Along with the muscle spindles there are also golgi tendon organs (GTO) within the musclotendinous junction of skeletal muscles, which are activated when there is tension placed on the muscle causing pull on the tendon. When the GTO is functioning it is sending messages to the CNS which results in inhibition of the motor neurons that are innervating the muscle. Therefore, some researchers believe that the GTO function as a protective mechanism for the muscle and tendons (Lephart et al., 1997).

Proprioception and the sensorimotor system

The bones, muscles, tendons, ligaments and neurological components all function together and contribute to one's proprioceptive ability. Proprioception is a term commonly used interchangeably with kinesthesia and JPS; however, proprioception was originally defined by (Sheeington, 1906) as a reference to the afferent information arising from the proprioceptors which are located in the proprioceptive field. Proprioception is a term that is used to describe the afferent information received from internal peripheral areas of the body (proprioceptive field), which include specialized receptors such as mechanoreceptors, thermoreceptors and pain receptors. This information contributes to postural control, joint stability and several other conscious sensations (Riemann & Lephart, 2002).

The proprioceptors are part of a complex system known as the sensoirmotor system (SMS). The SMS encompasses sensory, motor and central integration and processing involved in controlling the body's functional movements. Within the SMS there are peripheral mechanoreceptors which can be found in cutaneous, muscular, ligamentous and articular tissues. The firing rate of sensory receptors is altered by changes in the deformation of their parent tissues. This deformation occurs when afferent information triggers a change in the parent tissue. This afferent information travels along the afferent pathway to the CNS where it is incorporated with information from other levels of the CNS. This information is processed and elicits efferent motor responses which are responsible for producing coordinated movement patterns.

Joint proprioception becomes critical in providing joint stability (Riemann & Lephart, 2002). Therefore, proprioception was further divided into three main submodalities based on the following: posture, passive movement, active movement and resistance to movement. These submodalities include kinesthesia, JPS and sense of tension (Riemann & Lephart, 2002). Proprioception can be affected by external stimulus which causes there to be an increase in cutaneous stimulation via the cutaneous mechanoreceptors, which can have an effect on the SMS (Myers & Lehart, 2000).

Measurement techniques for sensorimotor system

Due to the complexity (interactions, relationships and compensatory mechanisms of the components) of the SMS it is very complicated to measure and analyze specific characteristics and functions. Currently there is no one method which directly assesses the higher processing centers of the SMS. Therefore, a combination of tests is utilized to assess the various components of the SMS. When trying to evaluate the integrity and function of the SMS, various tests can be conducted to measure variables along either the afferent or efferent pathways, or a combination of both.

When one is assessing proprioception or one of its submodalities, the testing is conducted along the afferent pathway. There are several testing methods for the three submodalities of proprioception (JPS, kinesthesia and sense of tension). JPS measures the accuracy of position replication which includes both the afferent and efferent components. JPS can be either passive or active and it can be performed in either open or closed kinetic chain positions. The two most common assessment tools that researchers use for JPS are position-reproduction and position matching. Position-reproduction is done by taking the joint through a ROM to a predetermined position and returning to starting position, and then the subject is asked to replicate the position, all in the absence of visual feedback. In position-matching the joint is taken through a ROM to the desired position, then the subject is asked to replicate the angle with the contralateral joint (Suprak et al., 2007). Kinesthesia is assessed by measuring the threshold to detection of passive motion (TTDPM). Threshold to detection of passive motion direction (TTDMD) is used to detect one's ability to detect that motion is occurring and what direction the motion is taking place. TTDPM usually is commonly measured at slower speed that range from 0.5-2°/s. Sense of tension is measured by comparing one's ability to reproduce the desired torque produced for varying conditions (Riemann, Myers & Lephart, 2002).

Variations in shoulder JPS

JPS is necessary to maintain muscle stiffness and coordination that help produce smooth movement patterns in relation to a joint; this is essential for accomplishing the desired task. Along with JPS there is also kinesthesia which is a necessary component of proprioception as it incorporates both active and passive limb movement. As a result, JPS provides a stabilizing effect about the joint; especially the shoulder joint, due to its natural lack of stability (Suprak et al., 2007). Researchers suggest that there are numerous factors that can have an effect on JPS. In the following research some of these factors will be explored.

Blasier et al., (1994) examined shoulder kinesthesia in 29 subjects with and without generalized joint laxity. A brief clinical exam was completed to determine the presence of generalized joint laxity. In order to be classified as having generalized laxity the subjects needed to present with two of the three criteria: passive hyperextension of the elbow, passive hyperextension of the knees or passive hyperextension of the thumb. Subjects were then tested for TTDPM for internal and external rotation of the humerus at an angular velocity of 1°/s.

Individuals with no joint laxity showed a smaller threshold angle than those individuals with joint laxity. Therefore, the group with no laxity performed better in the detection of rotation. The differences were observed in the sensitivity of proprioception during external rotation in individuals without generalized joint laxity. These results indicated that individuals with shoulder joint laxity experienced a decrease in proprioceptive sensitivity. From these results it can be concluded that joint laxity can encumber ones' proprioceptive abilities. These findings suggest that one mechanism for enhanced shoulder proprioception is capsular tightening. As seen in this study, the detection of rotation maybe an important component in JPS. However, the results of this study warrant further examination to assess the effects of elevation angle and JPS.

Suprak et al., (2006) provided some original research on the influence of elevation angle on shoulder JPS with an unconstrained task. The purpose of this study was to assess the effect of plane angle on repositioning tasks in multiple planes at a constant elevation. They also examined the effect of arm elevation angle on repositioning tasks in the scapular plane without any restrictions. Twenty-two healthy individuals were used for this study. The subjects were instrumented with the Polhemus Fastrak 3Space magnitude tracking system, so the movements of the humerus could be followed with respect to the thorax. All of the testing took place in one session. During the testing, the subjects were fitted with head-mounted goggles, which allowed them to receive visual cues indicating the target position and where their arm was in respect to that position, without actually seeing their arm. Once the targeted position was achieved the screen went blank and remained so for the rest of the trial. After holding this position for a count of five seconds, the subjects were instructed to relax and then to return to that position without the assistance. This was repeated for nine various joint angles.

There were no significant differences noted in absolute error (AE) among plane angles tested. However, significant findings between JPS and elevation angle were observed as the elevation angle increased. These results suggest that JPS can be altered by changes in elevation angle. In theory as the elevation of shoulder increases, the amount of torque required to maintain the target position increases due to the effects of gravity. However, in this study the amount of torque produced was constant throughout the plane angles tested. The results of this study do not support the hypothesis that as the plane angle approached 0° JPS would improve. This suggests that JPS maybe enhanced when there is an increase in muscle activity which can occur as elevation and plane angles increase due to the stretching of muscle, ligaments and capsule. Further research should be completed to evaluate the not only the muscle activity at varying plane and elevation angles but also what effects external torque on JPS.

A follow-up study to the previous study was conducted by, Chapman et al., (2008) to determine if external torque on the shoulder was the reason error was minimized at 90° of elevation, or was it something else regarding joint position. In this study they believed that alterations in external torque had more of an effect on JPS than changes in joint angle. This study included 27 healthy people who had no previous shoulder injuries. In this study, shoulder JPS was tested actively without constraint, similar to the previous study. The data was collected with a magnetic tracking device with the subjects were seated on a chair that had a movable back to allow for the position of the back of the chair to be changed. In this study, subjects were tested in the upright position, as well as in a reclined position (45°). All of the testing was completed on the subjects' dominant arm, in seven different target positions and two different chair angles. The subjects were given visual cues via the head-mounted goggles as in the previous study.

The researchers found no significant differences in repositioning error when the chair position was matched to the elevation angle. However, there were significant differences detected when positions were matched with respect to external joint torque. Therefore, from these results the conclusion can be drawn that the elevation angle maybe more important than the joint torque in JPS. The results of this study give clinicians insight, on ways to improve JPS through functional exercises that incorporate either joint positions that increase external torque or exercises with external resistance. However, more research is still needed to gain a better understanding for improving JPS and the effects that external resistance has.

As an adjunct to the results of the previous study, Suprak et al., (2007) assessed whether shoulder JPS improved with the presence of increasing external resistance at the same joint position. For this study, 24 healthy individuals with no previous shoulder pathologies were examined. The subjects' data was collected using the Polhemus Fastrak 3Space magnietic tracking system. Since the purpose of this study was to assess the effects that external resistance has on shoulder JPS, the subjects had varying weights attached to their wrists normalized to percentages of the external shoulder torque due to gravity at the position of interest. The subjects' were fitted with head-mounted goggle, which provided visual cues for the intended joint position. After this task was completed, the subjects were asked to replicate the position. Five different trials were completed for each of the five different conditions tested, with three repetitions performed at positions of interest (50° of elevation in the scapular plane).

The results indicated no significant effect of external resistance on vector repositioning, so the researchers further divided the repositioning into plane and elevation angles. Here they reported decreased repositioning error with increases in external load at a constant elevation angle. These results indicate that external resistance does in fact impact JPS, by possibly enhancing muscle spindle sensitivity which allows the subject to maintain the target position against gravity. This is due in part to CNS's ability to detect changes in sensorimotor function. Additional research is needed to further describe the importance of motor commands and muscle spindles in regards to JPS.

Suprak, (2011) carried out a supplemental study based on the results of the previous studies, to assess the importance of muscle spindles and motor commands in relation to JPS. For this study 23 healthy individuals with no previous shoulder pathologies agreed to participate. Data was collected in one session using the Polhemus Fastrak 3Space magnietic tracking system. Given that the purpose of this study was to study the effect of shoulder position in the horizontal plane; the elevation angle remained constant. All subjects were tested in nine different positions; five target positions and four distracter positions. The target positions included plane angles of 80° and then horizontal abduction ROM were calculated 22%, 45%, 67.5%, and 90%, of full ROM all at 90° elevation. The four distracter positions were all completed in the scapular plane and they included 30°, 50°, 70°, and 110°. All nine positions were tested three times each with a five minute rest interval in between.

