AN ANALYSIS OF KINESIO® TAPE ON MYOFASCIAL PAIN SYNDROME OF THE ILIOTIBIAL BAND

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ABSTRACT

This study analyzed the effects of Kinesio® Tape on pain pressure threshold (PPT) of trigger points (TrPs) within the iliotibial band (ITB). Fifty participants were evaluated for TrPs in the ITB. An algometer was used to measure pre-intervention PPT followed by a Visual Analogue Scale (VAS) score for pain. A sham or fascial taping technique was applied. After 10 minutes, a post-intervention PPT was obtained. After 48 hours, participants returned where post-intervention PPT and VAS was obtained with the tape on and PPT again 10 minutes following tape removal. Participants reported a decrease in pain. There was a slight increase in PPT from pre-tape to 10-minutes post tape. An ANOVA model incorporating all four measurements was statistically significant. There is sufficient evidence to suggest the fascial taping technique is effective at manipulating PPT of TrPs. Overall, more pressure was needed to elicit pain and the TrPs became less symptomatic.

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LIST OF ABBREVIATIONS

ACh .....Acetylcholine

ANOVA .....An Analysis of Variance

BT .....Botulinum Toxin

CKTP .....Certified Kinesio® Tape Practitioner

EMG.....Electromyography

ICC.....Intraclass Correlation Coefficients

IR.....Internal Rotation

ITB .....Iliotibial Band

ITBS.....Iliotibial Band Syndrome

LTR.....Local Twitch Response

MMG.....Mechanomyography

MPR .....Manual Pressure Release

MPS.....Myofascial Pain Syndrome

NPAD.....Neck Pain and Disability

NSAIDs.....Non-steroidal Anti-inflammatory Drugs

PPT.....Pain Pressure Threshold

ROM .....Range of Motion

TFL .....Tensor Fasciae Latae

TrP(s) .....Trigger Point(s)

UT .....Upper Trapezius

VAS.....Visual Analogue Scale

1. INTRODUCTION

1.1. Overview of the Problem

Myofascial pain syndrome (MPS) is a common soft tissue pathology, which presents in patients as a dull, persistent pain, affecting both competitive and recreational athletes. Associated myofascial trigger points, the hyperirritable nodules palpable within the taut band, often causes referred pain.[1–3] Muscle inefficiency as well as muscle overload can result in the formation of trigger points, often presenting as sustained muscle contraction, or more significantly, unorganized fascia.[4] Patients suffering from MPS can also develop a compensated movement pattern, gait, or posture in attempt to alleviate symptoms.[5] Specifically, the presence of MPS in the iliotibial band (ITB) can cause referred pain in the acetabulofemoral joint area, inferiorly in the anterolateral thigh, and most commonly, the lateral knee.[6] Trigger points (TrPs) within the ITB are common amongst the athletic population due to the biomechanical requirements of sport, which predisposes the athlete to 'friction' syndromes and other soft tissue restrictions.[7–13] Clinicians should be aware of the treatment options for MPS and their associated indications to treat the symptoms, but also the cause of the symptoms.

Kinesiology tape has grown in popularity since the premiere of the product in the 1980 and is now produced under several brand names by competing companies. Kinesio® Tape Association International (KTAI) was founded by Dr. Kenzo Kase and is one of the most prominent developed brands of kinesiology tape to date, including an educational system with application standards and protocols. However, the current research lacks a consistent methodology or a consensus in application techniques for specific pathologies.[14–19] The published studies utilizing kinesiology tape as treatment for MPS employ taping techniques targeting overactive or underactive muscles, omitting the fascial anatomy completely.

Additionally, there inconsistency is brand reporting and the qualifications and training of the clinicians who apply the tape. KTAI provides a set of recommendations along with a certification program to become a Certified Kinesio® Tape Practitioner (CKTP). Claims and recommendations made by KTAI need to be investigated properly with consistent methodology in order for clinicians to make informed, evidence-based treatment decisions.

Algometry is a reliable, noninvasive tool, and a valid way to measure pain pressure threshold (PPT). Although there is not standard of PPT that indicates presence of a TrP, the measurement of onset of pain is a valid method to track patient progress or outcome measures related to MPS.[20–28] Using an algometer to obtain PPT for myofascial trigger points within the iliotibial band can provide a quantitative measurement of the efficacy of Kinesio® Tape on MPS.

1.2. Statement of Purpose

The purpose of this study was to analyze the effects of Kinesio® Tape applied with the fascial taping technique on pain pressure threshold of trigger points (TrPs) within the iliotibial band (ITB) of those who are recreationally active[29,30] and recreational runners.[31–33]

1.3. Research Questions

1. What within subject differences exist in pain pressure threshold (N/s^2) measured via algometer at four points in time?
2. What within subject differences exist in pain scores measured via Visual Analogue Scale (VAS) at two points in time?

1.4. Dependent Variables

The dependent variable is the pain pressure threshold values measured via algometry as well as pain levels measured by a 11-point Visual Analogue Scale. In addition, a

Musculoskeletal History Questionnaire was used to report possible kinetic chain implications of the iliotibial band (ITB).

1.5. Independent Variable

The independent variable in this study is the application of Kinesio® Tex Gold FP.

1.6. Limitations

Due to multiple variables, this study was not completed without limitations. Participants included were between 18 and 55 years old and recreationally active[29,30] or a recreational runner.[31–33]Additionally, participants range substantially in terms of pain pressure thresholds (PPTs) and subjective pain. Although we are not comparing differences between participants, this degree of variance makes it difficult to generalize results to every individual pain threshold. Lastly, Kinesio® Tex Gold FP is manufactured with the purpose of treating the etiology of the pathology. The presence of Myofascial Pain Syndrome (MPS) and subsequent fascial TrPs in the ITB may be caused by another kinetic chain issue, which was not targeted in this study. Despite these limitations present in this study, future research may work to reduce limitations in the methodology by recruiting from larger population pools or using an objective outcome measure along with the subjective one.

1.7. Delimitations

This study was limited to the North Dakota State University and the Fargo-Moorhead metroplex in North Dakota and Minnesota, United States, due to geographical convenience and the demographics sought. Participants were included if they were recreationally active[29,30] or a self-reported recreational runner.[31–33] Recreationally active was defined by the American College of Sports Medicine as participating at least twice a week in aerobic activity for a total of 80 minutes at moderate intensity (~5-6 METS).[29,30] Runners will have to self-report at least 10 miles

a week for the last three months.[31–33] Finally, this study was completed over the course of 48 hours, providing data only the short-term effects of Kinesio® Tape on MPS.

1.8. Assumptions

First, it was assumed participants would continue normal training schedules and activities of daily living or did not tamper with the tape during the 48 hours between session. It is also assumed the participant was consistent and truthful in reporting patient-perceived outcomes. Finally, it was assumed the participants answered the musculoskeletal history questionnaire honestly.

1.9. Significance of Study

There is a lack of consistent evidence and proper use of Kinesio® Tape, especially as a treatment for MPS. Although there is consistent current research on myofascial pain and trigger points, researchers fail to employ the fascial taping technique, instead using non-KTAI standard techniques or the incorrect one. Further, the kinetic chain implications of fascial restrictions in the ITB seems to be overlooked, yet a significant source of pain for athletes. This study focused the KTAI approved application of Kinesio® Tex Gold FP as a treatment for MPS in the ITB in hopes to increase pain pressure threshold. The results will guide clinicians to make evidence-based treatment decisions for fascial restrictions.

1.10. Definitions

Iliotibial Band (ITB): a thickened piece of fascial tissue on the lateral part of the thigh. The band is a dense, fibrous connective tissue, which is not classified as a muscle, but instead an extension of three hip muscle tendons.[8,11]

Iliotibial Band Syndrome (ITBS): repetitive friction of the taut iliotibial band (ITB) against the lateral femoral epicondyle during flexion and extension of the knee.[7–13]

Myofascial Trigger Points (TrPs): noninflammatory, hyperirritable nodules within the fibers of the muscle and the surrounding fascia.[1]

Myofascial pain syndrome: a disorder associated with multiple trigger points and fascial abnormalities, often presenting as a persistent dull pain. Although the etiology of MPS is insidious, changes in loads on the muscle or increased demands can instigate a sustained muscle contraction.[4]

Kinesio® Tape: A therapeutic tape designed to enhance function of tissues and physiologic systems. May be applied for several purposes including muscle facilitation, muscle inhibition, mechanical support, increased proprioception, decreased pain sensation, and increased lymphatic drainage.[34]

Pain pressure threshold: is the minimum force (Newtons) needed to elicit a pain response distinguishable from pressure or discomfort.[23,24,28]

Algometer: tool used to measure pain pressure threshold, consisting of a standardized spring with a flattened rubber end and an associated pressure gauge.[20,22–28]

2. LITERATURE REVIEW

2.1. Anatomy

The base knowledge of musculoskeletal anatomy in relation to the hip, knee, and thigh is essential to understanding iliotibial band (ITB) syndrome. Crossing two joints, the ITB is considerable in length, thus the consequences of the structure become complex in nature.[6] Therefore, familiarity with the anatomical structures surrounding the ITB enables clinicians to correctly diagnose and treat the various pathologies that are associated with the ITB, such as myofascial pain syndrome.

2.1.1. Bony Anatomy

The acetabulofemoral joint, more commonly known as the 'ball-and-socket' or 'hip joint,' consists of the articulation of the head of the femur in the accepting space of the pelvis.[35,36] The acetabulum, or the socket, is the intersection of three bones of the pelvis: the lateral aspect of the pubis, the superior ischium, and the inferior ilium.[36] The pubis, ischium, and ilium articulate and fuse together completely between the ages of 12 and 16.[36] The fused socket is the resting point for the proximal head of the femur.[35,36] The femur is the longest bone in the body and is the singular bone comprising the thigh.[35,36]

The ball-and-socket joint plays several roles in hip mobility, stability, and overall movement of the lower extremity. Raised points on the bony surfaces of the acetabulum, the femoral head, and femoral shaft are points of origin and insertion for hip muscles that are essential for pelvic and hip stabilization.[35,36] For example, the greater trochanter, a long protuberance on the proximal femur, serves as an insertion point for several gluteal muscles.[6,35,36] Both the acetabulum and the femoral head have a layer of hyaline cartilage, which cushions the joint and allows for easy movement of the hip. Within the ball and socket joint is the labrum, a

fibrocartilaginous tissue padding the socket affectively deepening the socket and providing hip stability.

Distally, the femur articulates with two bones, collectively forming the two joints of the knee: the tibiofemoral joint and the patellofemoral joint.[35,37] Two large convex protuberances, termed condyles, on the distal end of the femur meet with the slightly concave plateau of the proximal tibia, constructing the tibiofemoral joint. This large hinge joint is lubricated and cushioned with two cartilaginous menisci on the tibial plateau, one medial and one lateral. Superficial to the sizeable tibia and femur sits the patella, the largest sesamoid bone.[35,37] The articulation between the patella and the femur form the patellofemoral joint. The patella is concave superficially and convex on the deep posterior surface, which allows the small bone to rest within the groove between the medial and lateral femoral condyles. The groove provides some bony stability as well as allows a smooth extension mechanism of the knee.[35,37] Together, these three bony articulations allow for the most basic, yet essential, movements of the knee under the guide and stabilization of various soft tissue structures.

2.1.2. Soft Tissue Anatomy

2.1.2.1. The Iliotibial Band

The iliotibial band (ITB) is a thickened piece of fascial tissue on the lateral part of the thigh.[8,11] The band is a dense, fibrous connective tissue, which is not classified as a muscle, but instead an extension of three hip muscle tendons. The ITB originates from the partial tendons of the gluteus maximus and gluteus medius, and most prominently, the entirety of the tensor fasciae latae (TFL) tendon. The ITB is a thickened component of the fascia lata and an extension of the tensor fasciae latae muscle tendon.[7,8,11] The fascia lata, which is separate from the notable TFL muscle, is a deep fibrous sheet tightly binding the muscles of the thigh and tethering the ITB to

the femur, both proximally and distally.[7,8] Proximal to the origin at the hip, the ITB is split into deep and superficial layers, enveloping the TFL muscle between the layers and helping affix the muscle to its origin at the iliac crest.[8,38] Distally, the fascia lata attaches the ITB in two places: the lateral femoral epicondyle and Gerdy's tubercle, a small protuberance on the anterolateral aspect of the tibia, distal to the patellofemoral joint.[8,11] The space between the lateral ITB and the femur is filled with adipose tissue, or fat tissue, and occasionally a bursa sac.[11] Each of these structures either constitute the ITB or effect it, therefore they risk compromise when an ITB pathology exists.

2.1.2.2. Muscles of the Hip and Thigh

The tensor fasciae latae (TFL) is a fusiform muscle that averages a length of 15 centimeters and assists multiple muscles with movement of the hip.[6,35] The muscle's origins include: the anterior aspect of the outer ridge of the iliac crest, the lateral part of the anterior superior iliac spine, and the deep surface of the fascia lata.[6,38] The superior belly of the muscle sits between the gluteus medius and sartorius muscles, then extends distally to bind with fascia superficial to the gluteus medius before descending further to integrate with the superficial and deep layers of the ITB. Referred to as a hip abductor, the TFL works in combination with gluteus medius and minimus muscles and performs approximately 11% of the total hip abduction range of motion.[6] Additionally, the TFL helps with other actions of flexion and internal rotation of the hip. If the hip remains in internal rotation, the posterolateral fibers of the TFL assist in terminal extension the knee. The posterolateral fibers also help stabilize the knee during the heel-strike and stance phase of gait, especially for running athletes. Overall, the TFL is active in tasks that require the three gluteus muscles, such as stepping down, lunging, and mid-stance and mid-

swing phases of gait.[6] Although the TFL does not perform substantial range of motion at the hip, it is essential in aiding major hip muscles perform daily movements.

The gluteal muscles play a much more prominent role in the biomechanics of the hip than the TFL and the ITB.[6] Specifically, the gluteus minimus and medius muscles work the closest with the TFL to stabilize the pelvis during single-leg stance portions of gait. From deepest to most superficial and smallest to largest, the gluteus minimus, medius, and maximus muscles perform actions at the hip ranging from minute to significant. For example, the gluteus minimus muscle is essential for normal biomechanics to occur within the gait cycle and abducts and internally rotates the hip, but only when the hip is flexed from zero to twenty degrees.[6,35] Additionally, the gluteus minimus is responsible for slight movements such as retracting the hip joint capsule during abduction, which provides dynamic stabilization. The gluteus minimus originates between the anterior and inferior gluteal lines on the outer ilium. The deepest and smallest of the three, the gluteus minimus has an identical fan shape to the overlying gluteus medius.[6,35] The orientation of the muscle fibers changes from anterior to posterior, gradually becoming more horizontal, which alters the angle of pull depending on the position of the hip. The insertion point of the gluteus minimus tendon is at the anterolateral surface of the greater trochanter, which combines with the piriformis tendon insertion and forms a large portion of the hip joint capsule. These tendon articulations with the joint capsule becomes a mechanical advantage by reducing unwanted movement of the femoral head during gait.[6,35] Though small and concealed, the gluteus minimus should not be overlooked as a contributor to larger movements and the stabilization at the hip and pelvis.