Both AE and variable error (VE) were calculated. The results support previous data, that plane angles had no effect on AE or VE. It was noted that in this study no attempt was made to control the movement velocity, which would not limit the contribution of the muscle spindles. Instead in this study the subjects were shown the appropriate movement velocity and instructed to perform smooth movements. It is believed that this may have enhanced muscle spindle activity, which is attributed to the obligation of the subject to actively achieve, maintain and replicate the target position without support and against gravity. Many researchers contend that muscle spindles are the driving force for afferent feedback regarding shoulder JPS and the results of this study further support this concept by showing that JPS is not affected at end ROM in unconstrained tasks. More research is needed to assess the contribution of motor commands and how they interact with the afferent signals which are used to manage JPS throughout ROM.

Janwantanakul, Magarey, Jones and Dansie (2001) examined the effects that various joint positions had on shoulder JPS. For their study they recruited 34 right-handed males with no previous history of shoulder pathologies. The subjects were tested in three positions which were determined by 50%, 75%, and 90% of each individuals total passive shoulder rotation ROM. All tests were conducted three times using the KinCom 125 AP dynamometer.

Findings of this study suggest that shoulder position acuity (measured with both AE and VE) varies across the ROM with the potential to experience greater position sense acuity at extreme end ROM. It was found that JPS was the most accurate as the shoulder approached end ROM for external rotation. However, the results of this study showed no alterations between the actual joint positions and shoulder position sense acuity from neutral position. In this study they limited their subjects to only right hand dominate so future studies may want to compare both dominant and non-dominate arms to see what the effects if any are. The results of this study are similar to those results previously describe by Suprak, (2011).

Voight, Hardin, Blackburn, Tippett and Canner, (1996) studied not only the effect of muscle fatigue on proprioception but also the relationship between arm dominance and proprioception. Eighty-four volunteers were summoned for this study and inclusion criteria included no previous history of GH pathology. The biodex was used to measure both active and passive JPS. Each subject was tested with both their dominant and non-dominate arm. For each condition, subjects three trials of both active and passive repositioning at 75° of external rotation, both at baseline and after completing a fatigue protocol. The order of active and passive repositioning, along with the order for arm dominance was randomized.

The results of this study failed to conclude that arm dominance affected JPS. The authors did find a relationship between muscle fatigue and decreased proprioceptive acuity. These results indicate that fatigue affects the contractile elements of the shoulder, which include the muscle and the receptors within the muscle. The onset of fatigue hinders one's ability to reproduce the targeted joint position. Another possibility is that, when fatigue is present, not only does the muscle not function properly, but the sensory components of the muscle (muscle spindle and GTO) are also affected and they rendered dysfunctional.

JPS can be affected by numerous factors: injury, fatigue, etc. When someone experiences any of the above factors, they can experience a loss of joint awareness; however, this can be prevented by improving a person's awareness of their joint position (Perlau et al., 1995). Tape is a means in helping increase perceived joint awareness. Researchers believe that tape provides constant pressure, along with cutaneous sensory cues that allow the joint, in conjunction with the skin, to work together and provide enhanced position awareness (Robbins et al., 1995).

Effects of bracing and bandaging on proprioception

Shoulder proprioception is affected by varying factors due in part to an increase in stimulation of the cutaneous receptors. These cutaneous receptors can be impacted by external resistance, which is provided by objects such as a strip of tape which increase pressure of underlying musculature or movement of tape against the skin. Therefore, heighten action of the cutaneous receptors increases muscle activity, which in turn, enhance JPS (Perlau et al., 1995).

Perlau et al., (1995) studied the effect that an elastic bandage had on knee JPS in uninjured people. For this study, 54 subjects were tested using the Kin-Com isokinetic dynamometer. First, the machine took the subjects through two cycles of predetermined motions. Then the tester moved the subjects through the same set of motions and the subject was asked to identify when the angle had been reached. After completion of this baseline test, an elastic bandage was applied to the subjects. With the bandage in place, the subjects completed between 60-90 minutes of light activity before they were tested again following the same sequence of events.

The application of the elastic bandage resulted in significant improvements in JPS when compared to no bandage. When the subjects were further divided into groups based on their JPS (good- $<5°$ of mean inaccuracy and poor- $\geq 5°$ on mean inaccuracy), there were remarkable improvements in those individuals with poor JPS. Since cutaneous mechanoreceptors respond rapidly to change in movement, there is reason to believe that the application of bandage stimulated the cutaneous mechanoreceptors. These changes provide proprioceptive feedback, which allows for enhanced JPS.

In a comparable study Jerosch and Prymka, (1996) examined the effect of knee bandage application on knee JPS in healthy subjects and subjects with anterior cruciate ligament (ACL) tears. During the testing procedure, subjects were completely relaxed. This was so the tester could manipulate the knee into the preferred joint angles, using a specialized splint. Then, the subjects were asked to replicate the joint angles with the same limb. Subjects in this study were their own controls, so they completed both the bandage and no bandage conditions.

In both the healthy individuals and the persons' with torn anterior cruciate ligament, there was a reduction noted in extension which was considered the angle of deviation after the knee bandage was applied. However, when pre and post-operative measurements were compared, the angle of deviation was significantly worse in the post-operative condition. One potential explanation for these results is that during reconstructive surgery the ligament is repaired, but the neurological structures cannot be repaired. These results do not indicate the use of a knee bandage for treatment of ACL tear. However, these results can imply that the use of knee bandage in combination with other treatments may help improve proprioception. From this study, it has been shown that bandaging can provide cutaneous stimulation enough to have an effect of JPS. Now that results show that something as simple as an elastic bandage can be effective researchers may want to study the effectiveness of bracing on JPS.

Ozer, Senbursa, Baltaci and Hayran, (2009) looked at the effects of ankle taping or bracing on functional balance, jumping performance, coordination and JPS upon comparison to barefoot. For this study, 20 physically active males, who had no previous history of ankle injuries, were recruited. For each condition tested (barefoot, taped, braced) subjects performed: single leg balance-balance, standing long jump, vertical jump and leg press. These testes were completed to assess the subject's balance, stability, coordination, proprioception and functional assessment of the lower limb. For the coordination and proprioception testing the subjects were tested using a function squat machine, which measures neurophysiological factors (coordination, reaction time, proprioception, and endurance). Specifically the testing for proprioception assessed the subjects' ability to maintain joint position with and without the visual aid.

The authors observed that taping or bracing did not have a significant effect on the subjects balance when compared to the barefoot condition. Subjects who were barefoot performed the best on the vertical jump test. For the coordination test using the leg press, it was noted that when the subjects were taped or braced they performed better than those who were barefoot and there was also differences noted in proprioception. These results indicate that taping and bracing can be utilized as a preventative measure and also can be a beneficial aspect of the rehabilitation process for injury.

Injuries can alter an individual's JPS, which can hinder their recovery process. However, something as simple as a piece of tape can significantly improve a person's awareness of their joint position. Although, in most cases tape can be advantageous in increasing JPS, there are some circumstances where the application of tape can hinder one's JPS. This is primarily seen amongst healthy individuals who have relatively good proprioception. It can be concluded from this research that along with other treatments, tape can be beneficial in improving proprioception for people who have decreased proprioceptive abilities. In the next couple of sections will explore what effect taping will have at the different joints.

Effects of ankle taping on proprioception

Prior to this study the effects of ankle taping on JPS had never been examined. Robbins et al., (1995) looked at whether ankle taping improved proprioception pre and post exercise. They took 24 males who were in good health and who participated in two testing sessions where they were randomly assigned to either tape or no tape group. For the tape group subject's had both ankles taped. All subjects were fitted with goggles prior to testing so they could not see the sloped surfaces that they would be standing on. During the two testing sessions, the subjects either exercised (basketball or running) or rested (non-weight-bearing) for 30 minutes. After the 30 minutes, the subjects' JPS was tested and they were asked to estimate the perceived direction and amplitude of a series of sloped surfaces both with their shoes on and with their shoes off; those in the tape group remained taped throughout the testing. The estimation for the slope angle was based on a ratio scale from 0-15, where 0 corresponded to 15-37.5°. There was a 12.5°

difference between the actual maximum slope and the scale maximum, this allowed for overestimation. Subjects were also given verbal reference angles of 0°, 12.5° and 25°.

The results of this study showed no significant differences in perceived slope between the tape and no tape conditions. However, all the variables measured (perceived surface slope, absolute mean estimation error, and net mean estimation error) there was found to be a significant interaction between the slope of the plane and the foot position awareness. Within these variables there was a significant interaction noted between tape, exercise, and angle. These results indicate that taping has an influence on JPS when subjects were standing on a sloped surface with athletic footwear. In comparison individuals who were taped but barefoot experienced relatively no changes in their JPS. Therefore, tape helps counter this lack of position awareness when wearing footwear, which can further prevent injuries. Since this is the first research of its kind, further research is needed to support the results seen above.

Researchers Simoneau, Degner, Kramper and Kittleson, (1997) further investigated what effects the application of athletic tape on the ankle would have on JPS and TTDPM. Subjects were screened for ankle deformities and instabilities, along with a detailed look into at their history to rule out and major ankle problems. Twenty healthy male subjects were used for this study. All subjects were tested for both submodalities, both with and without the application of tape, and in both weight-bearing and non-weight-bearing conditions. JPS was tested by placing the subject's ankle in a predetermined position, holding that position for five seconds. Then the subjects' ankle was returned to resting position for three seconds and after that, they were asked to replicate the previous position. When testing TTDPM, the subjects' ankle was passively moved into either dorsiflexion (DF) or plantarflexion (PF) at an angular velocity of 0.25°/s.

Subjects were instructed to press a stop button as soon as they could tell which direction their ankle was moving.

The researchers observed significant main effects with both weight-bearing and non-weight-bearing conditions when assessing. For the weight-bearing condition the main effect was present for the angular position of the ankle. However, for the non-weight-bearing situations, there was also a significant interaction found between the angular position and the tape, with the application of tape improving the subjects' ankle JPS in the position of PF. The results for TTDPM indicated that there was a significant main effect noted in one's ability to perceive the direction of movement for both the weight-bearing and non-weight-bearing conditions. However, the application of the tape did not significantly change the subjects' ability to perceive joint motion under any conditions. These results warrant further research into the effects of tape on ankle JPS in positions other than PF.

Overall, the results of this study suggest that the application of tape may increase the cutaneous stimuli for the joint. This increase of cutaneous stimulation can enhance kinesthesia and JPS. However, these results fail to show that the application of tape actually benefits one's proprioceptive abilities in healthy individuals. Therefore, further research is needed to further evaluate the effectiveness of taping and bracing in healthy individuals, as some studies have found tape beneficial while other studies have found the tape ineffective.

Effects of patellar taping on proprioception

Along with further investigation into the effectiveness of tape within an injured or unhealthy population, more research is need to further look into other joints in the body. Callaghan et al., (2002) conducted a study to assess the effectiveness of patellar taping on JPS in healthy individuals. Their study consisted of 52 healthy individuals who had never had any significant knee problems. The patellar taping consisted of one strip of tape across the center of the patella. The subjects in this study acted as their own control as they were tested with and without the patellar taping. Data was collected using the Biodex 2 Isokinetic Dynamometer. Subjects were instructed about the testing procedures prior to practice trials. All of the subjects' right legs were tested while the subjects were seated so their hips were in approximately 90° of flexion and the tibial pad was aligned just above the lateral malleolus. For the TTDPM testing the angular velocity was set at 30°/s. Under the tibial pad a sphygmomanometer was placed, which allowed for equal amounts of sensory input to the lower limb throughout testing. Each subject was tested for the two tape (tape and no tape) and testing (passive angle reproduction (PAR), active angle reproduction (AAR) and TTDPM) conditions. Between each trial, the subjects walked around to reduce the possibility of proprioceptive carryover from one trial to the other.

Researchers further divided the subjects into two categories (good (≤5°) and poor (>5°) proprioceptive ability), as there were no significant differences between the tape and no tape when all 52 subjects were assessed. Significant improvements were noted in proprioceptive abilities after the application of tape amongst the group classified as "poor"; while those in the "good" group remained unchanged or performed worse. Specifically individuals in the "poor" group showed significant improvements in PAR and AAR, while subjects in the "good" group demonstrated no improvements with AAR and during PAR they actually performed significantly worse. Some researchers speculate that the afferent stimuli which are enhanced by external apparatus, such as tape maybe a possible explanation to the results seen above. In this theory it is hypothesized that enhanced afferent stimulation is beneficial to those individuals who are classified as having "poor" proprioceptive abilities. Whereas those who are classified as having “good” proprioceptive abilities this enhanced stimulation maybe unhelpful or confusing to the CNS of these individuals, therefore, causing their proprioception to be worse (Perlau, Frank & Fick, 1995). In both groups there were no significance differences in the TTDPM. These results show that tape can be both beneficial and harmful depending on their proprioceptive abilities. For individuals who have a measureable deficit in proprioception, the application of tape can enhance their accuracy of JPS and kinesthesia. However, individuals who have relatively good proprioception, the application of tape can hinder their performance. Further research is needed for unhealthy populations.

Callaghan, Selfe, McHenry and Oldham, (2008) conducted research regarding the effects of patellar taping (a strip of Hypafix adhesive tape was placed across the center of patella) on knee proprioception in subjects with patellofemoral pain syndrome. This research was based off their previous research on the effects of patellar taping on knee proprioception in healthy patients. This study was set up virtually the same as previously described; the only difference was the number and type of subjects. For this study, 32 patients with patellofemoral pain were assessed.

When all the subjects were examined, the application of tape had no effect on JPS. Once again, the subjects were further divided into subgroups based on their proprioceptive abilities (good or poor). For those who were in the “poor” group, all but one of the subjects saw an increase in JPS, PAR and AAR. In comparison, those in the “good” group did not benefit from the application of tape, except for one individual who showed improvements. These results show that applying a strip of tape to the patella without any correction of patellar position can improve a person’s proprioceptive abilities, presumably due to sensation changes in the cutaneous receptors.

Within the SMS are sensory receptors which respond to changes in stimuli. Therefore, the application of tape, brace or elastic bandage may provide a change in stimulation which may affect the SMS. Hinman, Crossley, McConnell and Bennell, (2003) consider the possibility that taping the knee could have an influence on sensorimotor function. In their study they conducted two separate experiments; one addressed the immediate effects of the application of tape (A) while the other experiment looked at the short term effects that the application of the tape had (B). For both experiments three taping conditions (therapeutic tape, control tape, no tape) were assessed for three outcomes (proprioception, quadriceps strength, muscle activity of quadriceps) in both the vastus lateralis and vastus medialis. Proprioception was assessed by measuring JPS of the knee, quadriceps strength was tested by measuring isometric strength at 60° knee flexion, and quadriceps activity was assessed by collecting electromyography (EMG) data while the subject descended stairs. For part A of the experiment, 18 subjects over the age of 50 who had been diagnosed with osteroarthritis were summoned from the community. Each individual was tested for all outcomes with all three taping conditions. The results for experiment A were: JPS- for all taping conditions the application of tape did not change JPS scores, quadriceps strength- again for the application of tape did not immediately alter strength, and quadriceps activity- tape did not change EMG activity. For experiment B, 87 individuals with osteoarthritis were used for a randomized control trial, which lasted three weeks. Participants were also subdivided into “good” or “poor” based on baseline sesorimotor function. The results of experiment B were as follows: JPS- there were significant improvements in variable error noted in the “poor” control group, quadriceps strength- there were no significant changes observed in either group, or quadriceps activity- again there were no notable changes between groups. These results indicate that the application of tape does not appear to have an effect on sensorimotor function either immediately or short-term in patients with knee osteoarthritis.

The research that has been put forth has indicated that the application of tape does have an effect on proprioception. However, it has been shown that it can have both positive and negative effects, depending on the subject's proprioception prior to the application. Overall, it has been shown that non-elastic tape can have an effect on JPS, so further investigation is warranted to assess the effects that specialty tapes have on JPS.

Effects of kinesio tape on proprioception

KT is a specialty tape that functions as more of a therapeutic tape, rather than a supportive tape. KT is an elastic tape which can stretch up to 120-140% of its original length and this provides constant tactile stimulation and torque for the skin and cutaneous receptors (Yasukawa, Patel & Sisung, 2006). As reported by creator Kenzo Kase, KT can correct muscle function that improves muscle strength, improves circulation by helping eliminate excess fluid, decreases pain by suppressing nerve stimulus for pain and repositioning of joint by relieving muscle tension. However, current research has also purported that KT could improve proprioception by increasing stimulation of the cutaneous receptors. Since the application of KT allows for constant stretching and pressure on the surface of the skin, this can stimulate cutaneous mechanoreceptors, which can signal information to the brain about current joint position (Halseth et al., 2004).

Halseth et al., (2004) found that KT did not enhance ankle JPS in healthy subjects, but suggest that KT could facilitate proprioception in injured individuals during the acute phases of the injury process. This study consisted of 30 healthy individuals with no previous history of serious ankle pathologies. This study assessed the persons' ability to reproduce joint position by having the subject recreate joint positions that were randomly selected. Measurements were taken using an instrumental platform with moveable footplate and with an attached precision potentiometer. Measurements were taken utilizing the dominant foot. Both passive and active measures were taken as the subjects were passively placed in a position and then asked to reproduce that position actively.

Analyses of the results show no significant difference between the tape and no tape conditions for plantarflexion or for the combination of plantarflexion and inversion. These motions were selected because they are the most common mechanism for ankle sprains. These results suggest that the application of KT has no effect on active ankle reproduction of ankle joint in healthy individuals. Despite these findings, KT may be beneficial in the acute phases of injury in regaining proprioception. However, further research is needed to determine the more long term effects of KT.

Cortesi, Cattaneo and Jonsdottir, (2011) performed a pilot study on subjects with multiple sclerosis. In this study they assessed whether KT had an effect on these subjects' standing balance. Fifteen people with multiple sclerosis were tested using the Technobody Stabilometric platform and under two conditions: eye closed and eyes closed with the application of KT. The first measurement was taken without KT and then KT was applied. Then subjects left the tape in place for two days and then came back for more testing. Three positions of the center of pressure (COP) were calculated: sway (SWAY), velocity of sway (VEL) and length of sway (LENGTH) in both the anterior-posterior (AP) and medio-lateral (ML) axis.

The results for SWAY AP were mixed, as five out of fifteen showed improvements with the application of KT and three subjects were impacted negatively in the presence of KT. Therefore, these results were not found significant, however, they approached significance. The same effects were also seen in the VEL AP, as the results only approached significance as some subjects benefitted from the application of the KT, while others showed a decline in performance. The results for LENGTH showed significance as subjects who performed poorly on the initial assessment, performed better after KT was applied. For SWAY AP and VEL AP, about the same number of subjects got worse as those who got better with the application of KT tape, however, most were not affected. This result is not very supportive for the long term effectiveness of KT within a healthy population. As within this study the application of KT enhanced proprioception of subject with multiple sclerosis who experienced some proprioceptive deficit.

Having found that KT can have an effect on a person's postural sway, further research is needed to assess the effects that KT has on balance. Husk, (2010) researched the effects the application of KT had on balance, measured by postural sway. The subjects were assessed under four conditions: single leg stance with eyes open, single leg stance with eyes closed, double leg tandem stance with dominant foot in front with eyes open and double leg tandem stance with dominant foot in front with eyes closed. KT was applied using an "I" strip to the lateral aspect of lower leg. During both single and double leg conditions where the subjects kept their eyes open, there were not any significant differences between the tape and no tape conditions. However, the application of the tape significantly improved center of gravity (COG) sway during the double leg tandem stance with eyes closed. Similar results were seen with the single leg stance with eye closed, which trended towards significance. These results suggest that the application of KT may have a positive influence on a person's ankle proprioception. Improvements were noted in postural sway and balance while performing a task with their eyes closed.