The gluteus medius, similar in shape and orientation to the underlying minimus, originates from the outside of the ilium along a large fraction of the iliac crest, between the

anterior and posterior gluteal lines.[6,35] This multipennate muscle has multiple fiber orientations, which converge and insert at the lateral surface of the greater trochanter of the femur. The tendon insertion of the gluteus medius contributes to the conjunction of the gluteus minimus and piriformis muscles at the joint capsule. The gluteus minimus and medius work together as hip abductors and internal rotators.[6,35] Once the hip is flexed to greater than 20◦, however, the gluteus medius becomes solely responsible for internal rotation and is inadequate in performing abduction. The gluteus medius is described in three divisions of fibers, anterior, middle, and posterior, all of which are responsible for different actions. The anterior fibers prevent excessive anterior translation of the femoral head during non-weight bearing hip extension, in addition to internally rotating the hip.[6,35] The middle fibers solely perform abduction and internal rotation and are essential in stabilization of the pelvis during gait. Finally, the almost horizontal orientation of the posterior fibers allows for a small external rotation angle of pull when the hip is in minimal extension. Similar to the gluteus minimus and the TFL, the orientation and shape of the gluteus medius makes it a multifaceted, versatile muscle, essential for efficient ambulation.[6]

The synergistic unit of these three muscles, the TFL, gluteus medius, and gluteus minimus, allows the hip to function efficiently, but also leaves them vulnerable to one another.[6] Pathologies which affect one muscle significantly increases the likelihood of the same pathology affecting one of the other two muscles. Overall the three muscles are emphasized as a unit because of their functional interdependence.[6]

The quadriceps muscles of the anterior thigh have influence at the knee and the hip, much like the TFL and connected ITB. The four quadriceps consist of the rectus femoris, vastus intermedius, vastus medialis, and vastus lateralis muscles.[6,35] All four muscle cross the knee and perform extension; the rectus femoris, however, also crosses the hip and is a main hip flexor. At

the knee, all four muscles converge into the broad quadriceps tendon, which extends distally to the patella and finally forms the patellar tendon, inserting at the tibial tuberosity, a small bony protuberance of the proximal tibia. In addition to performing extension, one of the most basic and essential movements of the lower extremity, the tendons of the quadriceps provide needed stabilization of the knee.[6,35]

The largest and most lateral muscle of the quadriceps is the vastus lateralis.[6] The muscle's main origins are the intertrochanteric line of the femur, anterior and inferior borders of the greater trochanter, as well as the lateral lips of the gluteal tuberosity and linea aspera. Interestingly, the vastus lateralis also includes fibers originating from the gluteus maximus and biceps femoris. The insertion begins at the lateral patella before becoming a component of the quadriceps tendon. Of the quadriceps muscles, the vastus lateralis has the principle relationship with the ITB because it contributes to the lateral capsule of the knee, which attaches to the lateral tibial condyle as well as the ITB.[6] Although the vastus lateralis does not cross the hip joint proximally, the borrowed fibers from two muscles which do act at the hip, suggests there could be relationship between the hip and the lateral quadricep muscle.[6,39] The complete anatomical affect the vastus lateralis has on the hip and knee is undetermined.[6,39]

Although gross anatomy of the soft tissue is the primary effector, bony anatomy is important as well for ruling out pathologies or underlying predisposing causes. For clinicians to properly treat pathologies of the iliotibial band or any associated structures of the hip, thigh, knee, an understanding of the possible kinetic chain consequences is necessary.

2.2. Iliotibial Band Syndrome

Traditionally depicted as a chronic friction syndrome, Iliotibial Band Syndrome (ITBS) is prevalent in activities involving repetitive knee flexion and extension, such as running and

cycling.[7–13] The pathology is defined as repetitive friction of the taut iliotibial band (ITB) against the lateral femoral epicondyle during flexion and extension of the knee.[7–13] Depending on the population, incidence of ITBS has been reported up to 52%[10] and is the most common cause of lateral knee pain, accounting for up to 12% of overuse injuries in runners.[9–12] Moreover, the syndrome is associated with various field sports and can be linked to up to 22% of lower extremity injuries.[12,13]

2.2.1. Etiology

There are various reported causes of ITBS, most commonly cited are biomechanical or anatomical disadvantages combined with overuse subsequent to excessive training.[13] Activities involving repetitive knee flexion, exacerbated by overtraining, cause the distal posterior fibers of the ITB to shear against the femoral epicondyle, rolling over the protuberance, producing inflammation and irritation.[9–13] Additionally, the impingement zone is an area consisting of anatomical structures at a biomechanical disadvantage secondary to repetitive knee flexion.[7–9,11] The impingement zone is located deep and posterior to the distal ITB. Here, adipose tissue and posterior ITB fibers are affectively pinched during 20-30 degrees of knee flexion, spurring further irritation.[9,11] The impingement zone is most afflicted at approximately 30 degrees of flexion, occurring during the weight bearing portion of the running gait cycle.[9,11] Another biomechanical factor associated with aggravating ITBS is downhill running or training, which increase the degree of knee flexion at heel strike, worsening the friction of ITB fibers against the femur.[9] Consequently, ITBS is associated with repetitive knee flexion, which produces inflammation and harmful shearing forces at the knee.

However, a group of researchers have challenged the traditional etiology, suggesting ITBS is not triggered by friction, but by compression.[7,8] The theory is supported through an in-

depth evaluation of the anatomy involved in the most basic lower extremity movements, knee flexion and extension.[7,8] The authors suggest that because the ITB is not a stand-alone structure, but a thickened component of the fascia lata, friction is not necessarily occurring. Because the fascia lata is attached to the lateral epicondyle and supracondylar region of the femur, rolling of the band over the bony ridge cannot occur. Calling the action a perceived 'illusion,' researchers instead explain the sensation is caused by fluctuating tautness of the anterior and posterior fibers of the distal ITB.[7,8] The authors state significant anterior to posterior movement of the band is not plausible due to the fibrous fixtures, but conclude minute medial to lateral movement of the band within in the tract is possible. This small movement increases pressure on the impingement zone, which subsequently produces symptoms associated with ITBS. Nevertheless, this theory acknowledges chronic flexion and extension of the knee exacerbates the syndrome but by causing compression instead of friction.[7,8] Regardless of the controversial movements occurring or not occurring, the etiology of ITBS is inarguably repetitive knee flexion, which becomes detrimental to structures of the lateral knee.

2.2.2. Diagnosis and Treatment

ITBS is characterized by a sharp or burning lateral knee pain, which is reproduced upon palpation of the lateral femoral epicondyle, often worsening during flexion and extension of the knee.[7–10,12] Pain is often absent throughout short distances, worsening at longer distances or the next training day.[9] In severe cases, pain is reported outside of the training environment, such as walking or descending stairs.[9] During a normal orthopedic evaluation of the knee, ITBS will not present any remarkable findings other than local point tenderness on the distal fibers. Specifically, pain will be reproducible with palpation two to three centimeters proximal to the tibiofemoral joint line; this occasionally presents with minimal edema and crepitus.[9] There are

few orthopedic tests that clinicians use to diagnose the presence of ITBS, including Noble's compression test and Ober's test.[9,12,13] Noble's compression attempts to reproduce symptoms of ITBS that occur during knee flexion and extension.[9,13] The patient is positioned in side-lying on the unaffected side with the pathological knee flexed to 90 degrees. Next, the examiner palpates the distal ITB at the lateral femoral epicondyle while passively extending the patients' knee. A positive test is indicated when pain is reproduced within roughly 20-30 degrees of knee flexion.[9,13] The Ober's test has an inter-rater reliability 0.59-0.97 and an intra-rater reliability of 0.90- 0.91.[40,41] The purpose of this clinical test is to identify any reproducible symptoms associated with ITBS.

Ober's test involves an identical patient positioning, but instead examines tightness of the entire ITB.[12,42] A tighter ITB theoretically results in higher compression and shearing forces throughout the entirety of the gait cycle; there is minimal research exploring the correlation of ITB tightness to ITBS.[12] During this special test, the examiner stands behind the patient, using one hand to stabilize the pelvis and the other to maximally abduct hip of the involved side, simultaneously moving the hip into extension. Next, the examiner drops the hip into adduction until the patient's pelvis begins to rotate to compensate the movement, or the patient's thigh stops due to soft tissue restriction. The amount of hip adduction, or abduction if the soft tissue restricts the hip from adducting past neutral, is measured via goniometer.[12,42] If abduction degrees are observed, the test is considered positive for ITB tightness and any adduction degrees past neutral are considered negative for ITB tightness.[42] Differing from Noble's compression, Ober's does not attempt to reproduce symptoms, but to identify if there is a soft tissue restriction of the ITB.

Iliotibial band syndrome is typically treated conservatively, but in rare cases is managed surgically.[9,10,12] Conservative treatment of ITBS ideally follows the phases of healing, starting with the acute inflammatory phase. At this point in the process, treatment is aimed at diminishing pain and inflammation through various measures. Modification to activity volume or intensity, combined with the use of analgesics such as ice and non-steroidal anti-inflammatory drugs (NSAIDs), can assist in shortening the process.[9,12] By altering activities that contribute to stress at the lateral femoral condyle, symptom reduction should occur. As the phases of healing progress, sub-acute physiological changes to the soft tissue include the production of fibrous tissue to strengthen the damaged structures. Subsequently, active methods of treatment are indicated such as stretching, manual therapy, and muscle strengthening. Stretching of the ITB and the adjacent structures is recommended, although length or relative tightness of the band is not confirmed to be a precursor or indicator of ITBS.[12,43] The method of stretch most effective at lengthening the band involves the patient in an upright standing position, with the involved side's foot crossed behind the contralateral foot, in an adducted position. The patient then lifts arms overhead and laterally flexes torso towards the uninvolved side, thus, placing the ITB in a lengthened position.[12,43] Other literature suggests every patient differs regarding the best stretch technique; modifications can be made to optimize the stretch such as including trunk flexion combined with lateral flexion.[9]

Following the acute phase, soft tissue restrictions should be considered before muscle strengthening or correcting occurs.[9] As new fibrous tissue is arranged, the orientation is disorganized and misaligned and, therefore, not at its strongest. To advance the realignment process, manual manipulation of the tissue is indicated. Various methods of manual myofascial release have been suggested by researchers as effective, but the evidence confirming superior

benefits remains lacking.[12] Once myofascial restrictions have been addressed, in final phases of healing, strength of hip musculature can be properly addressed. The significance of strengthening weak hip musculature when treating ITBS will be discussed in the following section.

In rare cases of ITBS, symptoms of ITBS cannot be managed with conservative treatment, and surgical intervention is indicated.[9,10,12] There are numerous procedures, which can reduce the impingement of the ITB, most involving the excision of irritated structures: bursa, cysts, or, in some cases, a portion of the ITB itself.[9,10,12] Overall, treatment of ITBS requires a comprehensive approach and consideration to the phases of soft tissue healing.

2.3. Myofascial Pain Syndrome

One of the main contributory factors of muscular pain, myofascial trigger points (TrPs), are defined as noninflammatory, hyperirritable nodules within the fibers of the muscle and the surrounding fascia.[1] Fascia, both superficial and deep, is a composition of connective and fat tissue which lies between the dermis and the muscle.[44] A palpable taut band with likeness to a guitar string elicits pain upon compression, causing both local and remote symptoms.[3] Myofascial pain syndrome (MPS) is a disorder associated with multiple trigger points and fascial abnormalities. Myofascial pain varies in intensity and point of onset, often presenting as a persistent dull pain. Although the etiology of MPS is insidious, changes in loads on the muscle or increased demands can instigate a sustained muscle contraction.[4] Patients with myofascial pain tend to use protective and compensatory movement patterns to limit discomfort, such as altered gait.[5] Overall, myofascial pain is a disorder with an insidious onset and associated TrPs, which are treatable when correctly diagnosed.

2.3.1. Pathophysiology

There are two theories researchers combine to explain the phenomenon of myofascial trigger points.[1] The strenuous demand of the active TrP, even at rest, causes an increase in energy consumption secondary to the release of the neurotransmitter acetylcholine (ACh). ACh is a chemical message released by neurons to send messages to other cells.[45] Due to the excess of this activating chemical at the motor endplate of the muscle fiber, a prolonged depolarization phase occurs. The purpose of the depolarization phase is to open cell membranes, thereby allowing the flow of negative calcium ions to spur the contraction of muscle fibers.[1] However, in this state of disrupted homeostasis, cells cannot regulate correct exchange of nutrients, leading to a detrimental amount of free calcium ions.

The first theory discussed in literature is the energy crisis theory, in which researchers blame the influx in calcium on repeated microtrauma and neural demands placed on the muscle tissue.[4] The calcium ions cause a sustained muscle contraction, thereby resulting in a higher demand for energy, spurring the injurious cycle to repeat. The muscle contracture secondary to incessant flow of acetylcholine (ACh), combined with the provoked sensory receptors responsive to pain, explains the physical symptoms and pain associated with TrPs.[1] Consistent shortening at the motor end plate also depletes circulating oxygen, leaving the cells incapacitated and unable to produce energy at the rate the tissue needs to cease the contraction.[4] The lack of circulating blood through the vessels causes the fascia to become inflexible and a hindrance to movement.[44] Additionally, when tissue metabolism is forced to occur in an ischemic state, nociceptors become more sensitized, eliciting a pain response.[4]

The second theory, motor end plate theory, works in conjunction with the energy crisis theory. In this theory, the motor end plate, a synapse between the motor neuron and myocyte, can

be blamed for small amounts of muscle contracture. Intramuscular electromyography studies found the loci coinciding with motor end plates produce diminutive electrical activity, which represents the release of ACh.[4] As discussed previously, excess ACh exacerbates the issue by inciting more muscle shortening. By incorporating both motor end plate and energy crisis theories, researchers conjecture about the origin of myofascial trigger points; however, the exact derivation remains unknown.[1]

Myofascial trigger points can be classified into four categories depending on the mechanism or symptoms. The first, primary trigger points are produced by either an acute mechanism or repeated stress to the tissue. The symptoms associated with primary TrP are unrelated to any other muscle. One the other hand, secondary TrPs are the consequence of mechanical damage produced by a primary TrP.[1] Myofascial trigger points can be further grouped by symptoms as latent or active.[1] Active and latent trigger points differ in distinct mechanisms. Latent TrPs have less clinical significance than those of active TrPs; however, a latent trigger point has the ability to worsen and develop into an active TrP.[1] Pain associated with latent TrPs is only induced upon palpation of the taut band and does not produce any symptoms without provocation.[1,4] Furthermore, the pain initiated by a latent trigger point will not be familiar to the patient. In order for a TrP to be classified as active, the pain must be recognizable upon palpation.[4] A non-specific or unfamiliar pain produced upon palpation of the taut band is considered inconsequential to some clinicians.[4] Latent TrPs, considered by those standards, are insignificant and noncontributory to myofascial pain.[4] Regardless of being classified as latent, TrPs have the potential to worsen and become increasingly symptomatic, thus changing to the active classification.

Referred pain can be present in both latent and active TrPs and is a common chief complaint of MPS patients.[1] Common with active TrPs, referred pain is the only nociceptive sensation apparent and is often unrelenting.[1] Described as a 'misinterpretation of stimulus,' researchers have speculated about referred muscle pain for years. The convergence projection theory, a traditional explanation for referred pain, is centered around noxious stimulus to the posterior gray matter of the spinal cord, or the dorsal horn neurons.[4] Researchers theorize dorsal horn neurons become more sensitive to stimulus consequential to the incursion of chemical transmitters derived from pain. This explains the idea of referred pain because the dorsal horn neurons have links to more than one part of the body; therefore, when stimulus derives from multiple body regions, the dorsal horns are unable to differentiate where the pain originates.[4] Other researchers speculate there is an inactive version of convergent connections, which is initiated by the first stimulus of pain.[46–48] In this slightly varied theory, dorsal horn neurons receive noxious information from only one area. Once a stimulus is received, previously dormant receptors will begin transmitting. Referred pain occurs because the dorsal horn neurons detect the signals as originating from multiple areas.[4,46–48] The presence of referred pain as a symptom is a distinguishable factor between myofascial pain syndrome and other musculoskeletal pathologies such as fibromyalgia.[3] While referred pain has a systematic pattern, it does not correspond with the pattern of dermatomes. Although the mechanisms of referred pain are not absolute, it is an undeniable symptom of MPS and a clinically significant patient complaint.