Garcia, (2010) conducted a similar study to evaluate the effects of KT on single leg stance in varying conditions with and without tape. This study, however, excluded individuals who had previous knee pathologies. The KT was applied around the patella using two “Y” strips. COG and balance were assessed through four trials. All trials were tested using the single limb stance and the trials were conducted for both tape and no tape conditions and also eyes open and eyes closed conditions. This study also showed that balance was significantly improved with eyes closed with the application of tape. Now that balance has been assessed it would be more beneficial for researchers to look into the more intricate functions, such as motor skills.

Aytar, Ozunlu, Surekok, Baltaci, Oztop and Karatas, (2011) conducted a study which combined a number of the outcomes previous measured. Aytar et al., (2011) looked at the initial effects KT had on pain, strength, JPS, and balance (static and dynamic) in patients with patellofemoral pain syndrome (PFPS). For their study they assessed 22 females who were classified as having PFPS. Subjects were randomly assigned to one of two groups, KT or placebo tape. All subjects were taped around the patella and up the quadriceps using the “Y” shaped method for KT. All subjects were then tested for the four outcomes measured. An isokinetic dynamometer was used to assess muscle strength of the subjects’ quadriceps and JPS of the knee; while a Kinesthetic Ability Trainer (balance platform) was utilized to assess the subjects’ balance. Finally, each subject was asked to rate his/her pain experienced during walking and ascending and descending stairs on a visual analog scale (100 mm line with no pain on one end and most severe pain on the other end).

The results of this study suggest that the effects of KT initially are inconclusive when assessing JPS, pain, balance and strength in patients with PFPS. There were significant changes noted between pre and post testing in the KT group, with muscle strength at 60 °/s and 180°/s and dynamic balance. However, in the placebo group, there were significant changes between the pre and post testing for muscle strength at 60°/s and static balance. When both groups were compared, there were no significant differences between intensity of pain, muscle strength, balance (static and dynamic) and JPS. These results suggest that initially KT may not have significant changes; however, long-term effects of KT may be more beneficial. From this study, it can be concluded that KT may not provide enough cutaneous stimulation to have an effect on JPS acutely. Therefore, further research is needed to evaluate KT and its impact on cutaneous stimulation.

Lin, Hung and Yang, (2011) studied what effects scapular taping had on electromyography (EMG) activity and JPS. It was hypothesized that the application of tape would increase cutaneous stimulation, which would increase EMG activity, which would improve proprioceptive feedback, which is essential for JPS. For their study, 12 healthy males were recruited for this study. Subjects were implemented with surface electrodes on four muscles (upper and lower trapezius, serratus anterior and anterior deltoid) to record EMG data. They were also implemented with sensors (sternum, acromial process and humerus) for the electromagnetic motion capture system to assess JPS. For JPS testing, each subject was blindfolded and asked to reproduce positions throughout the ROM, for each target position (mid range and end range) six trials were completed. Both EMG and JPS were assessed under two conditions (KT and no tape). A strip of KT was applied on the scapula in the shape of an "I" from the subjects' clavicle to the level of T-12 vertebra.

Results of this study suggest that the application of tape has an effect on both EMG and JPS. An increase in EMG activity was seen in the lower trapezius and the serratus anterior with the application of tape; whereas the upper trapezius and anterior deltoid actually had a drop in

EMG activity with the application of tape that's a very promising result. There was a significant difference observed in JPS both at mid range and end range with the application of tape. These results suggest that the application of KT tape may be effective in increasing EMG of scapular stabilizer muscles and enhancing JPS in healthy individuals.

Summary

Injuries can alter an individual's JPS, which can hinder their recovery process. However, something as simple as a piece of tape can dramatically improve a person's awareness of their joint position. Although, in most cases tape can be advantageous in increasing JPS acuity, there are some circumstances where the application of tape can hinder one's joint position awareness. This effect is primarily seen amongst healthy individuals who have relatively good proprioception. It can be concluded from this research that along with other treatments, tape can be beneficial in improving proprioception for people who are classified as having "poor" proprioceptive abilities.

KT is a tape that has been around for several years, but it is a fairly new technique that is being used in the clinical setting. KT has numerous claimed benefits; however, there is a need for further research to determine if KT actually produces the purported results. KT can potentially be beneficial, especially during the acute phases of healing. The results of current research are very promising. Overall, these findings appear to be positive, however, the time period of assessment was not long enough to suggest the implementation of KT as a widespread intervention. Therefore, more research is needed to determine the long-term effects of the application of KT. Along with the long-term effect of KT there is no supporting body of evidence that KT can improve proprioception, specifically JPS in a healthy population.

Chapter III

Methods and Procedures

Introduction

The purpose of this study was to compare the effects of KT application versus no tape on shoulder JPS at various elevation angles in an unconstrained task.

Description of Study Population

Thirty athletes from a variety of sports- basketball, track & field-excluding throwers & multi-event athletes, cross-country, soccer, golf and rowing; who do not perform regular overhead activities-were recruited from the Athletic Training Room at Western Washington University in Bellingham, WA, following approval of the study from the University Human Subjects' Committee. Subjects were included in the study only if they had full shoulder ROM in scapular plane elevation and no history of upper extremity or thoracic spine injury within the past six months. If the subjects could not finish the testing they were removed from the study.

Study Design

Analysis of shoulder JPS was performed using repeated measures, utilizing a cross-over design. All subjects were tested at various shoulder elevation angles with KT and no tape.

Data Collection Procedures

Instrumentation. Kinematic data was collected using the Polhemus Fastrak 3Space magnetic tracking system. The Polhemus unit consists of a transmitter, three receivers, and a digitizer. The transmitter emits several electromagnetic fields that are sensed by the receivers and digitizer. In order to track and measure the movement of the humerus with respect to the thorax, receivers were placed on the sternum just inferiorly to the jugular notch and on the humerus slightly superior to the lateral epicondyle. The humeral receiver was held in place by a custom molded Orthoplast cuff and Velcro strap. Additionally another receiver was fastened to the acromion process of the scapula for calibration purposes, but this receiver was removed before testing took place. The transmitter was positioned level to the thoracic receiver when the subject was seated.

Following the fixation of the receivers, a range of bony landmarks were digitized on the thorax, humerus and scapula in order to institute anatomical coordinate system, in accordance with the standard endorsed by the International Society of Biomechanics (Wu et al. 2005). The landmarks which correspond with the digitizing points are: thorax- C7, T1, T8 spinous processes, jugular notch, SC joint and xiphoid process; scapula-AC joint, root of the spine, posteriolateral border and inferior angle; humerus-medial and lateral epicondyles. The center of the humeral head was calculated using a least squares algorithm which was defined as the point that moved the least during a number of small motions (Harryman, Harris & Matsen 1992). Euler angles were used to represent two sequence-dependent humeral rotations with respects to the thorax, consisting of plane of elevation and degree of elevation (An, Browne, Korinek, Tanaka & Morrey 1991).

Participants were fitted with head mounted goggles to occlude all visual cues. The goggles are adjustable and they were also modified with felt on the top, sides and bottom. The display screen within the goggles provided the subjects with kinematic output from the computer. Thus, participants were able to view computer output with complete visual occlusion of shoulder movement and position.

Pre-test protocol. Subjects completed an injury history form which also included personal information such as age, height and weight (self-reported), arm dominance (defined as the arm used to throw a ball) and current activity level. Subjects' hypermobililty was assessed using the Beighton Hypermobility Scale. Which classifies one as hypermobile if you score a five out of nine or greater based on the following tasks: passively dorsiflex the little finger beyonf 90°, passively apposition of the thumb to the flexor aspect of the forearm, hyperextension of elbows beyond 10°, hyperexention of the knees beyond 10° and forward flexion of the trunk with knees fully extended so that the palms of the hand rest flat on the floor. All testing was completed in a single session (Beigton,Paepe, Steinmann, Tsipouras & Wenstrup, 1998). Prior to testing the subjects completed a warm-up, which consisted of dynamic movement and stretching. Dynamic movements included: arm circles (clockwise and counterclockwise), Codman's pendulum swings with 2.5 pounds of external weight and back and forth sagittal plane arm swings. Subjects performed all dynamic movements one set of 15 repetitions. Stretching included: holding internal and external rotation position while the shoulder was abducted too approximately 90°, overhead stretch and adduction of the arm across the chest. All stretches were held for 15 seconds and repeated twice. Following the warm up subjects were asked to remove their shirt (females wore sports bras) and all jewelry as these items can impede results by adding to tactile input. Instructions regarding the testing protocol were described in detail prior to testing.

Skin preparation. The subject's shoulder was cleansed thoroughly with alcohol and non-sterile gauze pads for both the tape and no tape conditions. The subject was seated with their arm in a relaxed position at their side. There is no need for pre wrap or adhesive spray as the KT is applied directly to the skin and has specialized glue in it.

Taping technique for shoulder. For this study, the pre-cut KT for dynamic shoulder support was applied to the subjects' dominant arm. Tape was applied to the midpoint of the upper arm and around the deltoid; this strip of tape is referred to as a "Y" strip. In order to apply the "Y" strip the subject's arm was hyperextend to ~ 45° in order to apply the front tail and then the arm was flexed to ~45° in order to apply the back tail of the tape. The subject's arm was the placed in anatomical position to apply the remaining strips of tape. The "I" strip was applied from base of the "Y" strip to ~3-4 inches above the shoulder joint. Finally, the remaining "I" strip was applied from the base of the shoulder blade covering the shoulder joint. All strips of tape were applied with no stretch and rubbed to activate the adhesive (www.kinesioprecut.com).