A secondary characteristic attributed to both active and latent trigger points is a local twitch response.[3] A local twitch response (LTR) is a small but rapid contraction of the involved muscle upon palpation of the taut band. Also termed the "sensitive locus," the LTR is one of many loci mapped by clinicians using TrP injections. With elevated electrical activity compared

to neighboring tissue, the “active locus” typically correlates with the motor end plate. Based on the observation of spontaneous electrical activity during TrP injection, the proposed hypothesis is a TrP develops when a sensitive locus (local twitch response), active locus (motor end plate), and pain receptor (nociceptor), all overlap.[49] Researchers also speculate there is a scattered population of sensitive loci throughout a single muscle, increasing in concentration near TrPs, thus adding yet another level of complexity to the theory of referred pain.[49] Overall, the local twitch response is commonly discussed in the literature as a characteristic of all trigger points.

2.3.2. Diagnosis and Treatment

Myofascial pain syndrome is prevalent, not only in the competitive athletic population, but recreational athletes as well. Up to 54% of women and 45% of men experience myofascial pain in some regard.[1] In an athletic population, trigger points are common secondary to a dissimilar injury, or a soft tissue pathology such as muscle imbalance or poor posture.[4] In the general population, TrPs are common but may present with differing symptoms due to the mechanism. The demographic frequently affected is sedentary people ranging from 27.5-50 years old.[2] For example, office workers who sit for long periods of time with incorrect posture and sustained muscle contracture may develop cervical or thoracic TrPs, which present as a headache or neck pain.[4] Specifically, there are characteristics identified by researchers as criteria for diagnosis of MPS and the associated active and latent TrPs (Figure 1).[6] A more general diagnostic criterion includes a local twitch response, familiar pain on reproduction of symptoms, and a taut band associated with pain on palpation.[4] Overall, MPS is a common disorder affecting a diverse population and can be debilitating if the contributing factors go untreated.

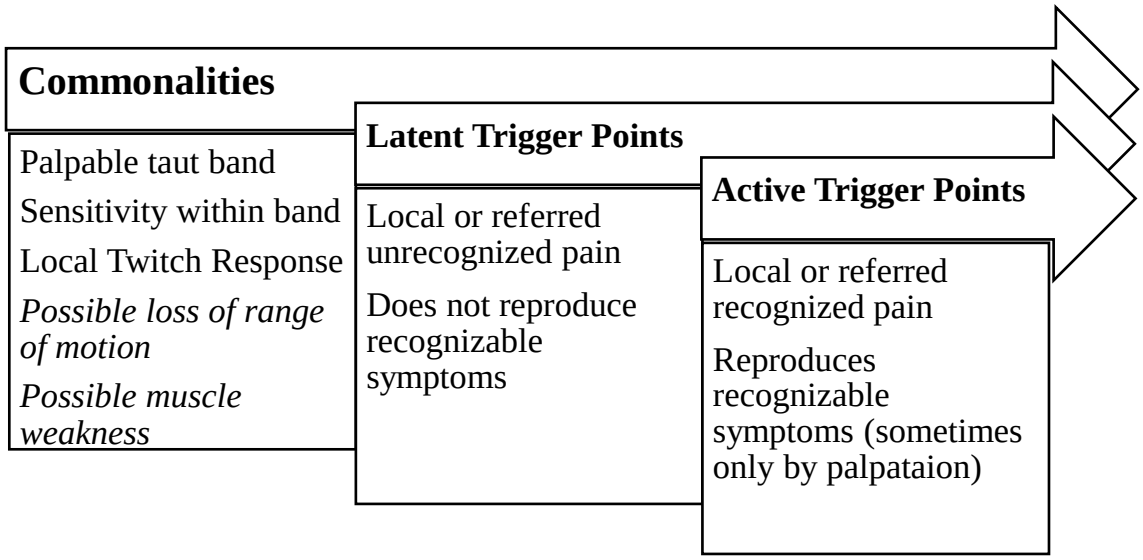

Figure 1. Diagnostic Characteristics of Myofascial Pain Syndrome[6]

Myofascial trigger points can be diagnosed in a variety of ways, but commonly through a detailed history of symptoms and reliable physical evaluation.[3] However, there are several factors that affect the reliability of diagnosing TrPs via clinician palpation.[4] Patient position, force applied to the tissue, and most significantly, palpation technique, influence the reliability of locating TrPs.[4] There are three main types of palpation methods clinicians utilize for TrPs: direct finger pressure, flat palpation, and pincer palpation.[1] Pincer palpation is the best maneuver for deep TrPs while the other two methods are valid for superficial tissue. Based on research, the most appropriate technique clinicians should consider when attempting to reproduce symptoms of a TrP is a pressure of approximately two kilograms per centimeter squared (km/cm^2) applied over two to five seconds. Researchers compared inter-rater reliability of TrP diagnosis between experts and trained and untrained clinicians.[50] Out of three TrP characteristics, referred pain was the only significant reliable diagnostic variable for expert clinicians compared to trained (kappa=.342) and untrained clinicians (kappa=.326). Overall, concurrence for referred pain among the trained examiners (kappa=.435) and untrained examiners (kappa=.320) was more significant than for presence of taut band (kappa= 1.08, -.019) or local twitch response (kappa=-

.001, .022).[50] The presence of a local twitch response or palpable taut band were found to be unreliable indicators between examiners. Considering inter-rater reliability, the most dependable indication of TrP diagnosis is the reproduction of local or referred pain via direct pressure.[50]

Additional diagnostic tests can be used for myofascial trigger points. Electromyography, algometry, and diagnostic ultrasound are frequently referred to in the current literature.[1] Electromyography (EMG) can be used in a variety of circumstances.[3] Intramuscular EMG is most effective and penetrates the muscle fibers, eliciting a heightened response when the clinician finds an active locus of TrP.[3] Furthermore, algometry measures pain pressure threshold (kg/cm^2) via hand-held device and aids the clinician in the understanding the location and severity of the TrP.[3] Algometry is a convenient way to quantify the progress of TrPs but can also be used to locate TrPs through the presence of a low pain pressure threshold score, measured in kilograms per centimeter squared (kg/cm^2).[27,28] Both accurate and accessible, ultrasound imaging techniques are useful, non-invasive complementary tools for pinpointing TrPs and will be discussed in further detail in a later section.[51] Although there are several tests to diagnose TrPs discussed in the literature, one does not noticeably surpass the others in reliability.

Myofascial trigger points can be treated through both invasive and non-invasive procedures. Injections are one example of an invasive treatment. Injections can be either non-medicated, such as dry-needling, or medicated with prescriptions such as botulinum toxin. Notably, there is an obvious risk of infection associated with invasive procedures, which does not exist with non-invasive treatments.[3] Botulinum toxin (BT) is an analgesic used under the assumption TrPs produce excess ACh because the base ingredient for the toxin blocks ACh before it enters the muscle.[4,52] As a result of inhibiting ACh, botulinum toxin has the effect of sustained muscle relaxation.[52] In a pilot study of subjects with chronic unilateral neck pain, BT

in multiple doses was compared to a placebo injection of saline into trigger points, which have been symptomatic for longer than three months.[53] Thirty-three subjects were randomized into three groups: placebo (n=11; 38.1±9.0 years), BT 50 units (n=11; 40.7±11.1 years), BT 100 units (n=11; 43.4±8.0). Pain measurements were obtained using the Neck Pain and Disability Visual Analogue Scale (NPAD) as well as pain pressure threshold at baseline, immediately post-injection and at six additional intervals in the four months following the treatment. A with-in groups analysis of variance (ANOVA) was conducted and researchers reported a statistically significant difference between the pre-test and each subsequent post-test in regard to pain pressure threshold ($F=11.44$, $P=.0001$) and NPAD ($F=8.36$, $P=.0001$).[53] However, between BT 50 units, BT 100 units, and placebo groups, there was no significant difference of effect for either outcomes ($F<1$). The researchers concluded based on the results that BT has no superfluous benefits over saline regarding injection of TrPs.[53]

A more recent study performed on a larger sample (N=132) similarly examined the effect of BT on myofascial pain syndrome.[52] Participants suffering from chronic neck pain were grouped randomly to receive either saline injection (n=35) or BT doses of 10 units (n=32), 25 units (n=34), or 50 units (n=31); the mean ages for each group were 45.3±10.1, 43.3±10.9, 46.6±15.1, and 46.5±12.2, respectively.[52] Subjects were assessed for pain via visual analogue scale (VAS) and pain pressure threshold via algometer at pre-injection, post-injection, and then every other week for 12 weeks starting one week post-injection. With a repeated measures ANOVA comparing each BT dosage group to the placebo group, researchers found no significant differences for VAS ($P=.87$) or pain pressure threshold ($P=.61$).[52] It should be noted that a delimitation of the study includes the use of several additional treatments for myofascial pain syndrome (MPS), which all groups received throughout the 12-week study. Regardless,

researchers conclude BT injections of TrPs are not a recommended treatment for MPS in the neck because the addition of the medication was not superior to saline .[52]

Another group of researchers have compared BT and other medications, such as anti-inflammatory steroids, in contrast to previous studies which have compared BT to a saline placebo.[54] In this comparative study, patients with chronic spasm in one or more specified muscles of the hip were recruited and randomized into two groups: BT injection (n=20) or steroid injection (n=20). The researchers reported the subject pool was 67.5% female with a mean age of 47.7 years; however, they did not indicate any implications related to the majority female subject population, nor did they analyze the nominal gender variable.[54] Furthermore, in similar methodology to the previously mentioned study, patients were analyzed for pain severity using VAS scores, but measurements were obtained at pre-injection, 30 days, and 60 days post-injection. Differentiating this methodology from the previous studies is the dosage of BT; in this study, dosage was predetermined and dependent on the size of the injected hip muscle, instead of being manipulated by the researchers.[52,54] The dosage of the steroid injection was constant regardless of muscle, but the motive was not stated. Furthermore, post-injection passive stretches were prescribed to all group participants (N=40), but researchers did not confirm compliancy. From baseline scores to 30 days post-injection, the BT group had a greater overall decrease in VAS scores compared to the steroid group (P=.06). However, the BT group's baseline VAS scores were significantly higher at baseline (P=.006) and there was no statistical difference at 60-days post-injection (P=.58). The results of the paired t-test for overall change in VAS scores are presented in Table 1.[54] Furthermore, at the 60-day follow-up, the BT group had statistically significant lower VAS scores than the steroid group (P<.0001).[54] Even more notable was the with-in group difference for BT with researchers finding a greater decrease in pain between the

30-day and the 60-day mark (P<.0001). Meanwhile, the effects of the steroid injection wore off and pain scores increased between day 30 and day 60.[54] Although initially there was no significant difference in changes in pain severity between baseline and day 30, the analgesic effects of the BT injection continued to day 60 whereas the effects of the steroid only lasted 30 days.[54] Overall, there is contradictory research on botulinum toxin regarding effectiveness compared to other medications and the necessary dosage to elicit clinical effects.

Table 1. Change in Pain Severity (VAS Score)

	BT Group (n=20)	Steroid Group (n=20)
30 days	-3.9 ± 0.2	-3.5 ± 0.9
60 days	-5.5 ± 0.3	-2.5 ± 0.7

The philosophy of the dry needling technique is to elicit the local twitch response of the TrP in order to lower muscle tension and pain through the insertion of small needles into specific muscles.[3,4] There are various methods of dry needling that have been developed to treat TrPs associated with MPS; for the purpose of this review, only a small portion of the literature will be discussed. Recruiting from an outpatient clinic, subjects who suffered from symptomatic TrPs for at least six months were obtained for a four week, double-blinded, randomized study.[55] The subjects were randomized into either a dry needling treatment group (n=22; 42.9 ± 10.9 years) or a sham needling group (n=17; 42 ± 12.0 years). The patients were assessed for perceived pain using VAS scores, as well as quality of life via a questionnaire called Short Form-36.[55] Patient outcomes from the questionnaire were only obtained pre-treatment and post-sixth treatment. The details of the tool were not reported by the researchers; therefore, the results will not be analyzed in this review. Furthermore, in this mixed methods study, patient outcomes of pain severity were measured with VAS.[55] Dry needling treatments were performed by a physician and took place over six sessions: twice a week for two weeks, then once a week for two weeks. In a repeated

analysis, researchers found significant lower VAS scores within the dry needling treatment group following session one (P=.000) and six of dry needling (P<.000). Additionally, VAS scores post-initial treatment (P=.034) and post-sixth treatment (P<.001) were significantly lower in favor of the dry needling treatment group.[55] For this reason, the researchers conclude dry needling treatments are effective in reducing perceived pain associated with MPS, with respect to this specific method of application.

Exploring comparable patient outcomes, researchers studied the novelty of dry needling to conservative physical therapy techniques for the purpose of comparing pain pressure threshold and VAS scores in patients with myofascial pain of the upper trapezius muscle.[56] Thirty-seven patients were recruited using convenience sampling and analyzed according to predetermined inclusion criteria, which consisted of the presence of active trigger points in the upper trapezius muscle for greater than two months.[56] The final randomized groups, who met the criteria and completed all follow-up appointments, consisted of 14 subjects receiving an invasive dry needling treatment, and 14 subjects completing a non-invasive physical therapy program. The pre-treatment characteristics for the treatment groups are listed in Table 2.[56] The physical therapy program consisted of 10 sessions, three times a week, during which the physical therapist applied stretching combined with various therapeutic modalities: superficial heat, transcutaneous electrical stimulation, and thermal ultrasound. In contrast, the dry needling group received one treatment to the two most symptomatic TrPs of the upper trapezius. Outcome measurements consisted of VAS scores, pain pressure threshold, and a quality of life questionnaire. Each outcome measurement was obtained one week and one month following the final treatment for both groups.[56] The same quality of life questionnaire, Short-Form-36, was utilized as Tekin et al.

(2012). However, in this study, researchers reported the outcomes obtained were categorized into eight scales, scored quantitatively from 0-100.[56]

Table 2. Pre-treatment Group Characteristics

	Dry Needling group (n=14)	Physical Therapy group (n=14)
Age (years)	32.0 ± 10.0	38.6 ± 4.2
Symptom Duration (months)	9.6 ± 8.4	9.8 ± 9.6

Paired *t*-tests were performed on data collected at one-week follow-up and indicated significant increases in pain pressure threshold for both the dry-needing and PT group ($P<.05$).[56] The physical therapy group, however, was alone in improving quality of life, with significant increases in three of the eight categories as shown in Table 3. However, since the physical therapy group received multiple therapeutic modality treatments throughout a 10-session program, the results of this analysis lose clinical significance because it is not determinable which aspect of the physical therapy session affected the patient's perceived outcomes. Nevertheless, at the one-month post-treatment, the dry needling group became equally effective in improving the measured outcomes compared to the physical therapy group.[56] Both groups had significant increases in pain pressure threshold and four out of the eight quality of life Short Form-26 categories ($P< .05$). Also, in the 1-month follow-up session, researchers conducted an ANOVA between both groups and found no significant differences in any measured outcome ($P>.1$).[56] Overall, the clinical implication of this study is limited by the multiple interventions within the physical therapy group. Nevertheless, the authors conclude a matched level of effectiveness between dry needling and physical therapy in treating patient outcomes and pain pressure threshold associated with myofascial pain syndrome.