Measurement techniques and procedures. Following the instrumentation, pre-testing protocol and skin preparation subjects were instructed to sit on an adjustable stool facing forward, with erect posture and the stool height was adjusted so that their feet were flat on the ground and their knees were flexed to 90°. Once the seat was adjusted subjects' were guided through a practice trial and then they were allowed to practice at least four positions so they felt comfortable with how the testing was going to be performed. All practice trials were conducted in a position which corresponds to a plane of 45° anterior to the corneal plane,45° of elevation; both with and without the head mounted goggles so they felt comfortable with the testing procedures.

If the subject was randomly assigned to start with the tape condition, tape was applied. All testing began with the subject's arm at their side. The screen which the participants saw was gray and had a black square in the center. On the four sides of the screen, red rectangular boxes appeared to direct the subjects how to move their arm in order to achieve the target position. Once the subject reached the desired position a red dot appeared within the black square on the screen and once the subjects had held that position for a second they heard a beep and the screen turned black. The subjects were then instructed to maintain their position for five seconds, after which they heard a voice command to relax, at which time their arm was returned to their side. After a three second break the subjects were prompted by voice command to return. Subjects' then attempted to return to the target position and once they perceived that they were in the target position they pushed a trigger with the contralateral hand. They were told to maintain the position until they heard a beep which indicated the end of the trial. The target positions consisted of elevation angles of 50, 90, and 110° which were randomly arranged into two testing sequences. Randomization of the testing sequence included each target position three times and this was completed for both taping conditions (KT and no tape). Conditions were separated by a ten minute break, so that the tape could be either applied or taken off depending on the randomization of the order. Then the testing procedure of the three elevation angles was repeated.

Data processing. The kinematic data were converted into humeral plane and elevation angles, using transformation matrices between the coordinate systems of the humerus and thorax. Three-dimensional vectors was calculated, using these plane and elevation angles, as lines running from the center of the humeral head through the midpoint between the medial and lateral epicondyles at the presented and reproduced angles. The angle between the presented and reproduced position vectors were calculated for each trial and taken to represent the absolute magnitude of the repositioning error, absolute error (AE). The AE from each target position for each condition was averaged across the three trials and the mean was used for further analysis. The variable error (VE) was calculated as the standard deviation of the AE at each position under each condition, to determine the consistency of the subject's performance.

Data Analysis

Statistical analysis was performed using the statistical package for social sciences (SPSS) version 20 software. Two, two-way repeated measures analysis of variance (ANOVA) was used to evaluate the effects of KT application (KT vs. no tape) and shoulder position (50° vs. 90° vs. 110°) on the absolute and variable repositioning error of the shoulder. The alpha value was defined as $p \leq 0.05$. In order to quantify the standardized mean difference between the two groups, the effect size was also calculated using the partial eta squared.

Chapter IV

Results and Discussion

Introduction

The effects that KT has on shoulder JPS at increasing shoulder elevations in athletes was examined in this study. It was hypothesized that the application of KT would not have an effect on JPS of the shoulder when compared to no tape. Further, we hypothesized that KT would not change the effect of elevation angle on shoulder JPS. The experimental design utilized was two, two-way repeated measures analyses of variance (ANOVA) to evaluate the effects of KT application (KT versus no tape) and shoulder position (50° vs. 90° vs. 110°) on the absolute and variable repositioning errors of the shoulder. The different shoulder positions (50°, 90°, 110°), as well as the tape conditions (KT and no tape), served as the independent variables, while absolute and variable errors serve as the dependent variables. In the subsequent section, a depiction of the subjects' demographics and results that are relevant to the analyses are presented and discussed.

Subject Characteristics

Thirty subjects (12 male, 18 female) volunteered for the study. Three subjects' data were disregarded from the study, due to previous injury of the shoulder tested, hyper-mobility and technical issues with the computer (failure to properly save subject's calibrations). A total of 27 subjects (11 male, 16 female) completed the study. The average age of the subjects was 20.44 ±1.05 years. The average height was 175.02 ± 11.67 cm and the average weight was 70.74 ± 9.65 kg. All 27 subjects were involved in intercollegiate athletics; six in basketball, nine in track and 12 in soccer. In conjunction with their participation in their sport, all of the subjects were resistance trained, with their training ranging from 2-5 days per week. The dominant arm of each subject was tested (26 right, 1 left). Of the 27 subject's tested, 13 completed the no tape condition first, while 14 had the KT condition first. See appendix C for additional individual subject data (subject number, sex, age, height, weight, arm dominance, history of shoulder injuries, and whether they thought KT helped).

Results

Two, two-way repeated measures analyses of variance (ANOVA) were used to evaluate the effects of KT application (KT vs. no tape) and shoulder position (50° vs. 90° vs. 110°) on the absolute and variable repositioning errors in the shoulder, with significance reported when the alpha value was $p \leq 0.05$. The partial eta squared approximates the omega squared value and is representative of a large (ω^2= .15), medium (ω^2= .06) or small (ω^2= .01) effect size (Vincent 2005).

Absolute Error

The results of Mauchly's test indicated that sphericity was assumed (*p* = .487). The ANOVA revealed a significant interaction effect between tape and position (*F* [2, 52] = 4.07, *p* =.023) on absolute error (Figure 1). Since there was an interaction, there was no examination of main effects of tape and position. However, further analysis of simple effects revealed a significant increase in error with KT, showing a 2.65° increase in error at 90° elevation, when compared to no tape (*t* (26) = 2.65, *p* = .014). There were no other differences between KT and no tape at the other positions tested (35/50, (*t* (26) = .346, *p* = .732) and 35/110 (*t* (26) = .546, *p* = .589). The application of KT increased the absolute error when compared to the no tape condition at 90° elevation and an effect size was calculated via the omega squared (ω^2= .135), which revealed a medium effect size.

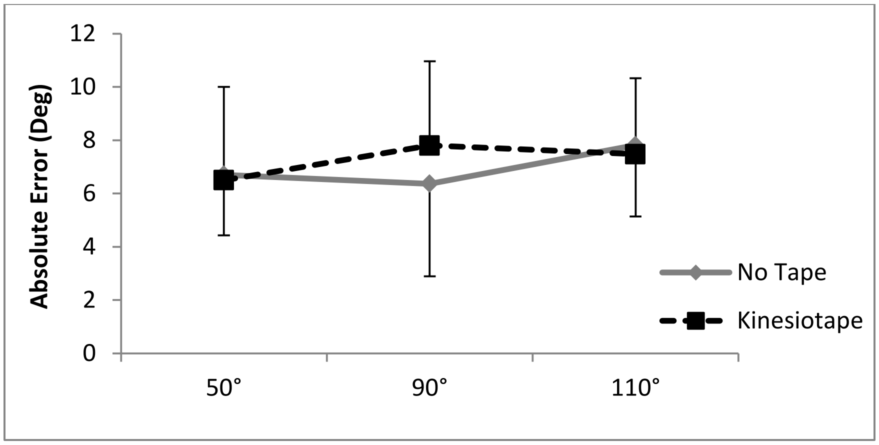


Figure 1. Depicts the Absolute Error at Across Elevation Angles Between Taping Conditions.

Variable Error

The results of Mauchly's test indicated that sphericity was assumed (*p* = .438). The ANOVA revealed no interaction of tape and position (*F* [2, 52] = .709, *p* = .497). There was also no significant main effect of tape (*F* [1, 26] = .045, *p* = .834) or position (*F* [2, 52] = 2.018, *p* = .143) on variable error (Figure 2). Since there was not an interaction between tape and position, there was no need for further analysis of simple effects. However, the effect size was still calculated using the omega squared method. The effect size was calculated for tape, position and tape x position; tape x position (ω^2 =.027), position (ω^2 = .072) and the tape (ω^2 = .002) were all calculated as a small effect size.

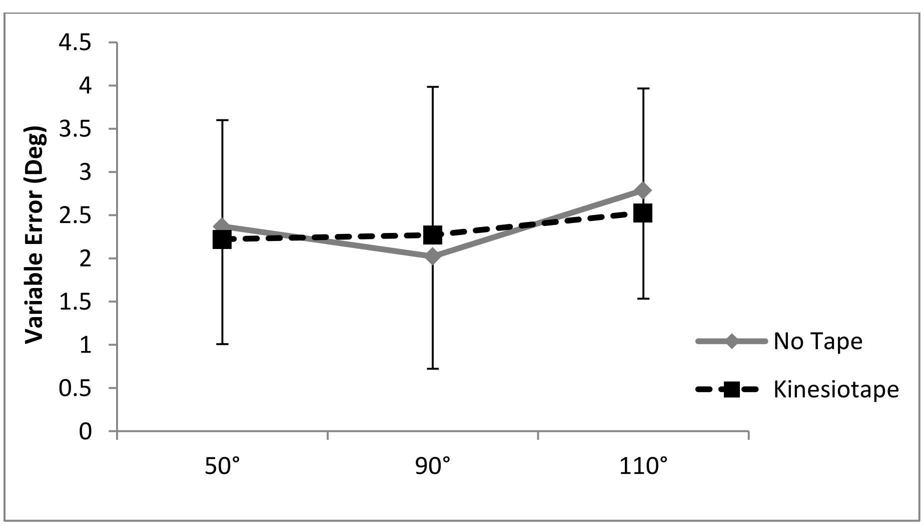


Figure 2. Depicts the Variable Error Across Elevation Angles Between Taping Conditions.

Discussion

The purpose of this study was to assess the effects of the application of KT on shoulder JPS at increasing shoulder elevations in athletes. Based on previous literature regarding shoulder JPS, it was found that repositioning error decreased as elevation angle increased from 30-90° and from 90-110° (Suprak et al. 2006 & Suprak et al. 2007). Therefore, theoretically at 90° of elevation the repositioning error would be minimal and the application of KT would further decrease the repositioning error. Hsu, Chen, Lin, Wang and Shih, (2009) concluded that the application of KT to the lower trapezius muscle enhanced electromyographic (EMG) activity which improved scapular motion, ultimately improving the muscle's performance. From these findings in conjunction with the claims put forth by advocates for KT, it was hypothesized that the application of KT would not provide enough of an increase in cutaneous stimulation to enhance shoulder JPS when compared to no tape. It was further hypothesized, that KT would not change the effect of elevation angle on shoulder JPS. However, this hypothesis was not supported, as absolute error increased significantly at 90°elevation with the application of KT when compared to no tape condition. A study by Suprak et al (2006) produced contrasting results where the lowest repositioning error was recorded at 90° elevation.

Based on the findings of this study, there was a significant difference in absolute error between no tape and KT at the position of 90° elevation. These results challenge the claims put forth by Kinesio Taping Association International, that KT enhances neuromuscular performance (http://www.kinesiotaping.com/global/association.html). There are a number of possible explanations for the results seen. The present application of KT consists of three strips of KT applied to the shoulder with paper-off tension meaning that no added stretch was applied after the paper backing was removed. According to KT manufacturer the paper-off tension is equivalent to ~10% stretch (http://www.kinesiotaping.co.uk/history.jsp). However, when applying the “Y” strip around the upper arm, the arm is placed in approximately 45°of flexion for the anterior portion of the strip and roughly 45° of hyperextension for the posterior portion of the strip, while the remaining two “I” strips were applied while the arm was in a neutral position (at the subject’s side). Based on the arm position for application, the paper-off tension and the elevation of the target position could have resulted in an increased stretch of the KT; particularly the posterior tail of the “Y” strip. This added stretch could have varied in degree depending on the elevation angle being tested, which could have resulted in fluctuating amounts of cutaneous stimulation. This fluctuation in cutaneous stimulation could have resulted in an increase in repositioning error.

Along with the possible alterations in tape tension, come changes in cutaneous stimulation which could provide an explanation for the results seen in this study. According to Kinesio Taping Association International, KT lifts the skin microscopically, providing additional space which promotes circulation of lymph and blood (http://www.kinesiotaping.com/global/association.html). This increase in interstitial space could promote an increase in muscle activation, resulting in enhanced JPS (Lins, Neto, Amorim, Macedo & Brasileiro 2013). In a study conducted by Murray & Husk (2001), the application of KT on the ankle increased cutaneous stimulation, which facilitates an increase in neuromuscular activity and enhanced proprioception. In a similar study by Simoneau et al. (1997), the application of athletic tape to the ankle resulted in increased proprioceptive abilities. However, the results of this study concur with results reported by Halseth and colleagues (2004), that the application of KT did not enhance kinesthetic sense. The KT provided external tension which increases the cutaneous stimulation, but one can assume that the additional cutaneous stimulation from the tape was not enough to improve JPS. This added stimulation from the KT in combination with the stimulation from tissue tension produced from the shoulder motion, could have resulted in overstimulation of the cutaneous mechanoreceptors, causing alterations in JPS acuity (Janwantanakul et al. 2001). We found that the added cutaneous stimulation may have actually hindered JPS at 90° of elevation.

Another possibility that one must consider is the population being tested. A majority of the literature is conducted on healthy population, so the results could be different for an unhealthy population; with whom may be the majority of athletes wearing KT. In a study by Lins et al. (2013), found that KT had no effect on lower limb function in healthy individuals. They attributed the results seen to the study population who exhibited no neuromuscular dysfunction. For this study, healthy, non-overhead athletes were recruited. The results of this study show that the KT had no effect on JPS at 35° & 110° elevation but interestingly KT had a negative effect on JPS at 90° elevation, which was found by Suprak et al. (2006) to be the optimal elevation angle for JPS. Suggesting that at elevation angle of 90°, the application of KT hindered JPS acuity. This could be due to the fact that there is some neuromuscular discrepancy occurring between the components of the proprioceptive feedback mechanism at that angle.

Summary

In summary, the results of this study do not support the claims put forth by Kinesio Taping Association International that the application of KT improves neuromuscular performance; specifically JPS. When KT is applied to apparently healthy, non-overhead athletes, the KT may hinder their performance as seen in this study. However, these results are limited to a healthy, non-overhead athletic population; so further research is needed to explore other athletic populations; such as overhead athletes or those athletes who have a current shoulder pathologies. Another, consideration for future research, would be to assess the longer term effects; as this study only looked at the initial effects of KT immediately after application. In conclusion, the application of KT on the shoulder seems to have a negative effect on JPS acuity at 90° of elevation, which could be indicative of altered performance. Further research is needed to evaluate whether these results are consistent with overhead athletes or those individuals with shoulder pathologies.

Chapter V

Summary and Conclusions

Summary

Athletes are always exploring new technologies that may improve performance. While KT has been around since the 1970's, it was only recently that KT has become popular amongst athletes of all back grounds, partly because the more recent use of KT by many world class athletes. In spite of all the clinical applications of KT, there still remains a great deal of ambiguity regarding the scientific evidence supporting the claims of advocates for the use of KT. While numerous studies have been published on the efficacy of KT, many of the results are inconclusive; however, athletes still wear the KT without knowing if the tape is helping or hindering their performance. The purpose of this study was to assess the effects of the application of KT has on shoulder JPS at increasing shoulder elevations in healthy athletes.

Participants for this study consisted of sixteen females and eleven males from Western Washington University. Subjects were recruited from the Athletic Training Room at Western Washington University. Subjects met with the researcher once for approximately one hour. Each subject's dominant shoulder was digitized in order to establish an anatomical coordinate system, followed by an assessment of JPS in nine different positions under conditions of no tape and KT application. Testing conditions were randomized, so 13 subjects' completed the no tape condition first while the other 14 participants had the KT condition first. All taping and measurements were carried out by the same ATC. The results indicated a significant difference in absolute error at the position of 35/90, in which the subjects actually performed worse with the application of KT. However, when participants were informally asked if they thought the KT helped them return to the target position with more accuracy, 15 participants stated that they thought the KT helped them. There was no significant difference in variable error between the taping conditions.

Conclusions

The results of this study suggest that the application of KT could hinder one's shoulder JPS at the position of 35/90; however, KT had no effect on JPS at the position of 35/50 and 35/110. Therefore, further expanding this study and looking at more angles between ≤ 50°-≥110° of elevation to see if the application of KT produces has an effect on repositioning error at previously tested positions which have a greater degree of repositioning error. This could potentially provide a better picture for the effectiveness or ineffectiveness of KT. It is important to note that these findings are limited to non-overhead athletes without any shoulder pathologies. Therefore, it is suggested that future studies be conducted on both overhead athletes and those athletes with shoulder pathologies in order to better assess the effects of KT on shoulder JPS. However, from the results of this study, athletes, especially overhead athletes who are performing at or above 90° elevation, might take into account that the application of KT may hamper their JPS and consequently, their performance.

Recommendations

The following recommendations are suggested for further investigation:

1. Using overhead athletes as subjects may show more pertinent results.
2. Using subjects with current shoulder pathologies might show different results.
3. Having a longer period for the application of the tape may show more of the lasting effects of the tape (12, 24, 48 or 72 hours).
4. Testing a greater variety of elevation angles may produce more accurate results.

References

1. An, K., Browne, A., Korinek, S., Tanaka, S., & Morrey, B. (1991). Three-dimensional kinematics of glenohumeral elevation. *Journal of Orthopaedic Research*, *9*(1), 143-149.
2. Andrews, Harrelson &, Wilk. (2004). Physical Rehabilitation of the Injured Athlete. Philadelphia, PA: Saunders.
3. Allegrucci, M., Whitney, S. L., Lephart, S. M., Irrgang, J. J., & Fu, F. H. (1995). Shoulder kinesthesia in healthy unilateral athletes participation in upper extremity sports. *Journal of Orthopedic & Sports Physical Therapy*, *21*(4), 220-226.
4. Aydin, T., Yildiz, Y., Yanmis, I., Yildiz, C., & Kalyon, T. A. (2001). Shoulder proprioception : a comparison between the shoulder joint in healthy and surigically repaired shoulders. *Archives of Orthopaedic and Trauma Surgery*, *121*(7), 422-425.
5. Aytar, A., Ozunlu, N., Baltacai, G., Oztop, P., & Karatas, M. (2011). Initial effects of kinesio® taping in patients with patellofemoral pain syndrome: A randomized, double-blind study. *Isokinetics and Exercise Science*, *19*, 135-142.
6. Beighton, P., Paepe, A. D., Steinmann, B., Tsipouras, P. and Wenstrup, R. J. (1998), Ehlers-Danlos syndromes: Revised nosology, Villefranche, 1997. Am. J. Med. Genet., 77: 31–37.
7. Blaiser, R. B., Carpenter, J. E., & Huston, L. J. (1994). Shoulder proprioception: Effects of joint laxity, joint position, and direction of motion. *Orthopedic Review*, *23*(1), 45-50.
8. Briem, K., Eythorsdottir, H., Magnusdottir, R. G., Palmarsson, R., Runarsdottir, T., & Sveinsson, T. (2011). Effects of kinesio tape compared with nonelastic sports tape and the untapped ankle during a sudden inversion perturbation in male athletes. *Journal of Orthopedic & Sports Physical Therapy*, *41*(5), 328-335.
9. Callaghan, M. J., Selfe, J., Bagley, P. J., & Oldham, J. A. (2002). The effects of patellar taping on knee joint proprioception. *Journal of Athletic Training*, *37*(1), 19-24.
10. Callaghan, M. J., Selfe, J., McHenry, A., & Oldham, J. A. (2008). Effects of patellar taping on knee joint proprioception in patients with patellofemoral pain syndrome. *Maunal Therapy 13*, 192-199.
11. Chapman, J., Suprak, D. N., & Karduna, A. R. (2008). Unconstrained shoulder joint position sense does not change with body orientation. *Journal of Orthopedic Research, 27*(7), 885-890.
12. Cortesi, M., Cattaneo, D., & Jonsdottir, J. (2011). Effect of kinesio taping on standing balance in subjects with multiple sclerosis: A pilot study\m{1}. *Neurorehabilitation*, *28*(4), 365-372.
13. Enoka R. M. (1988). Neuromechanical Basis of Kinesiology. Champaign, IL: Human Kinetics Publishers, Inc.
14. Garcia, D. K. (2010). Balance awareness and kinesio taping of the ankle. Unpublished manuscript. University of New Mexico.
15. Gugino, L. D., Rowinski, M. J., & Stoney, S. D. (1990). Motor outflow to cervical motoneurons from raccoon motorsensory cortex. *Brain Research Bulletin*, *24*(6), 833-837.
16. Halder, A. M., Itoi, E., & An, K-N. (2000) Anatomy and biomechanics of the shoulder. *Orthopedic Clinics of North America*, 31(2), 159-176.