Table 3. Quality of Life Scores: Physical Therapy Group: Pre-treatment and 1-week Follow-up

	Physical functioning	Role limitation due to physical problems	Social Functioning
Pre-treatment	72.5 ± 19.8	41.3 ± 44.3	71.4 ± 17.9
1-week follow-up	80.0 ± 15.9	53.5 ± 40.3	67.8 ± 18.2

On the other hand, non-invasive treatments for myofascial pain syndrome include vapocoolant spray and stretch, thermal ultrasound, and ischemic massage. Additionally, thermal modalities are frequently used as treatment interventions; vapocoolant spray with stretch and thermal ultrasound are just two examples. Vapocoolant spray with stretch or 'spray and stretch' was originally marketed as the most effective treatment option for myofascial pain by Travell and Simons in 1983.[6] Since the original claim, studies have been conducted exploring the effects of the spray and stretch modality, which is claimed to enable stretching of the muscle with a lessened pain response.[21] TrPs commonly result in a hypersensitive stretch reflex of the involved muscle; the vapocoolant spray works to prevent the painful stretch reflex through cryotherapy applied to the superficial tissue.

Following an application of vapocoolant spray and stretch, the researchers explored the changes in pain levels with patients presenting with unilateral and bilateral neck pain.[21] A subject pool of N=20 (f=14, m=6) was recruited from a pain management center for suffering from chronic neck or head pain. Descriptive statistics of the population as well as the categorization of groups are displayed in Table 4.[21] Two separate studies were conducted using the population recruited via nonprobability sampling; Study 1 with the unilateral pain group as subjects and Study 2 with the bilateral pain group as subjects.[21] Within each study, the same protocols for spray and stretch were employed, and the untreated side of the neck acted as the control for each subject. In Study 2 for bilateral pain subjects, the treatment side was randomly assigned. Similar to previous studies related to MPS, VAS and pain pressure threshold (PPT) were obtained to

quantify patient outcomes. However, the VAS in this study specifically measured pain intensity of referred pain instead of localized pain, and PPT values were reported separately for active and latent TrPs for Study 1.[21] Both pain measures were obtained pre-treatment and immediately post-treatment and analyzed via paired *t*-tests.

Results of the paired *t*-test on pre- and post-treatment VAS and pain pressure threshold scores for both studies are shown in Table 5.[21] Study 1 has similar pain measures with significant improvement in pre- to post- outcomes for VAS [($t(14) = -4.17$, $P<.001$)] and PPT [($t(14) = .33$, $P=.74$)]. In Study 2, researchers found statistically significant improvement in perceived pain (VAS) [($t(4) = 6.46$, $P= .004$] and pain pressure scores [($t(4) = - 4.91$, $P= .01$] following the one-time treatment of vapocoolant spray and stretch on the treated side.[21] Based on the obtained results of perceived pain and PPT, the researchers concluded vapocoolant spray and stretch treatment affected sufficient reduction in TrP sensitivity. More recently, evidence regarding vapocoolant is considered outdated and controversial because researchers cannot differentiate if the effects are a result of the coolant or the fascial stretch.[4,21] Nevertheless, the reported results of patient outcomes in the aforementioned study indicates some level of clinical significance of vapocoolant spray and stretch to treat MPS.[21]

Table 4. Descriptive Statistics and Group Categorization

	Population	Age (yrs)	Duration of Pain (yrs)
Unilateral Pain (Study 1)	n=15 (f=11, m=4)	39.3 ± 12.5	10.3 ±12.5
Bilateral Pain (Study 2)	n=5 (f=3, m=2)	30.0 ± 8.6	7.4 ± 5.3

Table 5. Pre- and Post-treatment Results; VAS and Pain Pressure Threshold (PPT)(kg/cm^2); Study 1 (Unilateral Pain) and Study 2 (Bilateral Pain)

	Study 1: VAS	Study 1: Active PPT	Study 1: Latent PPT	Study 2: VAS	Study 2: Treated side PPT	Study 2: Untreated side PPT
Pre-	34.9 ± 18.9	2.4 ± 1.47	3.3 ± 1.7	61.0 ± 28.9	2.8 ± .97	2.7 ± .73
Post-	11.1 + 14.3	4.1 ± 2.16	3.3 ± 1.97	35.2 ± 22.6	3.8 ± 1.82	2.9 ± .81

Massage, in various forms, is a common choice for clinicians when managing TrPs, often combined with a stretch or vapocoolant spray and stretch. Ischemic massage is used in cases where clinicians deem direct pressure to the TrP will create an oxygen deprived environment, causing the TrP to release.[3] Hanten et al. (2000) interpreted the literature regarding treatment for TrPs and determined no matter the method of treatment, applying a stretch to the muscle following the treatment, will offer longer analgesic effects.[6,57] Therefore, the researchers combined stretch and an ischemic pressure massage and compared it to an active range of motion program.[57] Forty subjects (m=17, f=23; 30.6 ± 9.3 years) were randomized into treatment or control groups mentioned above and instructed, verbally and written, to perform at-home sessions twice a day for five days. Pain scores ($F=4.4$; $df=1,37$; $P=.043$) and pain pressure threshold scores ($F=23.0$; $df=1,37$; $P=.000$) improved significantly in the treatment group versus the active range of motion group, thereby supporting the researchers' theory that stretch and ischemic massage is a more effective treatment for TrPs.[57] Although the results support the use of ischemic massage and stretch, it does not give any indication that massage or ischemic pressure alone would yield the same effects.

To further explore stretch and massage as treatment options for chronic MPS, researchers compared the two instead of combining them.[58] Researchers obtained VAS scores, cervical range of motion via goniometer, ischemic pain threshold via tourniquet, and quantity of TrPs pre- and post- treatment session related to group assignment. The randomized groups consisted of a

connective tissue massage treatment group (n=20; 31.0 ± 5.0 years) or a vapocoolant spray and stretch treatment group (n=20; 30.7 ± 6.0 years).[58] Connective tissue massage was performed on the subjects by predetermined method for 15 sessions, while treatment for vapocoolant spray and stretch was applied per the instructions of Travell and Simons (1983) for six sessions.[6,58] Both groups were also instructed to complete a combined intervention of active therapeutic exercise three times a day, however, there is no report of compliance. There was significant difference between the two treatment groups in regard to VAS scores pre- (P<.01) and post- (P<.01). The same was true for number of trigger points post-treatment in both left and right sides (P< .001, P<.05, respectively) in support of the spray and stretch group.[58] Researchers also report a comparison of pre-post treatment within both groups, and there was significant improvement in pain, range of motion, and number of trigger points (Table 6).[58] No significance was found in the same analysis of ischemic threshold. Notably, the combined intervention of exercise prescribed to all subjects is a delimitation within the study because the patient outcome could be affected by the exercises instead of the treatment.[58] Researchers conclude both interventions of massage and vapocoolant spray and stretch have clinically beneficial effects on pain, range of motion, and number of trigger points, but spray and stretch is slightly more effective when equating the two.[58] The impact of ischemic massage can be effective in improving patient outcomes related to MPS, even more so when followed with a muscle stretch; however, it may be superseded by the use of the original treatment option, vapocoolant spray and stretch. Based on the results reported by researchers, clinicians can conclude the muscle stretch is the effective component in both treatment methods.[3,4,6,21,57,58]

Table 6. With-in Group Pre-post Comparison for Connective Tissue Massage Group and Vapocoolant Spray and Stretch Group

	Connective tissue massage group p	Vapocoolant spray and stretch p
Number of TrP Right	<.01	<.001
Number of TrP Left	<.001	<.001
VAS	<.001	<.001
ROM Flexion	<.05	<.01
ROM Extension	<.05	<.01
ROM Rotation Right	<.01	<.01
ROM Rotation Left	<.01	<.01
ROM Lateral Flexion Right	<.001	<.001
ROM Lateral Flexion Left	<.01	<.001

Therapeutic ultrasound is another commonly mentioned thermal intervention for TrPs, but the wide range of methodology with lack of universal procedures weakens the significance of the current evidence.[59] The therapeutic aspects of ultrasound can be either thermal or non-thermal effects caused by vibrations of sound waves.[59] Reportedly, thermal effects on soft tissue include increased blood flow and collagen elasticity in tendons, ligaments, and joint capsules, subsequently reducing stiffness.[59] Possible non-thermal properties of the ultrasound waves are analgesic in nature and incorporate decreased painful stimulus received by the central nervous system with general desensitization of the nervous system to reduce the patients' perceived pain.[59] Due to inadequate controlled methodological studies regarding the efficacy of therapeutic ultrasound in treating MPS, Kavadar et al. (2015) performed a study analyzing pain, pain pressure threshold, and psychological implications following conventional ultrasound.[59] Fifty-nine (N=59; m=10, f=49) patients with upper trapezius myofascial pain received either an ultrasound treatment (n=30; 37.43 ± 9.07 years) or a sham ultrasound (n=29; 35.83 ± 5.68) for six-minute sessions, 15 times. Outcome measures were acquired pre-, immediately post- and three-month post- treatment.[59] The researchers' report states an equivalent significant difference

($P<.01$) for the treatment and control groups in all outcome measures when comparing pre-treatment outcomes to immediately post- and three-month post. The groups differ upon between-group analysis; the placebo group fell short of the treatment group in all patient outcomes immediately post- and three-months post- ultrasound treatment ($P<.0001$).[59] Regardless of the significant difference between the groups in favor of the ultrasound group, the analogous significance within the groups' pre-post analyses lessens the implication of ultrasound as a treatment for TrPs considerably. [59]

Despite the extensive collection of research on therapeutic ultrasound, a gold standard protocol does not exist for the treatment of myofascial pain syndrome. For this reason, Ilter et al. (2015) equated separate settings of ultrasound in attempt to establish a set of best practice parameters. Comparing pulsed, also referred to as interrupted, to continuous ultrasound, the researchers examined several patient outcomes related to MPS: pain, function, severity of muscle spasm, and several aspects of mental health and quality of life.[60] As a result of convenience sampling at a physical rehabilitation clinic, N=77 subjects met the diagnostic criteria for trigger points detailed by Travell and Simons (1983).[6] Due to attrition, the randomized groups (N=60) were subcategorized as the following: continuous ultrasound (n=20; 33.0 ± 8.0 years), pulsed ultrasound (n=20; 32.0 ± 7.0 years), and sham ultrasound (n=20; 33.0 ± 8.0 years).[60] The participants were further characterized by occupation, duration of pain, sex, and education; however, there was no statically significant difference between these nominal scales ($p>.05$). All three intervention groups were given the pre-assigned five-minute treatment five days per week for two weeks. Further therapy prescribed to all subjects included standard stretching and range of motion exercises as well as superficial heat, which was documented with journal entries.[60] Notably, the patients were allowed over the counter acetaminophen pain relief medication when

needed. The use of medication is a considerable limitation of the study because the dosage and time of intake was not controlled and could have affected the patient perceived outcomes.[60]

Researchers measured pain as the primary outcome via a 11-point VAS assessing the patient's pain in the most recent 48 hours. Secondary outcomes included an ordinal scale severity for muscle spasm, and interval scales for psychological state, quality of life, function, and patient satisfaction.[60] All outcomes were obtained pre- and post- treatment, as well as at a six- and 12-week follow-up. For VAS pain scores, a Wilcoxon paired *t*-test revealed significant improvements in the continuous (P=.003), pulsed (P=.001), and sham (.001). The researchers found a similar trend for both severity of muscle spasm (P<.001) and disability scores (P=.007, P=.001, P<.001, respectively).[60] Identical to the previous study, this indicates all subjects, no matter the group, perceived improvement in pain, muscle spasm, and function.[59,60] Again, it could be assumed that this is due partly to the placebo effect of a single-blinded study. Furthermore, a Kruskal-Wallis ANOVA analysis was completed to compare changes between the groups following the ultrasound treatment. Researchers reported significant improvement in pain (VAS) scores at the 6-week (P=.035) and 12-week follow-up (P=.013) for the group treated with continuous ultrasound.[60] The same statistics for the pulsed and sham ultrasound group were not insignificant and not reported by the researchers. Conclusions based on the results indicate continuous ultrasound may be indicated over other parameters when treating pain associated with MPS.[60] Although research analyzing the effectiveness of therapeutic ultrasound for MPS exists, it remains inconsistent procedurally and inconclusive.

Due to the various treatment options for symptoms associated with MPS and TrPs, careful consideration and evidence-based clinical application should be used regardless of the treatment applied. There is contradictory research validating the use of one treatment as the 'gold

standard' for myofascial pain syndrome. Whether invasive or non-invasive, the clinician applying the specified treatment should have background knowledge of the treatment as well as the patient's symptoms. Lastly, because myofascial pain syndrome is multifaceted and can manifest several symptoms, clinicians should take care to understand the nature or cause of the symptoms when choosing a treatment option.

2.3.3. Kinetic Chain Implications

Given the broad arrangement of the TFL and ITB, there are numerous anatomical structures affected and kinetic chain implications to consider regarding ITBS. In regard to myofascial pain syndrome of the TFL and ITB, there are areas where trigger points and referred pain can manifest. Patients with ITBS often present with TrPs of the entire hip stabilizing complex: TFL, ITB, and gluteus muscles. Furthermore, if a patient suffers from active TrPs in one of these muscles, it is rarely a singular issue.[6] More often, the MPS will carry over to functionally similar muscles. Referred pain originating from the TFL is often confused with pain in the gluteus minimus, gluteus medius, or vastus lateralis muscles. Additionally, referred pain of TrPs within the ITB and TFL can be experienced in the acetabulofemoral joint area, inferiorly in the anterolateral thigh, and even spanning to the lateral knee.[6] Pain caused by TrPs in the TFL is often incorrectly attributed to trochanteric bursitis at the femur or friction of the distal ITB against the femoral epicondyle. Additionally, the vastus lateralis muscle, along with the TFL, refer pain to the same locations as the ITB.[6] Most often, this is noted clinically in the lateral knee. Due to the close proximity in the thigh, the ITB and vastus lateralis share a close kinetic chain relationship. If the vastus lateralis becomes hypertrophied or overrun with taut bands associated with MPS, the adjacent ITB is pulled and compressed medially, spurring further myofascial restrictions in the thigh. Familiar to the mechanism of injury of ITBS, the closer

proximity of the ITB to the vastus lateralis exacerbates the pain causing friction at the femoral epicondyle.

As discussed in the anatomy section, the TFL and ITB complex have a close working relationship with the gluteus muscles, specifically the gluteus minimus and medius.[6] Because these hip stabilizers work as a unified entity, they largely affect one another, in both helpful and detrimental ways.[6] Due to the synchronous relationship of the TFL muscle and the gluteus medius, certain hip inefficiencies can exacerbate pathologies of the ITB. A muscle imbalance or weakness of the gluteus medius often contributes to altered gait and subsequently, ITBS associated symptoms. Specifically, runners suffer from weaker hip musculature on the pathological side when compared to the contralateral side and to non-pathological runners.[6,61] Therefore, in rehabilitating to strengthen the gluteus minimus and gluteus medius, as well as the TFL, hip stability in the single-leg stance phases of the running gait cycle will improve. As a result, symptoms associated with ITBS will diminish. Furthermore, muscle imbalances of the gluteus muscles also affect gait; this is attributed to soft tissue restrictions produced by TrPs. By treating TrPs in the TFL and gluteus muscles, which share a kinetic chain with the ITB, restrictions and abnormal biomechanical movements can be corrected.

2.4. Kinesiology Tape

First developed by Dr. Kenzo Kase in the late 1970's, Kinesio® Tape differs from traditional athletic tape in structure as well as function.[44] While athletic tape has little to no stretch capacity and works to immobilize, kinesiology tape was intentionally designed to stretch up to 140-160% of the original length.[15,44] Subsequently, other manufacturers responded with the invention of similar kinesiology tapes. Regardless, all of the tapes have adhesive and elastic properties, which were designed to mimic qualities of human skin through structure and

material.[15] The majority of manufacturers produce a tape constructed from an intertwined cotton fabric, which also contains a large degree of elastic properties.[15] Overall, several primary effects of kinesiology tape are repeated throughout the literature: the creation of space in the tissue, increased circulation and lymph drainage, decreased pain, sensory feedback for proprioception improvement and joint realignment, and muscle facilitation or inhibition.[5,14–19,44,62–64] With these claims in mind, kinesiology tape has understandably become a current treatment choice for musculoskeletal pathologies.

2.4.1. Kinesio® Tape

The benefits of Kinesio® Tape do not differ from the aforementioned claims made by competing manufacturers, however, there is a lack of literature specific to Kinesio® Tape that validates these claims.[14–19] Aside from its non-invasive quality, Kinesio® Tape is a prevalent treatment method due to anecdotal reports of improved patient perceived outcomes.[14,18,19] Besides pain, additional outcomes affected positively by kinesiology tape include range of motion (ROM), strength, balance, and muscle activity.[63] In a review of recent clinical trials, researchers quantified the significant and insignificant results of the abovementioned results (Table 7).[63] Based on these results, it is difficult to determine superiority of one outcome, however, the total percentage of positive results reflect some effectiveness in strength and proprioception. Although the researchers do not conclude kinesiology tape is an effective treatment for pain, only ten articles met the researchers' criteria, thereby limiting the amount of data available to analyze. With a small pool of literature that exists for kinesiology tape, the significance of the outcome measures' effectiveness is reduced.[63] Additionally, the researchers do not include a brand specification in the inclusion or exclusion criteria. Therefore, it cannot be assumed all included clinical trials used the brand Kinesio® Tape.[63] Effects of Kinesio® Tape

can be advantageous in various respects, making it a popular, non-invasive treatment option for musculoskeletal pathologies, but the extent of current literature is insufficient.[14–19]

Table 7. Number of Significant and Insignificant Results, and Percentage of Overall Positive Results, for Pain, ROM, Strength, Proprioception, and Muscle Activity

Outcome measure	Statistically significant positive results	Nonsignificant results	Overall positive results (%)
Pain	2	6	25
ROM	16	56	22
Strength	6	10	38
Proprioception	2	2	50
Muscle Activity	4	18	18

2.4.1.1. Characteristics

The materials and structure of most kinesiology tapes are not made public by the manufacturers; however, understanding the properties is important for correct application and to achieve the desired outcome.[15] Since the commercialization in 1982, the brand of kinesiology tape, Kinesio® Tape, has made several expansions concerning structure and purpose.[17,44] The original construction of the tape consisted of cotton and polyurethane synthetic fibers with an acrylic adhesive backing, however, new developments to tape materials have been introduced with the intention of increasing elastic and adhesive abilities.[16] The current label of the brand, Kinesio® Tex Tape, was designed to cause miniscule folds in the superficial skin and tissue. This creates space between the skin and the underlying fascia, thereby allowing specific therapeutic effects, such as joint repositioning, lymphatic drainage, and subsequent pain reduction.[17] Regardless of minute manufactural changes throughout the years, the proposed advantages of Kinesio® Tape have remained unchanged.

Although there is inadequate literature regarding the materialistic qualities of the types of Kinesio® Tape, the manufacturer of TEMTEX® tape claims the tape is an imitation of Kinesio®

Tape.[15] For this reason, researchers investigated physical and mechanical aspects of TEMTEX® tape, including comfort when adhered to the skin.[15] TEMTEX®, like Kinesio® Tape, is a porous, elastic material with a woven pattern and an adhesive backing.[15] TEMTEX® tape was evaluated for yarn type, adhesive and thermophysical properties, mechanical function, porosity, and permeability to air and water at zero and 50% tension. Upon testing the materials, two yarn types, warp and weft, were found to have maximum elongation of 110 and 100%, respectively. The different types of yarn textile allow the parallel fibers to stretch to 140-160% but prevent the perpendicular fibers from stretching the tape horizontally. This is essential because the wider the tape, the higher the tensile strength, which ranges from 80-180 N. The width of the tape is established in production and is available to the consumer in two and a half, five, or seven and a half centimeters.[15] The porosity of the fabric, as well as permeability to air and water, are directly correlated to the amount of tension (r=.9737). When tension is placed on the tape, the pores of the woven fabric grow, subsequently increasing permeability properties. In addition, with higher permeability to air and water, thermal conductivity lessens. Therefore, a correlation also exists between thermal resistance and tension length (r=.9922). Due to confined air insulating the pores, thermal conductivity reduces significantly, and the comfort of the tape is enhanced for the patient. Nevertheless, the length of time the tape remains adhered to the skin could alter the correlations as well as physiological outcomes.[15] The characteristics of kinesiology tape can affect the clinical outcomes and should be understood fully prior to application of the treatment.

Since the debut at the 1988 Seoul Olympics and more recent media attention at the Beijing games in 2008, bounding popularity has resulted in the replication of the kinesiology tape by several different companies. Claiming new material, which improves elastic and

adhesive qualities, manufacturers continue to compete with one another.[16] For example, RockTape, although not well published, has emerged as a kinesiology tape product of late. Few researchers report using RockTape in the methodology, and there are no studies to date comparing the clinical outcomes of Kinesio® Tape to RockTape.[65,66] However, mechanical characteristics of Kinesio Tex Gold- FP® and RockTape brands of kinesiology tape were compared in a cross-sectional laboratory study.[16] Researchers examined the tapes by comparing the maximums in four categories: tension (Pascal x 10^4), deformation (%), load (Newtons), and relative stiffness (Newtons/mm).[16] Two stress tests, traction and adhesion, were performed on all brands. An analysis of variance (ANOVA) was used to demonstrate any statistically significant difference ($P<.05$) between groups. Researchers reported no statistically significant variances during the traction test between Kinesio Tex Gold- FP® and RockTape in any of the four categories: tension, deformation, load, and stiffness (Matheus, 2016). On the other hand, the adhesion test proved statistically significant between the two brands related to maximum tension and load (Matheus, 2016). Furthermore, in the traction stress test, Kinesio Tex Gold- FP® had the most impressive values in tension (M=301.42, SD=10.64), load (M=215.87, SD=7.62), and stiffness (M=5.14, SD=.53). [16] The Kinesio Tex Gold- FP® also allowed deformation up to 250-400%, markedly higher than previous research states.[15,16] Still, there is no evidence indicating a range of deformation past the indicated recommendations would yield any therapeutic benefits. The researchers also reported Kinesio Tex Gold – FP® held the highest values in stiffness in comparison to the four other brands, which could be beneficial when taping to correct joint mechanics. It should be noted the researcher did not report any numerical value; therefore, there is no quantitative evidence to substantiate the claim nor is there an explanation of the benefits.[16] Despite the comparability, the five tapes, specifically RockTape and Kinesio Tex Gold- FP®,

performed differently under the stress tests indicating they should not be interchanged without motivation. It can be concluded that although manufacturers claim similarities or differences to alternative brands, further research should be conducted to observe if any notably different clinical outcomes exist.

2.4.1.2. Methods of Application

Developed by Dr. Kenzo Kase as a product as well as a method of application, the main purpose was to apply therapeutic interventions usually performed in the clinic to the patient's home.[44] The methods of application are used with the intention to achieve specific outcomes. A common method repeated in the literature is the space correction method.[44] The space correction method is claimed to increase the space beneath the soft tissue, facilitating circulation and movement of lymph fluid. Lack of proper circulation and oxygen to the tissue triggers the energy crisis, the leading etiological theory for myofascial pain syndrome.[44] Theoretically, application of kinesiology tape using the space correction method could improve circulation of the surrounding tissue, remove inflammation, and reduce pressure on the pain sensors, which ideally increases patient tolerance of the pain pressure threshold. [44] Drainage of lymph fluid can also accelerate healing of tissue by releasing fascial lesions, or TrPs, associated with MPS. A negative-pressure pump, the mechanism that moves the lymph fluid, works via contraction and relaxation of muscles.[44] When pressure within the skin and fascia is elevated due to fluid, muscles are inhibited and the pump cannot properly guide flow thus producing swelling. By creating space between the layers of tissue, the fluids can run through the circuit efficiently, and thereby possibly progressing the healing process.

Another popular application of kinesiology tape uses the direction of tension applied on the tape to either facilitate or inhibit a muscle.[44] The clinician starts with the tape at the insertion

of the muscle adding very little tension along the belly toward the origin, which employs the muscle to relax and inhibits it from excessive contraction. This inhibitory technique is based on the presence of the Golgi tendon organ (GTO), a physiological component where the muscle meets the tendon, which works to prevent over contraction of muscle fibers by inhibiting the muscle while concurrently stimulating the opposing muscle. The opposite technique, facilitation, assists in muscle contraction by applying the tape from the muscle origin to inerstion.[44] Clinicians utilize the origin to insertion application when the desired effect is to stimulate contraction of the muscle fibers. Although the methods differ, the muscle facilitation and inhibition techniques have similar benefits to the space creation method, such as increased lymph flow. [44] Other uses of the facilitation or inhibition applications are to improve balance and proprioception by targeting a muscle to fire when desired. The tape allegedly provides the tissue with a mechanism of biofeedback, or reception of a neural stimulation, to either contract or relax depending on the applied methodology.[44] Based on the desired outcome, there are different methods of tape application that can be utilized by clinicians. However, there are limited studies in which researchers validate the claimed effects of the various methods and how they can be applied to treat pathologies.

2.4.2. Kinesiology Tape and Myofascial Pain Syndrome

Although under researched, kinesiology tape has become a treatment option for patients with musculoskeletal pathologies or deficits, specifically MPS. The alleged effects kinesiology tape has on muscle inhibition and facilitation, soft tissue alignment, space creation, and circulation are equally beneficial in treating symptoms associated with myofascial pain syndrome (MPS). [5,14,18,19,44,62,64] The symptoms of myofascial pain syndrome, as discussed previously, arise from the fascial layer of tissue. Because there are several existing theories

regarding the origin of MPS, the issue of how to resolve the detriment is left to question. Current researchers exploring kinesiology tape as a treatment method for MPS utilize the space creation method or, more often, the muscle facilitation or inhibition method. Various methods of application are employed in the literature, however, the literature does not reflect a standard method that is most effective in treating MPS and associated TrPs.[44]

Utilizing the space creation technique to apply kinesiology tape, researchers conducted a randomized, sham-controlled study to compare kinesiology tape to an alternative type of taping named cross taping.[64] Participants (N=73) were recruited via convenience sampling from a medical school setting and were confirmed to have asymptomatic, latent TrPs in the upper trapezius (UT).[64] Notably, latent and asymptomatic TrPs as inclusion criteria diverges from previous studies regarding MPS; more often the criteria includes symptomatic TrPs with pain continuing for an extended period of time.[21,53–60,64] Overall, the majority of the subjects were female (n=68) (*P*=0.0701), which could be due to convenience sampling, but no statistical analysis of the nominal data point is reported in the results.[64]

After randomization into one of three groups, cross tape (n=24; 20.2 ± 1.1 years), kinesiology tape (n=25; 20.6 ± 1.5 years), or sham tape (n=24; 19.9 ± 0.8 years), the subjects were assessed for electrical activity of the UT via surface electromyography, cervical range of motion (ROM), as well as pain levels via VAS. All outcome measures were obtained pre-tape application, post-tape application, and at a 24-hour follow-up; participants were required to wear the tape for 72 consecutive hours. The cross tape is portrayed as similar in material to kinesiology tape but applied in smaller strips with a woven patten directly over a TrP. The method of space creation used to apply the kinesiology tape (Nitto Denko K-Active Tape) was described by the researchers as a star-shape consisting of four straight strips applied to the UT

with 50% tension.[64] The tape applied to the sham group was a nonelastic medical tape, ensuring no therapeutic effects were applied to the tissue. Although not specifically identified as a CKTP, all taping techniques were applied by a certified kinesiology tape clinician. It should be mentioned that the patients were blinded to the type of tape applied, but the researcher was not, permitting the possibility of bias error on the part of the clinician.[64]

Mean values of EMG activity of the UT muscle were recorded along with cervical ROM, and perceived pain using a zero to ten VAS. To analyze the statistical differences within the three groups at pre-, post-, and follow-up, a repeated Friedman ANOVA was conducted EMG scores of the UT had no statistical significance in the cross-taping group (P=0.1152), kinesiology tape group (P=0.3260), or sham group (P=0.0542). However, the opposite was true for VAS scores and cervical flexion; there was significant differences between pre-, post-, and follow-up for each group in range of motion and pain (Table 8).[64] Finally, an independent Kruskal- Wallis ANOVA was employed to compare the differences between group. Researchers reported no statistically significant differences between any of the groups in almost every outcome measure; however, the kinesiology tape group had a greater improvement in VAS scores when compared to the sham group (P=0.0018).[64]

Although kinesiology tape is claimed to improve all of the outcome measures the clinicians obtained in this study, it is undetermined why the researchers chose the space creation method to affect change on muscle activity and ROM.[44,64] It is theorized an excess of lymph fluid within the tissues prevents muscles from contracting to facilitate the pump that travels the fluid; however, the preferred method for altering muscle activity and range of motion is the facilitation or inhibition technique.[44] In addition, Kinesio Taping Association International (KTAI) suggests using a fascial application in instances of fascial disturbance. Because of this

limitation, no statistically significant changes were observed in muscle EMG and the authors conclude kinesiology tape has no effect on muscle activity.[64] Despite these lacking findings, a similar study utilizing a separate technique of tape application may yield different results.

Table 8. Friedman ANOVA *P*-values for VAS and Cervical Flexion in the Cross Tape, Kinesiology Tape, and Sham Tape Groups

	Cross tape group	Kinesiology tape group	Sham tape group
VAS	*P*=0.0001	*P*=0.0001	*P*=0.0011
Cervical flexion	*P*=0.0000	*P*=0.0000	*P*=0.0004

The benefit of using inhibition technique over facilitation, or vice versa, for the treatment of MPS is not indicated in the literature. TrPs associated with MPS can develop due to overstimulation or deficient activation of a muscle, as previously mentioned. Without first understanding the etiologic source of the TrPs, clinicians cannot make an educated decision between facilitation or inhibition methods.

Researchers employed the inhibition Kinesio® Taping technique in attempt to treat active ROM and pain associated with TrPs in the piriformis muscle.[5] Despite naming the method, the authors neglect to report the brand of kinesiology tape utilized in the methodology. Recruited via convenient sampling, subjects (N=51) were partially randomized into an experimental (n=33; 42.2 ± 15.8 years) or control group (n=18; 42.7 ± 12.7 years) based on order of inclusion. A clinician confirmed piriformis involvement using several diagnostic special tests.[5] Based on the diagnostic evaluation, n=31 subjects presented with right piriformis MPS and the remaining n=20 subjects with left piriformis MPS. Outcome measurements of pain intensity via VAS, and active hip internal rotation (IR) of the involved side via goniometer were obtained at three points: pre-tape, ten minutes post-tape, and 72-hour post-tape. The researchers reported employing an inhibition taping technique by pulling tension on the tape from origin to insertion

or on the involved piriformis of the kinesiology tape group.[5] However, this is an incorrect application of the inhibition technique. If the desired result is to relax or inhibit the muscle fibers, opposite direction of tension is indicated, pulling the tape from muscle insertion to origin. By pulling tension from origin to insertion, the researchers, in fact, applied a facilitation taping technique. In side-lying with the patient's involved side facing up, the hip was positioned in flexion, adduction, and internal rotation. The base of a Y-shaped strip of tape was adhered to the opposite side of the sacrum with no tension. The top tail of the tape was then applied to upper piriformis, ending at the greater trochanter of the femur.[5] Finally, the bottom tail was applied to below the TrP, on the lower half of the piriformis, ending at the same point of the greater trochanter. Researchers also explain a modification to the technique called 'unloading,' which involved the clinician lifting the buttocks tissue surrounding the TrP while attaching the second tail of the tape. Other than the muscle being unloaded, the clinicians do not state a benefit to this modified technique.[5] Regardless, the taping technique used by the researchers was utilized incorrectly, voiding the significance of the results.