17. Halseth, T., McChesney, J. W., DeBeliso, M., Vaughn, R., & Lien, J. (2004). The effects of Kinesio™ taping on proprioception at the ankle. *Journal of Sports Science and Medicine, 3*, 1-7.
18. Harryman, D., Sidles, J., Harris, S., & Matsen, F. (1992). The role of the rotator interval capsule in passive motion and stability of the shoulder. *The Journal of Bone and Joint Surgery. (American), 74*(1), 53-66.
19. Hinman, R. S., Crossley, K. M., McConnell, J., & Bennell, K. L. (2004). Does the application of tape influence quadriceps sensorimotor function in knee osteroarthritis? *Rheumatology, 43*, 331-336.
20. Houglum, P. A. (2005). Therapeutic exercise for musculoskeletal injuries. Champaign, IL: Human Kinetics
21. Hsu, Y., Chen, W., Lin, H., Wang, W. J., & Shih, Y. (2009). The effects of taping on scapular kinematics and muscle performance in baseball players with shoulder impingement syndrome. *Journal of Electromyography & Kinesiology, 19*(6), 1092-1099.
22. Husk, L. J. (2010). Balance awareness and kinesio taping of the ankle. Unpublished manuscript. University of New Mexico.
23. Janwantanakul, P., Magarey, M. E., Jones, M. A., & Dansie, B. R. (2001). Variation in shoulder position sense at mid and extreme range of motion. *Archives of Physical Medicine and Rehabilitation, 82*, 840-844.
24. Jerosch, J. & Prymka, M. (1996). Knee joint proprioception in normal volunteers and patients with anterior cruciate ligament tears, taking special account of the effect of a knee bandage. *Archives of Orthopedic and Trauma Surgery, 115*, 162-166.
25. Kelly, B. T., Weiland, D. E., Schenker, M. L., & Philippon, M. J. (2005). Arthroscopic labral repair in the hip: Surgical technique and review of the literature. *Arthroscopy: The Journal of Arthroscopic & Related Surgery, 21*(12), 1496-1504.
26. Kinesio Holding Company (2010). *Kinesio taping association international*. Retrieved from http://www.kinesiotaping.com/global/corporation/about.html.
27. Kinesio USA, LCC (2010). *Kinesio taping applications*. Retrieved from http://www.kinesiotaping.com/global/corporation/about/kinesio-taping-applications.html.
28. Kinesio USA, LCC (2010). *About Kinesio*. Retrieved from http://www.kinesiotaping.com/global/corporation/about.html.
29. Kirkpatrick, L., Allouh, M., Nightingale, C., Devon, H., Yablonka-Reuveni, Z., & Rosser, B. (2008). Pax7 shows higher satellite cell frequencies and concentrations within intrafusal fibers of muscle spindles. *The Journal of Histochemistry and Cytochemistry: Official Journal of The Histochemistry Society, 56*(9), 831-840.
30. Lephart, S. M., Pincivero, D. M., Giraldo, J. L., & Fu, F.H. (1997). The role of proprioception in the management and rehabilitation of athletic injuries. *The American Journal of Sports Medicine, 25*(1), 130-137.

31. Lin, J-J., Hung, C-J., & Yang, P-L. (2011). The effects of scapular taping on electromyographic muscle activity and proprioception feedback in healthy shoulders. *Journal of Orthopedic Research*, *29*(1), 53-57.
32. Murray H, Husk LJ. Effect of kinesio taping on proprioception in the ankle. J Orthop Sports Phys Ther. 2001;31:A37
33. Myers, J. B. & Lephart, S. M. (2000). The role of the sensorimotor system in the athletic shouder. *Journal of Athletic Training, 35*(3), 351-363.
34. Myers, J. B., Guskiewicz, K. M., Schneider, R. A., & Prentice W. E. (1999). Proprioception and neuromuscular control of the shoulder after muscle fatigue. *Journal of Athletic Training, 34*(4), 362-367.
35. Ozer, D., Senbursa, G., & Hayran, M. (2009). The effect on neuromuscular stability, performance, multi-joint coordination and proprioception of barefoot, taping or preventative bracing. *The Foot, 19*, 205-210.
36. Perlau, R., Frank, C., & Fick, G. (1995). The effect of elastic bandages on human knee proprioception in the uninjured population. *The American Journal of Sports Medicine,* 23(2), 251-255.
37. Prentice, W. E. (2009). Arnheim's Principles of Athletic Training: A Competency-Based Approach. McGraw-Hill Higher Education: New York.
38. Prentice, W. E. (2008). Essientials of Athletic Injury Management. McGraw-Hill Higher Education: New York.
39. Rienmann, B. L. & Lephart, S. M. (2002). The sensorimotor system, part I: The physiologic basis of functional joint stability. *Journal of Athletic Training, 37*(1), 71-79.
40. Rienmann, B. L. & Lephart, S. M. (2002). The sensorimotor system, part II: The role of proprioception in motor control and functional joint stability. *Journal of Athletic Training, 37*(1), 80-84.
41. Riemann, B. L., Myers, J. B., & Lephart, S. M. (2002). Sensorimotor system measurement techniques. *Journal of Athletic Training*, *37*(1), 85-98.
42. Robbins, S., Waked, E., & Rappel, R. (1995). Ankle taping improves proprioception before and after exercise in young men. *British Journal of Sports Medicine, 29*(4), 242-247.
43. Saha, A. K. (1971). Dynamic stability of the glenohumeral joint. *Acta Orthopaedica Scandinavica, 42*(6), 491-505.
44. Sheeington, C. S. (1906). On the proprioceptive system, especially in its reflex aspect. *Brain, 29*, 467-482.
45. Simoneau, G. G., Degner, R. M., Kramper, C. A., & Kittleson, K. H. (1997). Changes in ankle joint proprioception resulting from strips of athletic tape applied over the skin. *Journal of Athletic Training, 32*(2), 141-147.
46. Suprak, D. (2011). Shoulder joint position sense is not enhanced at end range in an unconstrained task. *Human Movement Science, 30*, 424-435.
47. Suprak, D. N., Osternig, L. R., Donkelaar, P., & Karduna, A. R. (2006). Shoulder joint position sense improves with elevation angle in a novel, unconstrained task. *Journal of Orthopedic Research*, *24*(3), 559-568.

48. Suprak, D. N., Osternig, L. R., Donkelaar, P., & Karduna, A. R. (2007). Shoulder joint position sense improves with external load. *Journal of Motor Behavior, 39*(6), 517-525.
49. Starkey, C., Brown, S. D., & Ryan, J. L. (2010).Examination of Orthopedic and Athletic Injuries. F. A. Davis Company: Philadelphia.
50. Terry, G. C. & Chopp, T. M. (2000). Functional anatomy of the shoulder. *Journal of Athletic Training, 35*(3), 248-255.
51. *The Kinesio Tex Taping Method*. Retrieved from http://www.kinesiotaping.co.uk/history.jsp.
52. Vincent, W. J. (2005). Statistics in Kinesiology. Champaign, IL: Human Kinetics:Champaign.
53. Voight, M. L., Hardin, J. A., Blackburn, T. A., Tippett, S., & Canner, G. C. (1996). The effects of muscle fatigue on and the relationship of arm dominance to shoulder proprioception. *Journal of Orthopedic & Sports Physical Therapy, 23*(6), 348-352.
54. Wilkerson, G. B. (2002). Biomechanical and neuromuscular effects of ankle taping and bracing. *Journal of Athletic Training, 37*(4), 436-445.
55. Wu, G. E., van der Helm, F. C. T., Veeger, H. E. J., Makhsous, M., van Roy, P., Anglin, C., . . . Buchholz, B. (2005). ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion-Part II: Shoulder, elbow, wrist, and hand. *Journal of Biomechanics, 38,* 981-992.

Appendix A

Informed Consent

Informed Consent

Western Washington University
Consent to Take Part in a Research Study
Project: The Effect of Kinesio Tape on Shoulder Joint Position Sense

You are invited to participate in a research study conducted by Lindsay Aarseth, Graduate Student, from the department of Physical Education, Health, and Recreation at the Western Washington University. The purpose of this investigation is to study the ability to actively reposition the shoulder in a previously presented active target position with and without the application of kinesio tape. You were selected as a possible participant in this study because you have no history of shoulder pathology.

If you decide to participate, you understand that the following things will be done to you. You will be asked to fill out a brief form to provide basic information such as age, height and weight and which arm is your dominant arm. Non-invasive measurements will be made throughout the experiment. To perform these measurements, small sensors will be attached by straps or tape to your arm, breastbone and shoulder. You will be asked to actively position your shoulder in a specified target position, with the aid of a moving cursor on a head-mounted display screen, corresponding to the location of your arm in space. You will then be asked to attempt to replicate the presented angle without the benefit of visual feedback. Several different target positions will be attempted. You will also be asked to perform simple arm elevation. All of this will be done with and without the application of kinesio tape. The entire testing process should take about 90 minutes.

There is no direct benefit to you by participating in this study. However, you understand that information gained in this study may help in the understanding of the function of the shoulder.

Participation in any research study carries with it possible risks. Because multiple trials will be performed, there is a risk of muscle fatigue. However, precautions have been taken to minimize this risk. However, you may discontinue participation at any time during testing.

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. Subject identities will be kept confidential by coding the data with subject numbers, rather than names. You will be given the opportunity to give written consent to be contacted in the future for the purpose of follow-up regarding this project.

Your participation is voluntary. Your decision whether or not to participate will not affect your relationship with the Western Washington University. If you decide to participate, you are free to withdraw your consent and discontinue participation at any time without penalty.