The researchers use a repeated measures ANOVA to analyze the significant differences between the experimental and control groups for pain and ROM at three points of time (pre-, post-, and 72- hours post-). Although there was no statistically significant difference found between groups, researchers report significant correlation between point of time and group assignment for both outcomes, VAS [$F(1,49) = 8.75$; $P = 0.001$] and hip IR [$F(1,49) = 4.68$; $P = 0.027$].[5] Additionally, there are significant differences between pre-, post-, and 72-hours follow-up scores for both outcome measures, VAS [$F(1,49) = 8.82$; $P = 0.001$] and hip IR [$F(1,49) = 3.1$; $P = 0.049$]. It is unknown how much effect the unloading modification had on the results and should be considered a limitation because it is slightly altered from the, erroneously

reported, inhibition technique. Based on the results, the researchers support the effectiveness of the inhibition Kinesio® taping technique, modified with unloading, in treating pain and active ROM associated with TrPs in the piriformis muscle.[5]

Another group of clinicians who utilized the same inhibition Kinesio® taping technique to explore the effects of the method on pain and muscle strength as opposed to of ROM.[14] All subjects were being treated at a rehabilitation clinic and were recruited using a biased, nonprobability convenience sampling. Participants (N=37) with sedentary desk jobs, subsequent neck pain, and TrP of the trapezius muscle were randomized into treatment (n=20; 29.95 ± 4.9 years) or sham groups (n=17; 33.86 ± 8.47 years). All participants were analyzed for trapezius pain and strength following an application of Kinesio® Tape.[14] Group 1, the treatment group, had tape applied with the insertion to origin, or inhibition method, while Group 2 had no therapeutic method applied to the tape to act as the control. To correctly apply the inhibition Kinesio® Tape method, the patients' neck was positioned in lateral flexion in the opposite direction of the afflicted trapezius muscle. The tape was anchored inferior to the acromion, and stretched maximally along the muscle belly before ending the tail of the tape at the muscle origin, or the patient's hairline.[14] The tape was applied to both groups at the start of the week, remaining on for three days. Throughout the entirety of the study, the tape was adhered to each patient twice, with one day rest between the applications.

All subjects were analyzed for pain using VAS as well as pain pressure threshold (PPT) using an algometer.[14] Furthermore, strength of shoulder elevation, specific to the trapezius, muscle was obtained using a dynamometer. Each outcome, pain, PPT, and strength, were measured pre-intervention, immediately post-intervention, and at a one-month follow-up. In addition, subjects in both groups were asked to participate in an at-home stretching and

strengthening program.[14] Comparing VAS scores between the two groups for the one-month follow-up and pre-treatment, there is a significant difference in favor of the treatment group ($P<0.05$). Additionally, within both groups, VAS scores reduced significantly ($P<0.0001$). Also, in favor of the treatment group, PPT scores were significantly different when comparing measures for immediately post-intervention to one-month follow-up ($P<.0.05$).[14] Similar to VAS scores, PPT scores improved within both the treatment group ($P<0.0001$) and the control ($P<0.05$). Differing slightly, trapezius strength improved significantly in the treatment group alone ($P\leq0.0001$). Despite finding significant mean improvements in several categories in favor of the treatment group, the taping intervention was combined with an at-home therapy program.[14] Therefore, the clinical effects portrayed in the significant outcomes may feasibly be due to the at-home exercises, rather than the Kinesio® Tape. If researchers presume there was total compliance within both groups, the conclusion is supported that Kinesio® Taping with the inhibition method of application could provide significant relied for patients with myofascial pain of the trapezius muscle.[14]

Analogously, the effectiveness of Kinesio® Tape combined with manual pressure release (MPR), was compared to MPR alone, on treating TrPs.[19] In this single-blinded, randomized control trial, researchers recruited N=31 participants and allocated them into two groups: manual pressure release (MPR) (n=16; 30.0 ± 6.5 years) or manual pressure release combined with kinesiology taping (MPR/MKT) (n=15; 28.0 ± 4.6).[19] Researchers applied Kinesio Tex® Tape using the insertion to origin, or the inhibition method. As discussed previously, clinicians employ the facilitation technique if the desired effect is to assist muscle function. A Y-shaped strip of tape with two tails was adhered with the patient sitting upright and neck laterally flexed to the afflicted side.[19] The tape was anchored at the insertion of the upper trapezius, the acromion

process, ending at the upper cervical spine. The two tails of the Y-strip encircle the muscle belly; no level of tension is reported by the researchers. Subjects wore the tape for three days (72-hours); it was then re-applied with identical methods by the same clinician for another four days, for a total of seven days.[19] The second intervention, MPR, was performed on TrPs of the upper trapezius, identified by a therapist, who applied pressure to the adhesion with the pad of a thumb. Pressure was gradually increased until the patient reported pain as a seven, on a zero to ten scale. Even pressure, at this moderate level of perceived pain, was sustained until the therapist detects release of the adhesion.[19] Then, an increased pressure was applied, until the same moderate pain level, seven out of ten, was reported by the subject. This cycle of manual therapy was repeated until the patient no longer perceived pain or 60 seconds passed. Though detailed, this manual therapy application is subjective to the patient's pain pressure threshold.[19] Furthermore, the therapist performing the MPR may experience fatigue and therefore cannot guarantee the sustained pressure is evenly applied.

The primary outcome measures were pain (VAS), pain pressure threshold (algometer), muscle stiffness (myotonometer), and muscle contraction (mechanomyography (MMG)) of the upper trapezius muscle. Outcome measures were obtained pre-intervention, post-intervention, and at a seven-day follow-up point.[19] Within both MPR and MPR/MKT groups, PPT improved significantly (d=1.79; $P<0.005$). Additionally, strength of muscle contraction, measured via mechanomyography amplitude, was significantly higher in favor of the MPR/MKT group ($P<0.05$). The same was true for muscle stiffness, measured with a myotonometer, which was analyzed using a Mann-Whitney test and yielded statistically significant differences within the MPR/MKT group (0.27 mm to 0.49 mm).[19] Based on these results, the authors conclude both MPR and the inhibition method of Kinesio® Tape are successful in treating symptoms

associated MPS in the upper trapezius. However, they also note the treatments become most effective when used in combination of one another. It is difficult to ascertain the weight of the results regarding Kinesio® Tape in this study because of the combined intervention limitation.[19]

Overall, there are various techniques of kinesiology tape application, which clinicians can choose from depending on the preferred outcome. However, lack of consistent methodology in the literature deters evidence from supporting one method as the gold-standard to treat MPS or associated TrPs. Despite the existence of an alternative method of kinesiology tape application specifically for fascial pathologies, researchers have not employed the technique in clinical trials, instead maintaining the use of conventional methods.[5,14,19,62,64] This furthers the already wide gap in literature for kinesiology tape as an effective treatment for MPS.

2.5. Algometry

2.5.1. Purpose

Pain pressure threshold (PPT) is previously experienced pain induced by mechanical pressure and is commonly measured with an algometer.[20–28] Due to the ischemic and inflammatory aspect of trigger points (TrPs), which causes the soft tissue to be painful upon palpation, algometry is a prevalent choice for objective examinations.[4,23,24] Specifically, PPT is the minimum force (Newtons) needed to elicit a pain response distinguishable from pressure or discomfort.[23,24,28] The patient's ability to differentiate between pain and other sensations is vital in measuring accurate PPT. The tool itself consists of a standardized spring with a flattened rubber end and an associated pressure gauge. The diameter of the rubber plunger is typically one-half, or one-centimeter^2 and the pressure gauge is calibrated to read force in N/cm^2 or kg/cm^2. The application of an algometer to measure PPT is executed at a 90 degree angle to the surface of the skin and applied at a predetermined constant rate (N/s) until the patient verbalizes the

pressure sensation becomes painful.[20,22–28] It is imperative the patient is aware of the difference of pain threshold and pain tolerance, meaning the goal of algometry is to determine the first onset of pain, not the amount of pain endurable.[25] Overall, pain pressure threshold is a convenient, non-invasive method to measure a significant patient outcome.[20,22–28]

2.5.2. Clinical Relevance

Other than determining pain threshold, algometry is useful in tracking the prevalence of TrPs and progress in relation to treatment or therapy.[23] Although averages of PPT have helped determine standard values in some muscles, there is no defined quantity that distinguishes pathological tissue from healthy tissue.[22,24] However, some standards of pain tolerance have been established to form a standard bone to muscle tolerance ratio.[23] If a patients' pain tolerance is generally low over several muscles, this bone muscle ratio is helpful in determining if soft tissue hypersensitivity is present.[23] In two related studies, Van Wilgen et al.,2011 and Kregel et al., 2013, assessed pain using PPT in patellar tendinopathy.[67,68] A group of asymptomatic athletes (n=20, 21.0 ± 3.1 years) were used to establish a 'normal' PPT for the patellar tendon.[67] The researchers established a maximum pressure applied of 45 N in order to prevent negative effects of the test. Of the bilateral measurements taken, 86% of them reached the maximum pressure, 5% noted pain before 40 N, and 9% noted pain between 40 and 45 N. On the other hand, the symptomatic group (n=48, 21.9 ± 2.9 years), 97% of the PPT measurements were lower than 40 N.[67] Compared to the symptomatic group of athletes diagnosed with a patellar tendinopathy, the PPT of asymptomatic athletes was significantly different ($P< 0.001$). The researchers concluded a PPT change of 19 N is adequate in identifying a clinically significant change for patient with patellar tendinopathy. Although this determined significant change in PPT is related to patellar

tendinopathies and not MPS, it can be used as a guideline in determining clinically meaningful measurements in other studies.[67]

In 2013, the same researcher completed a related study to find a specific value of PPT to differentiate healthy patients and those with patellar tendinopathies.[68] In all, N=234 athletes of various male and female sports were evaluated. Of those N=234, n=114 (49%) were diagnosed with a patellar tendinopathy and n=120 (51%) were healthy. PPT scores were significantly higher in the healthy athletes (median = 51.6, min = 19.5, max = 56.9) than the patellar tendinopathy athletes (median = 20.0, min = 3.7, max = 53.3) (P<0.001).[68] The researchers employed a receiver operating characteristic (ROC) curve to determine the discriminatory point between healthy athletes and patellar tendinopathy athletes. The sensitivity, specificity, and area under the curve were 96% (95% CI: 92–100%), 97% (95% CI: 94–100%), and 0.98 (95% CI: 0.96–1.0), accordingly.[68] Based on the plotted coordinates on the ROC curve, the optimal PPT numeral was 36.8 N, meaning there was a positive predictive value of 96.5% that athletes with a PPT below the cut-off have a patellar tendinopathy.[68] Again, it is important to note these two related studies evaluated a demographic with a soft tissue pathology on tendon tissue and not MPS. However, the clinically significant change of 19 N and the distinguishable point between healthy and unhealthy tissue of 36.8 N are paramount in evaluation clinical significance in PPT studies in the future.[67,68]

Two additional studies are cited as determining a minimal clinically significant change in PPT.[69,70] Although these two researchers analyze PPT of muscles, instead of tendons such as in the previously discussed studies[67,68], they still merely include healthy tissue. However, the purpose of these comparable studies was to observe the changes in PPT on healthy individuals following a bout of either TENS[69] or IFC[70] electrical stimulation with differing parameters.

From these protocols, two clinically meaningful changes in PPT were identified to be ≥10.78 N/cm^2 [69] and ≥11.38 N/cm^2 [70], respectively. It is important to note, although these authors utilized muscle to obtain the PPT's; pathological tissue was not included in either samples.

In a further analysis of PPT and its ability to detect change in pain, Walton et al. (2014)[71] used a sample of N=206 people with mechanical neck pain in an observational study. Mechanical neck pain is termed based on common findings of neck pain associated with structural pathologies, which can be traumatic in origin or insidious.[71] Using two anatomical sites, the upper trapezius muscle and tibialis anterior muscle, the authors attempt to understand the tool's ability to identify true change. Testing PPT at a distal site of the tibialis anterior muscle was performed as a control to compare to the local site of upper trapezius, where the patients were expected to have symptoms. Based on an analogous statistical analysis as above, the ROC curve, the authors found PPT at the tibialis anterior ($P<0.5$)[71] was not indicative of change for patients with neck pain, but the upper trapezius site was ($P=0.76$). Conclusively, the authors report PPT is better at detecting change than ruling out change. This theory was further supported by comparing changes in PPT measurements to the patients' perceived change in pain.[71] Overall, eight percent of participants who did not state a decrease in pain had a PPT difference of at least 83.85 kPa. Therefore, a PPT change of that amount is unlikely to be a false positive on account of the measurement tool. On the other hand, half of those who did state an improvement in pain had a PPT difference less than the previous amount.[71] This indicates a high prevalence of false negatives in fault of the measurement tool. Largely, the authors suggest PPT is a reliable tool in identifying change, but to be confident true change has occurred, other outcome measures should be employed.[71] In a related 2011 article, Walton et al.[72] reported important conclusions regarding PPT employed to detect change overtime. The authors state PPT

may not accurately detect worsening, or decreased, PPT in patients whose baseline is very low. Overall, PPT is more adept at identifying change when the baseline is higher to begin with, such as asymptomatic patients.[72] In a related 2011 article, Walton et al.[72] reported important conclusions regarding PPT employed to detect change overtime. The authors state PPT may not accurately detect worsening, or decreased, PPT in patients whose baseline is very low. Overall, PPT is more adept at identifying change when the baseline is higher to begin with, such as symptomatic patients.[72]

2.5.3. Reliability

There are several sources of error that can alter the reliability of algometry in measuring pain pressure threshold. Due to the manual application and the required verbal contribution from the subject, three sources of error emerge: observer error, participant error, and measurement error.[26] Specifically, inter-rater reliability becomes compromised when untrained clinicians cause observer error. Actions that trigger observer error are performed by untrained clinicians or multiple clinicians and involve poor application techniques, such as inconsistent angle of application or rate of pressure.[22,26] For this reason, researchers suggest algometry measurements should be taken by one clinician during the course of a study.[22] The second source of error, participant error, arises due to the subjective nature of perceived pain. Participant error is entirely dependent on the ability of the subject to differentiate pain from other sensations and verbalize the onset of the sensation.[26] The final source of error affecting algometry reliability is measurement error, which is the difference between the reported PPT and its true value. Measurement error, much like observer error, is heavily dependent on a constant rate of pressure applied through the tip of the algometer during application.[22,26] Despite the possibility of these

identified sources of error, algometry remains to be widely researched and a popular technique in measuring PPT in the clinic.

To evaluate the inter-rater reliability of algometry in measuring pain pressure threshold in healthy subjects, two phases of a study were conducted.[26] Phase 1 consisted of the training in algometry with a fixed angle algometer of five clinicians (23.0 ± 3.5 years) from a class of final year undergraduate physical therapy students. Training was completed until the observers could successfully apply the algometer at a rate of five N/s without visual feedback. A final test to ensure proper training consisted of five consecutive algometry applications at the predetermined rate, each 15-seconds apart for 10-second periods.[26] The training and testing were completed on the first dorsal interosseus muscle. Following this training phase, Phase 2 was aimed at determining the inter-rater reliability of the newly trained clinicians in measuring PPT in healthy subjects' first dorsal interosseus muscle of the dominant hand. Using convenience sampling, N=13 students (22 ± 2.25 years) were recruited and screened for pathologies that could affect PPT, however no subjects were excluded.[26] Because this examination was performed on healthy tissue, the midpoint of the muscle belly was marked by a clinician on both the dominant and non-dominant hands of the subject. Using the non-dominant hand, the subject was awarded two practice tests with the purpose of understanding the difference between pressure and pain. The subjects were coached to verbalize "stop" at the first onset of pain; at that time the algometer pressure is read and immediately released.[26] As trained, the clinicians applied the algometer at a constant rate of five N/s until verbally cued by the subject to 'stop'. This technique was completed three times on the dominant hand, 15-seconds apart, and the scores recorded and averaged. Each of the 13 participants were examined by five clinicians and had a 10-minute rest between each observer. The testing was completed double blinded, as neither the subjects nor the

clinicians were privy to the display reading the PPT scores, which were recorded by a third party.[26] The clinicians were randomly assigned an order of subject examination and all readings were taken on the same day.

A repeated measures ANOVA was used to identify a systematic bias or significant difference in the five clinicians' average PPT for all N=13 participants (Table 9). The researchers determined there was no statistically significant difference between these mean scores ($F_{4,48}$= 1.000, *P*= 0.417) suggesting a bias does not exist among the observers.[26] Furthermore, researchers calculated a Spearman's rho to examine the relation between the mean PPT scores, and the sequence of measurement. They concluded no significant correlation (r_s= 0.343, *P*= 0.211), also suggesting no change in the subjects' PPT scores over time. An ICC was calculated to determine inter-rater reliability of the five clinicians trained in algometry and was determined to be very high with a narrow confidence interval (ICC= 0.91, 95% CI 0.82, 0.97).[26] Finally, the researchers utilized a SEM, an indicator of measurement error, or the mean of each clinicians' three measurements for each subject. SEM was calculated using the standard deviation of measurement errors and the ICC. The calculated SEM was 6.27 N/cm^2 (95% CI 5.35, 7.59) suggesting the researchers are 95% confident that an interval of 12.30 N/cm^2 on either side of the observed PPT score contains the true value. This small SEM value suggests low measurement error within the observed PPT values and a high reliability. However, it is notable the PPT values reflect algometry readings on healthy tissue. Overall, the researchers conclude training of the originally unskilled clinicians was successful in providing reliable measurements of PPT with low measurement and observer error.[26]

Table 9. Mean (SD) (N/cm^2) PPT Values for All N=13 Participants for Each Observer

	Observer 1	Observer 2	Observer 3	Observer 4	Observer 5
Mean (SD)	32.7 (21.8)	34.8 (22.7)	39.7 (21.5)	38.1 (17.9)	37.0 (24.6)

An additional group of researchers completed several studies in attempt to determine the reliability of algometry in measuring the PPT of TrPs associated with myofascial pain syndrome of the head and neck.[20] With each study designed to answer a specific research question regarding algometry and TrP sensitivity, Study 1 was used to determine the inter-rater and intra-rater reliability of algometry on pre-marked TrPs. Fifteen subjects (f=11, m=4) with a mean age of 40 ± 10.9 years and average pain duration of 13.4 ± 10.6 years were recruited from a local pain clinic. An algometer with a one-centimeter^2 rubber tip at the end of plunger was applied to six marked locations where TrPs are commonly associated with head and neck pain. The pressure was applied at a constant rate of one kg/cm^2/sec; the angle of application was not reported by the researchers.[20] The subjects were instructed to verbalize to the clinician when they experienced 'a just noticeable amount of pain.' PPT values were measured from the marked TrPs on two separate occasions by two different examiners. Each TrP was measured twice by each examiner for a total of four times.[20] The sequence of examiner was counterbalanced and the order of TrPs measures was randomized. For both within- and between-experimenter reliability of the six TrP locations, there was significant correlation (P<0.01). Thus, the researchers concluded algometry readings of marked TrPs by two separate examiners, as well as by the same examiner on separate occasions, are reliable measurements of pain pressure threshold.[20]

A comparable study completed by the same researchers, a specific methodology was employed to determine if TrPs represent a distinct area of tenderness, which can be measured effectively with a one-centimeter^2 diameter algometer.[20] Nine participants (f=7, m=2), with a mean age of 30.6 ± 10.4 years and average pain duration of 7.5 ±12.5 years, were recruited from the same clinic and analyzed for PPT using the same TrP locations as Study 1, omitting one location. Using the identical algometry application technique, each examiner obtained one PPT

value from the five TrPs, as well as a PPT value from a non-trigger point, two centimeters within range of the TrP, but distal from an adjacent TrP. By measuring PPT at proximal non-trigger point, the researchers can differentiate if the TrP causes a definite area of sensitivity within the tissue.[20]

A repeated measures ANOVA was calculated to determine significant difference between measurement locations. Researchers report significant differences at all five locations between the TrP and non-trigger point (Table 10). Therefore, the researchers conclude TrP locations have a discrete point of tenderness, which can differentiate the ischemic tissue from other tissue, within two centimeters. Based on the results, it can be determined algometry is valid tool for measuring pain associated with TrPs.[20]

Table 10. Results of Repeated Measures ANOVA for Measurement Locations

Location	1	2	3	4	5
	$F_{(1/16)}= 6.08$, $P<.05$	$F_{(1/16)}=15.4$, $P<.01$	$F_{(1/16)}= 7.51$, $P<.05$	$F_{(1/16)}= 13.56$, $P<.01$	$F_{(1/16)}= 7.64$, $P<05$

Delving further into algometry, researchers conducted a study to explore various aspects of the measurement tool's reliability.[22] The first question the researchers posed is how PPT scores obtained over three consecutive days would alter the reliability of the outcome measurements. Additionally, they explored the inter-rater reliability of PPT scores between clinicians. Finally, the researchers examined the number of measurements considered necessary to produce the most accurate PPT.[22] Two clinicians acted as the examiners in this study; the authors reported the clinicians were certified physical therapists, but none with algometry. The examiners were allotted practice time with the goal of applying the algometer at a constant rate until 5 kg/cm^2 of pressure was reached over five seconds. Using an unreported sampling method,

N=35 (m=5, 36.4 ± 11.86 years; f=30, 29.2 ± limitation of skewed female participants in the population.

The algometer used had a one-centimer^2 diameter tip and was applied perpendicularly at a consistent rate of one kg/cm^2 to a marked point on the participants' nondominant biceps brachii muscle. Each examiner performed three practice tests on the dominant arm, followed by three tests on the non-dominant arm, which was recorded for data analysis.[22] The subjects were given 10-second rests between each measurement, and a 20-minute rest between examiners. The order of testing by each examiner was counterbalanced. The subjects were instructed to verbalize aloud "pain" at the point the pressure sensation becomes painful, at which point the examiner immediately removed the algometer and recorded the PPT value.[22] The scoring was single blinded at the time of testing as the subjects were not permitted to view the reading of the pressure gauge. Testing was completed with the same protocol by both examiners for three consecutive days.

Intraclass correlation coefficients (ICC) were determined for inter-rater reliability, as well as intra-rater reliability between trials and testing days.[22] Within the three trials, researchers concluded the highest reliability occurred between trials two and three on days two (ICC=.95) and three (ICC=.98). Similarly, day-to-day reliability was most reliable when calculated with the mean PPT values of trials two and three (ICC=.90). The highest day-to-day reliability occurred in trial three in regard to a single trial measurement (ICC=.89).[22] Furthermore, the reliability of PPT values for the three trials over three days are ICC= .85, .84, and .84, respectively.

Based on these results, the authors concluded consecutive days of algometry testing on healthy tissue does not significantly impact reliability of PPT values. Notably, it is unknown if similar consistent reliability would occur in pathological tissue.[22] Additionally, the average PPT

values for both examiners were 7.0 kg/cm^2 and 10.25 kg/cm^2, respectively. The discrepancy between the two examiners is obvious with one examiner recording overall higher PPT scores than the other. Regardless, of the three trials, inter-rater reliability was lowest for first trial and highest for the third (ICC= .74- .98).[22] Overall inter-rater reliability increased when the all three trial scores were averaged compared to a using values from a single trial. Researchers report the greatest reliability occurring when the second and third trials were averaged, omitting the first trial altogether (ICC= .85- .88). Overall, the most reliable algometry readings occurred in trial three, or the means of trial two and three. Therefore, the researchers conclude averaging the values of more than one algometry measurements is a more reliable representation of PPT than one measurement alone.[22] Based on the results of this study, the authors determine from day-to-day with consecutive days of testing, reliability of algometry measurements are not compromised. However, to ensure the most reliable PPT values, multiple trials should be recorded via a single examiner.[22]

Algometry is a commonly utilized technique to measure pain pressure threshold of tender sites of tissue. Research reflects the claim that algometry is a reliable tool to measure PPT of focal points.[20,26,73] Due to the physiological make-up of trigger points associated with myofascial pain syndrome, algometry is a valid tool to quantify pain elicited by pressure, such as palpation.[20] With minimal training, clinicians from various backgrounds can accurately apply algometry to quantify severity of TrPs or other sensitive areas.[20,22,26] These PPT values can then be employed to track patient perceived progress following a specific treatment or throughout a rehabilitation program.

Myofascial pain syndrome and associated trigger points are frequent within the general population and a significant source of soft tissue related pain. Although there is a myriad of

reported treatments for MPS, overall, a single method is not proven to be more effective than another. One treatment option, kinesiology tape, is profoundly under researched as a soft tissue modality. Specifically, there is a major gap of evidence-based research regarding Kinesio® Tape as a treatment for MPS. With regard to the iliotibial band, myofascial pain is a large factor for the physically active population. Myofascial pain syndrome of the ITB can be a significant hinderance, causing widespread pain affecting the hip, thigh, and knee. Despite the broadening popularity of Kinesio® Tape as a method of soft tissue treatment, no research has appropriately utilized the tape to investigate its effects on myofascial restrictions, such as TrPs. In summary, research should be conducted to understand the impacts of Kinesio® Tape on TrPs within the ITB and fill this gap.

3. METHODOLOGY

The purpose of this study was to analyze the effects of Kinesio® Tape applied with the fascial taping technique on pain pressure threshold of trigger points (TrPs) within the iliotibial band (ITB). Current literature regarding Kinesio® Tape as a treatment for MPS and TrPs includes the use of inconsistent methodology or erroneous taping techniques. This chapter outlines the participants of this study, the setting in which it was completed, data collection, procedures, and data analysis. The following research questions are the cornerstone of this study:

1. What within subject differences exist in pain pressure threshold (N/s^2) measured via algometer at four points in time?
2. What within subject differences exist in pain scores measured via Visual Analogue Scale (VAS) at two points in time?

3.1. Participants

A convenience sample of 50-75 participants between the ages of 18 and 55 were recruited from the Fargo-Moorhead metroplex. Email, word-of-mouth, and in-person recruitment was utilized to obtain participants. Inclusion criteria for participation consisted of meeting minimum requirements for being recreationally active or a recreational runner. Recreationally active was defined by the American College of Sports Medicine as participating at least twice a week in aerobic activity for a total of 80 minutes at moderate intensity (~5-6 METS).[29,30] Runners will have to self-report at least 10 miles a week for the last three months.[31–33] Exclusion criteria included acute strain or surgery to the knee, quadriceps, or hamstrings within the previous six months. Contraindications for Kinesio® Tex Tape including any allergy to adhesive, malignancies, cellulitis, skin infection, diabetes, or fragile skin are also cause for exclusion.[34] Twenty dollars of compensation was awarded to each participant upon completion of the study.

Informed written and verbal consent was obtained from each participant prior to collection of information and completion of any part of the study.

3.2. Setting

This study was completed in the Athletic Training and Exercise Science Laboratory in Benson Bunker Fieldhouse one the campus of North Dakota State University, Room 14, 1301 Centennial Blvd. Fargo, North Dakota, 58102 or at a confidential, professional location of the participant's choosing. Equipment required for this study, namely the JTECH Commander Echo Console Pain Algometer (JTECH Medical; Midvale, Utah) and Kinesio® Tex Gold FP Tape, was easily portable.

3.3. Equipment and Instrumentation

The JTECH Commander Echo Console Pain Algometer was used to measure pain pressure threshold (PPT) of trigger points within the ITB. The machine consists of a digital console, which connects via Bluetooth to the wireless algometer gauge. The gauge consists of a spring-loaded arm with a one-centimeter rubber tip on the end. It can measure up to 25 pounds of pressure (111.206 Newtons).

Additionally, a patient outcome of pain was included measured via an 11-point Visual Analogue Scale (VAS). VAS was administered twice total, once at the beginning of the first session, and again at the beginning of the follow-up session.

Kinesio® Tex Gold FP tape was utilized to tape the trigger points within the ITB because trigger points occur in the myofascial tissue, and the FP tape is indicated to affect the fascial layer of tissue. Application recommendations provided by Dr. Kenzo Kase include applying a Y-strip with oscillation at 25% tension.[34] All tape applications were applied by a Certified Kinesio® Tape Practitioner (CKTP).

Lastly, a Musculoskeletal History Questionnaire modeled off of the Extended Nordic Musculoskeletal Questionnaire[74] was used to gather participants' musculoskeletal history within the last 12 months. The purpose of the questionnaire was to understand any lower extremity pathologies that could be associated kinetic chain implications secondary to myofascial pain syndrome of the ITB.

3.4. Procedures

For this research study, participants were recruited through email, word-of-mouth, and in-person recruitment at North Dakota State University and in the Fargo-Moorhead area. The first 50-75 people who met the inclusion criteria were included in this study. The North Dakota State Institutional Review Board approved this research study prior to completion. Data were collected in the Athletic Training and Exercise Science Laboratory of Benston Bunker Fieldhouse or in a professional, confidential location of the participants' choosing. Participants were sent information detailing the expectations of the study and forms to be completed. Prior to any testing, participants completed the informed consent paperwork. In the instance that any participant reported neurological impairment (i.e. Parkinson's disease; nerve entrapment; MS; ALS; or paresthesia); history of medical conditions involving joints, muscles, bones, or connective tissue in the lower extremity (i.e. Osteoarthritis, fibromyalgia, Lyme disease); or any allergy to adhesive or Kinesio® Tex tape, they were unable to complete the study.

Participants reported for data collection twice throughout the duration of the study. Participants were required to wear loose fitting shorts to provide the CKTP with the ability to assess and tape the ITB. During the first visit, the informed consent was signed, and the Musculoskeletal History Questionnaire, which was modeled off of the Nordic Musculoskeletal

Questionnaire[74,75], was completed and reviewed with the participant. Self-reported age, height, weight, sport, and dominant leg was documented at this time.

With the participant in side-lying on their non-dominant leg, between one and four TrPs within the ITB were identified with criteria set by Travell and Simons using a cross fiber flat palpation technique.[6] Criteria for a trigger point included taut band, pain with palpation, referred pain, and a local twitch response. After one to four trigger points were identified, they were each marked on the skin with semi-permanent marker. Then, the JTECH Commander Echo Console Pain Algometer was used to quantify pain pressure threshold (PPT) pre- Kinesio® Tex Gold FP Tape application. The rubber tip of the algometer was applied to the marked trigger point at a 90-degree angle to the tissue, such that the circumference of the tip laid flat on the ITB. Pressure was applied at a constant rate until the participant verbalized "now" upon the first sensation of pain. The participants were informed the test was to quantity pain threshold, not pain tolerance, and to verbalize the onset of pain, not when the pain become intolerable. Each trigger point was analyzed for PPT three times and averaged by the JTECH Commander Echo Console Pain Algometer. Immediately following baseline PPT was obtained, a pain assessment via an 11-point VAS scale was given to the participant with the question "on average, how painful was the pressure?"