If you have any questions regarding the project procedures, please feel free to contact Dave Suprak, (360) 650-2586, Department of Physical Education, Health and Recreation, Western Washington University, Bellingham, WA, 98225. If you have questions regarding your rights as a research subject, or if you should suffer any research-related adverse effects, contact Janai Symons in the

Office of Research and Sponsored Programs, Western Washington University, Bellingham, WA, 98225, (360) 650-3082. You have been offered a copy of this form to keep.

Your signature indicates that you have read and understand the information provided above, that you willingly agree to participate, that you may withdraw your consent at any time and discontinue participation without penalty, that you have received a copy of this form, and that you are not waiving any legal claims, rights or remedies. The signature below indicates that the participant is 18 years of age or older.

Print Name____

Signature____

Date________________________

Audiotaping, Videotaping, and Photography

By initialing on the lines below, I am indicating that I give permission to the research team permission to (please initial any that apply):

_____Photograph, audiotape and/or videotape my participation in this study.

_____Use photographs, audiotape or videotape recordings of me when they present this research in educational and professional venues, even if I am personally identifiable.

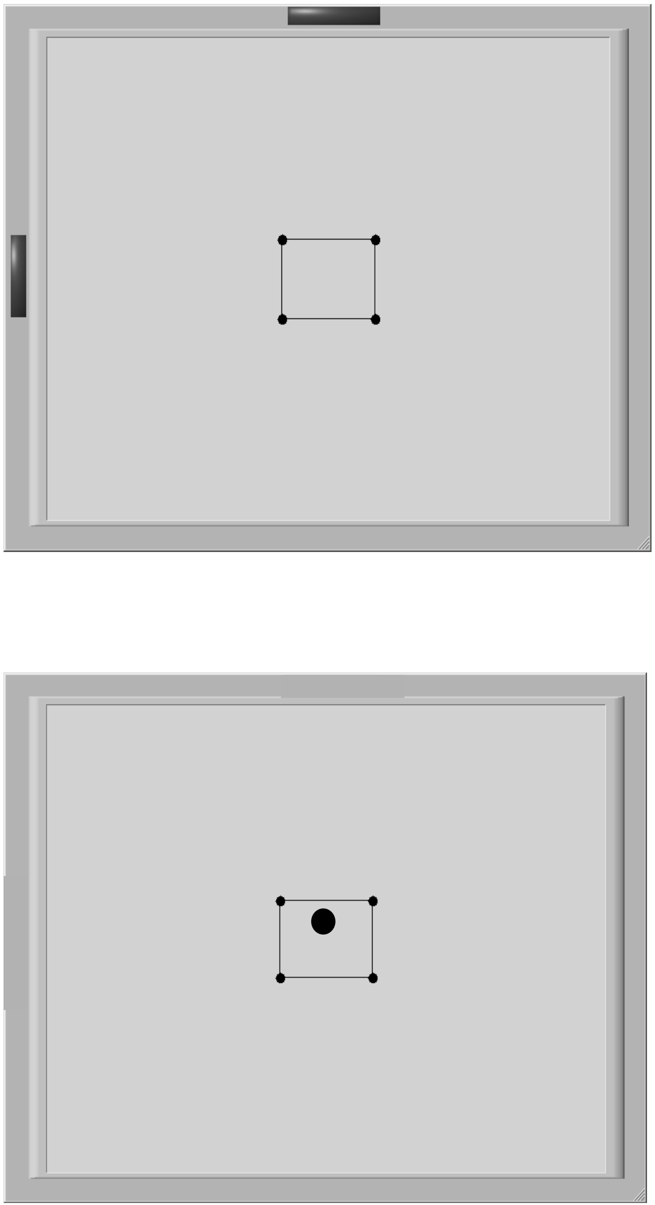
_____Use photographs, audiotape or videotape recordings of me when they present this research in educational and professional venues, only as long as I am not personally identifiable.

*Note: permission to record the sessions in not required for participation in this study, but will improve my ability to present the findings at educational and professional venues.

Appendix B

Kinesio Taping Photos

A.



B.

Figure 3. Computer output seen through the head-mounted display a) guiding the subject to the target position and b) with the shoulder in the target position.

Figure 4. Experimental set-up showing, sensors, head-mounted display and kinesio tape.

Appendix C

Raw Data

Raw Data

Subject Characteristics

Subject	Sex	Age	Height (cm)	Weight (kg)	Arm Dominance	Previous Shoulder Injury?	Thought KT Helped?
3	M	21	170.18	72.72	R	None	N
4	M	18	177.8	69.09	R	None	N
5	F	21	162.56	63.63	L	None	Y
6	F	22	170.18	65.90	R	None	Y
7	M	21	182.88	77.27	R	None	Y
8	F	21	162.56	61.36	R	None	N
9	F	22	163.83	60.90	R	None	Y
10	M	21	182.88	79.54	R	None	Y
11	M	19	170.18	75	R	None	N
12	F	19	175.26	77.27	R	Broke R) Collarbone	N
13	F	22	182.88	68.18	R	None	Y
14	M	19	185.42	79.54	R	None	Y
15	F	22	187.96	81.81	R	None	Y
16	M	21	205.74	90.90	R	None	N
17	F	21	165.1	61.36	R	None	Y
19	F	20	193.04	88.63	R	None	Y
20	F	20	167.64	56.81	R	None	N
21	M	21	160.02	78.63	R	None	Y
22	F	20	167.64	67.27	R	None	N
23	M	21	175.26	70.45	R	None	N
24	F	19	176.53	65.90	R	None	Y
25	M	20	198.12	86.36	R	None	Y
26	F	20	163.83	59.09	R	None	Y
27	F	20	175.26	61.36	R	None	Y
28	M	20	172.72	68.18	R	None	N
29	F	21	165.1	63.63	R	None	N
30	F	20	165.1	59.09	R	None	N

Shoulder Tape List

Subject	No Tape First	Kinesio Tape First
3		X
4	X	
5		X
6		X
7	X	
8	X	
9		X
10		X
11		X
12		X
13		X
14		X
15	X	
16	X	
17	X	
19	X	
20		X
21	X	
22		X
23	X	
24		X
25	X	
26		X
27		X
28	X	
29	X	
30	X	

Raw Data

Absolute Error

Subject	No Tape			Kinesio Tape		
	35/50	35/90	35/110	35/50	35/90	35/110
3	2.83	3.97	5.95	5.33	2.84	3.4
4	1.5	6.58	5.75	4.96	7.06	7.44
5	7.93	4.73	10.64	4.21	5.71	8.41
6	7.22	7.02	10.59	5.33	6.8	8.36
7	8.87	7.25	10.8	6.36	6.13	3.25
8	8.19	5.97	7.0	7.76	7.09	9.51
9	3.91	7.71	8.68	6.66	10.07	12.71
10	2.66	4.94	7.75	4.43	11.78	6.3
11	7.38	3.94	6.39	7.99	9.12	5.74
12	3.54	0.86	5.04	6.31	2.09	6.91
13	13.89	8.33	6.02	9.32	11.08	10.25
14	6.79	2.65	7.23	4.43	6.69	11.08
15	10.8	17.54	11.37	13.0	11.44	11.99
16	3.69	6.13	6.19	4.01	8.03	8.51
17	12.81	5.95	7.86	10.24	5.44	3.95
19	4.77	5.61	6.73	6.2	6.28	8.68
20	7.25	4.48	9.8	5.16	6.91	7.7
21	5.21	6.45	10.79	5.37	8.26	5.65
22	8.62	7.17	5.14	8.87	7.58	3.33
23	3.14	6.6	5.56	4.16	6.12	5.8
24	14.92	6.8	14.78	3.8	5.03	6.94
25	2.78	5.18	2.27	4.4	3.41	3.86
26	7.48	9.08	11.92	9.19	10.3	11.25
27	4.24	6.49	6.35	7.21	10.37	8.16
28	6.54	3.21	4.14	5.74	6.39	5.68
29	5.22	4.56	5.69	5.92	8.84	7.56
30	8.8	12.65	10.49	9.1	19.83	9.38

Raw Data

Variable Error

Subject	No Tape			Kinesio Tape		
	35/50	35/90	35/110	35/50	35/90	35/110
3	1.279	0.638	2.624	1.35	0.52	1.98
4	1.016	3.064	2.887	2.84	4.20	1.15
5	4.516	1.484	2.77	1.95	1.42	2.21
6	2.008	1.42	2.316	1.78	0.63	2.50
7	3.82	4.621	4.68	1.79	1.02	1.05
8	2.747	1.116	2.042	1.02	4.41	1.87
9	1.502	1.023	2.996	0.98	1.68	3.48
10	0.587	2.662	1.783	1.12	2.80	2.62
11	2.628	2.32	1.443	2.54	2.60	1.77
12	2.946	0.354	2.772	2.88	1.50	6.82
13	3.299	2.887	1.932	4.84	0.72	5.04
14	1.74	0.981	3.466	2.87	4.39	4.97
15	1.7	2.358	2.704	6.85	7.99	3.20
16	0.272	3.368	1.647	2.96	3.77	1.13
17	4.581	1.367	4.105	3.85	1.49	0.92
19	0.813	0.516	3.678	2.35	2.05	2.19
20	1.276	1.286	3.441	1.92	1.13	2.61
21	2.252	1.093	4.289	2.32	0.63	3.42
22	3.37	1.854	1.714	1.82	1.57	1.90
23	0.594	1.718	1.673	0.89	1.29	3.03
24	5.879	0.857	2.158	1.34	1.55	0.42
25	1.938	2.069	1.106	0.53	1.77	2.19
26	3.144	4.426	6.566	2.69	5.15	3.80
27	3.493	4.596	3.155	2.78	1.09	2.99
28	2.531	0.175	4.222	1.91	2.13	0.99
29	2.495	2.697	0.904	0.12	1.79	1.39
30	1.547	3.7	2.208	1.68	2.00	2.68