Prior to the taping application, the area was trimmed of hair, cleaned with an isopropyl alcohol preparation pad, and sprayed with tape adherent. While waiting for the area to dry, the CKTP prepared one to four Y-strips of three squares of Kinesio® Tex Gold FP tape. The participant remained in side-lying with the top leg in approximately 45 degrees of knee flexion, 30 degrees hip flexion and 15 degrees adduction, to place the ITB at a stretch. A bolster was placed under the participant's knee for comfort. The anchor of each Y-strip was applied with no

tension lateral to the ITB, and each tail was applied with a side-to-side oscillating fascial taping technique with 25% tension. The marked TrP was centered between the tails of the Y-strip. The end of each tail was applied with no tension. Of the participants, n=5 received a sham taping treatment instead of the fascial taping technique. With the patient standing, sham taping was applied with one long y-strip parallel to the length of the lateral thigh, with each tail adhered anterior and posterior to the ITB, with no tension. With the tape applied for 10-minutes, a post-taping PPT reading was obtained on all TrPs using the same protocols as above.

Following a second PPT reading, participants were instructed to continue with activities of daily living until they return for their second appointment. The second appointment was scheduled 48 hours following the first. Upon arrival to the second appointment, the CKTP confirmed the tape application remained intact. In the instance that the tape application is no longer correct, the participant's data was excluded from the study. At this time, participants were evaluated for PPT for a third time using the previous testing protocols. Then, the participant completed a second VAS with instructions to rate pain from the pressure during PPT testing. Finally, the tape was removed from the participants' ITB using the pressure method as described by Dr. Kenzo Kase.[34] A timer was set for 10-minutes, then PPT was obtained for each TrP one last time. Lastly, the participant was awarded 20 dollars compensation for completion of the study and was dismissed.

3.5. Data Analysis

In addition to descriptive statistics, analysis was conducted using repeated measures ANOVA, with each participant serving as his or her control. The analysis compared data from the four points in time PPT was measured as well as the two VAS scores.

3.6. Conclusion

The purpose of this study was to analyze the effects of Kinesio® Tex Gold FP tape applied with the fascial taping technique on pain pressure threshold of trigger points (TrPs) within the iliotibial band (ITB). Results of this research study provided information regarding kinetic chain implications of MPS of ITB, which is lacking in literature. The use of a fascial taping technique to affect myofascial TrPs also fills an essential gap in the current research. Based on the pathophysiology of MPS and associated TrPs, past researchers who employed different KTAI taping techniques did so erroneously. For this reason, we hypothesized the fascial taping technique applied with parameters set by KTAI will increase pain pressure threshold of TrPs within the ITB.

4. MANUSCRIPT

4.1. Abstract

[Study Design] Randomized Control Trial

[Background] Myofascial pain syndrome (MPS) is a common soft tissue pathology, which presents in patients as a dull, persistent pain. Published studies utilizing kinesiology tape as treatment for MPS employ techniques targeting overactive or underactive muscles, thus omitting the fascial anatomy completely. We hypothesized an application of the fascial taping technique would increase Pain Pressure Threshold (PPT) and decrease subjective pain.

[Objective] The purpose of this study was to analyze the effects of Kinesio® Tape applied with the fascial taping technique on PPT of trigger points (TrPs) within the iliotibial band (ITB).

[Methods] This randomized control trial was conducted at a mid-sized university research laboratory. A pilot study was conducted on N=9 participants to verify the method as well as to estimate the effect size to determine an adequate sample size of N=42, which has 90% power. Following the recruitment of recreational runners and recreationally active, data from N=49 participants were included in statistical analyses. Participants were evaluated for trigger points (TrPs) in the ITB via palpation by one certified Athletic Trainer. At four different occasions (pre-tape, 10-minutes post-tape, 48-hours post-tape, and 10-minutes post-tape removal), an algometer was used to measure pressure necessary to elicit the onset of pain. Once pre-intervention PPT was obtained, a pre-tape Visual Analogue Scale (VAS) score regarding pain associated with the pressure was recorded. For n=44 participants, an oscillating fascial taping technique was applied using Kinesio® Tape FP in attempt to increase threshold of pain while n=5 received a sham tape.

[Results] Participants reported a decrease in pain via VAS (t[43]=4.80, p<.001, d=0.36). There was a slight increase in PPT from pre-tape to 10-minutes post-tape (t[43]=2.12, p=.040, d=0.14), signifying more pressure was needed to elicit pain and the TrP became less symptomatic. An ANOVA model incorporating all four measurements was statistically significant (F[3, 172]=7.96, p<.001). PPT was significantly less after tape removal while the other three measurements were not statistically distinguishable. The sham group was not significantly different among any measurement (F[3,16]=0.25, p=.86).

[Conclusions] Applied with the oscillating fascial technique, Kinesio Tape® FP can be effective at decreasing patient-perceived pain associated with pressure on TrPs. Further, the statistically significant differences in PPT at four distinct time frames indicates the tape application can affect PPT of TrPs within the ITB. Due to the sham tape producing no significant variance between any PPT measurements, there is sufficient evidence to suggest the oscillating fascial technique is effective at manipulating PPT of TrPs.

[Level of Evidence] Therapy, Level 2b

[Key Words] Pain Pressure Threshold, Trigger Points, Algometry, Recreational Runner

4.2. Introduction

Myofascial pain syndrome (MPS) is a common soft tissue pathology, which presents in patients as a dull, persistent pain, affecting both competitive and recreational athletes. MPS is characterized by myofascial trigger points, hyperirritable nodules palpable within the taut band that often cause referred pain in other regions along the kinetic chain.[1–3] Muscle inefficiency as well as muscle overload can result in the formation of TrPs, often presenting as sustained muscle contraction, or more significantly, unorganized fascia.[4] Based on the muscle pathophysiology, patients can develop a compensated movement pattern, gait, or posture in an attempt to alleviate

symptoms..[5] Changes in muscle activation patterns can lead to additional pathologies or pain along the kinetic chain.

Specifically, the presence of MPS and TrPs in the iliotibial band (ITB) can cause referred pain in the acetabulofemoral joint area, inferiorly in the anterolateral thigh, and most commonly, the lateral knee.[6] Trigger points (TrPs) within the ITB are common amongst the athletic population due to the biomechanical requirements of various sports, which predisposes the athlete to 'friction' syndromes and other soft tissue restrictions.[7–13] Because of the pain associated with MPS in the lower extremity, clinicians must approach treatment options with an understanding of the patient-reported symptoms as well as the etiology.

Algometry is a reliable, noninvasive tool and a valid way to measure pain pressure threshold (PPT). Although there is not an established value of PPT indicating the presence of a TrP, the measurement of onset of pain is a valid method to capture patient progress or outcome measures related to MPS.[20–28] Using an algometer to obtain PPT for myofascial trigger points within the iliotibial band can provide a quantitative measurement of the progress or changes of TrPs.

Within the existing literature regarding kinesiology tape, there are a myriad of gaps and limitations. The studies utilizing kinesiology tape as treatment for MPS employ taping techniques targeting overactive or underactive muscles, thereby omitting the fascial anatomy completely. This restricts the effectiveness of the tape as it influences the muscle tissue of trigger points and not the fascia. Additionally, there are reporting inconsistencies regarding the brand of the tape as well as the qualifications of the clinicians who apply the tape. Kinesio® Tape Association International provides a set of recommendations along with a certification program to become a Certified Kinesio® Tape Practitioner (CKTP). However, the lack of reported tape

brand and clinician qualifications diminishes the significance of the results and impedes the test-retest reliability. The lack of test-retest reliability within Kinesio® Tape literature leaves room for clinicians to question the products' overall efficacy. Overall, claims and recommendations made by Kinesio® Tape Association International (KTAI) need to be investigated properly with consistent methodology in order for clinicians to make informed, evidence-based treatment decisions.

Given the available literature on MPS, algometry, and fascial restrictions, the purpose of the research study was to determine the efficacy of Kinesio® Tape applied with the fascial taping technique on pain pressure threshold of trigger points of the ITB. We hypothesized Kinesio® Tex Gold FP Tape applied to TrPs within the ITB using the oscillating fascial taping technique would increase PPT and decrease pain levels. Based on the previously explained symptoms associated with MPS and TrPs within the ITB, we also hypothesized the majority of our participants would report pain or discomfort elsewhere in the kinetic chain.

4.3. Methods

For this research study, participants were recruited through email and word-of-mouth at a mid-sized university and within the surrounding communities. The first 50 people who met the inclusion criteria were included in this study. Inclusion criteria for participation consisted of meeting minimum requirements for being recreationally active or a recreational runner. Recreationally active was defined by the American College of Sports Medicine as participating at least twice a week in aerobic activity for a total of 80 minutes at moderate intensity (~5-6 METS).[29,30] Runners needed to have self-reported at least 10 miles a week for the last three months.[31–33] Exclusion criteria included acute strain or surgery to the knee, quadriceps, or hamstrings within the previous six months. Participants reported for data collection twice

throughout the duration of the study. Following IRB approval and during the first visit, the informed consent was signed and the Musculoskeletal History Questionnaire, which was modeled off of the Nordic Musculoskeletal Questionnaire,[74,75] was completed.

Following baseline information, the patient was placed in a side-lying position on their non-dominant leg for the purposes of allowing the Athletic Trainer to evaluate the dominant leg. Between one and four TrPs within the ITB were identified through a palpation technique using a cross-fiber, flat palpation method.[6] Then, the JTECH Commander Echo Console Pain Algometer (JTECH Medical Industries, Inc., Midvale, UT, 84047)was used to quantify pain pressure threshold (PPT). The rubber tip of the algometer was applied to the marked trigger point at a 90-degree angle to the ITB. Pressure was applied at a constant rate until the participant verbalized the first sensation of pain. The participants were informed the test was to quantify pain threshold, not pain tolerance, and to verbalize the onset of pain. Each trigger point was analyzed for PPT three times and averaged by the JTECH Algometer. Immediately following baseline PPT, a pain assessment via an 11-point VAS scale was given to the participant with the question "on average, how painful was the pressure?"

Prior to the taping application, the area was trimmed of hair, cleaned with an isopropyl alcohol preparation pad, and sprayed with tape adherent. The participant remained in side-lying with the dominant leg placed in approximately 45 degrees of knee flexion, 30 degrees of hip flexion, and 15 degrees of hip adduction thereby placing the ITB on stretch. The anchor of each Y-strip was initiated posterior to the ITB such that the tails of the Y would lay perpendicular to the fascial fibers of the ITB. Each tail was applied with a side-to-side oscillating fascial taping technique with 25% tension. The end of each tail was applied with no tension. To test the influence of the fascial taping technique versus a sham application, five participants were taped

in a manner that would not elicit a therapeutic response. This technique involved one long Y-strip parallel to the length of the lateral thigh with each tail adhered anterior and posterior to the ITB. To ensure no therapeutic effects were applied to the sham group, the tape was applied with no tension. All 50 participants remained in a non-weight-bearing position for 10 minutes after which a post-taping PPT reading was obtained on the identified TrPs using the protocol as previously described.

The second appointment was scheduled 48 hours following the first. At this time, participants were evaluated for PPT for a third time using the previous testing protocols. Then, the participant completed a second VAS with instructions to rate pain from the pressure during PPT testing. Finally, the tape was removed from the participants' ITB, and a timer was set for 10-minutes. Then, PPT was obtained for each TrP one last time. Lastly, the participant was awarded 20 dollars compensation for completion of the study and was dismissed.

4.4. Results

A total of N=49 participants (m=23, f=26; 23 ± 6.4 years old) completed all aspects of the study and are included in the reported results. Attrition occurred with the loss of one participant due to the admission of false reporting. Further descriptive statistics can be observed in Table 11. Participants who met the inclusion criteria participated in a variety of activities, and the specifics of the recreational activity can be observed in Table 12.

Table 11. Descriptive Statistics

Mean Height (cm.)	Mean Weight (kg.)	Mean TrPs (#)
171.12 ± 8.88	68.47 ± 11.98	2.51 ± 0.681

TrPs- Trigger Points

Table 12. Activity/Sport of Sample Population

Recreational Runner (n)	Weightlifters (n)	Cardiovascular or Cycling (n)	Team Sports (n)	Individual Sports (n)
25	6	3	6	9

Within the data collected from the Musculoskeletal History Questionnaire, some participants reported no pain within the last 12 months, whereas others reported pain in multiple areas. The results of the questionnaire are reflected in Tables 13 and 14 below.

Table 13. Musculoskeletal History Questionnaire: Participants (n) Reporting Pain in the Last 12 Months

None (n)	Hip/Pelvis (n)	Upper Leg/Thigh (n)	Knee (n)	Lower Leg/Shin (n)	Ankle/Foot (n)	Lateral Pain (n)
13	7	6	19	9	15	8

Table 14. Musculoskeletal History Questionnaire: Diagnoses by a Medical Professional (n)

Patellar Tendinitis (n)	Iliotibial Band Syndrome (n)	Medial Tibial Stress Syndrome(n)
2	4	6

Prior to our study that included 49 participants, a pilot study was conducted on N=9 participants to verify the method as well as estimate the effect size for the purpose of determining an adequate sample size. Comparing pre- and post-measurements in the pilot group resulted in an effect size of .46 (Cohen's d). Using that figure as an estimated effect size with a 5% alpha level implies that a sample size of N=42 was sufficient to attain 90% power. The sample size in the study was N=49 with n=5 holdout participants for sham taping to provide a comparison and manipulation check. Therefore, we can be reasonably confident that the sample had sufficient power to detect a meaningful difference between the groups (Table 15).

Table 15. Visual Analogue and Pain Pressure Threshold (N/cm^2) Scores for Experimental and Sham Groups

	VAS (pre)	VAS (post)	Pre-tape (N/cm^2)	Post-tape (N/cm^2)	Follow-up (N/cm^2)	Post-removal (N/cm^2)
Experimental group	3.95	3.36	35.24	37.15	37.07	25.22
	(1.67)	(1.64)	(13.48)	(13.92)	(14.70)	(11.30)
Sham group (n=5)	4.00	3.20	29.97	29.73	29.92	25.92
	(0.71)	(0.84)	(3.41)	(2.76)	(2.78)	(3.85)

Participants reported a decrease in pain when measured using the VAS with a small to medium effect size ($t[43]=4.80$, $p<.001$, $d=0.36$). There was also a slight increase in PPT from the measurement pre-tape to the first measurement with tape in place ($t[43]=2.12$, $p=.040$, $d=0.14$). The sham group similarly reported a decrease in pain on the VAS ($P=.016$), suggesting a possible placebo effect in self-reported pain; however, the sham group did not experience a similar change in pain pressure threshold.

An ANOVA model incorporating all four measurements was statistically significant ($F[3, 172]=7.96$, $p<.001$). Follow-up tests using Tukey's HSD showed that all meaningful differences occurred in comparison to the final measurement, with p-values below .001 for all pairwise comparison. The threshold was significantly less after removal of the tape, while the other three measurements were not statistically distinguishable.

The sham group, by contrast, did not show any statistically significant difference among all measurements ($F[3, 16]=0.25$, $p=.86$). This result serves as a manipulation check to show that the tape made a meaningful difference.

All analyses were repeated with biological sex as a covariate to check for differences, but all results were qualitatively similar.

4.5. Discussion

The overall purpose of this study was to analyze the effects of Kinesio® Tape applied with the fascial taping technique on myofascial trigger points (TrPs) within the iliotibial band. Although there is existing research pertaining to manufacturer specifications for muscle and space creation applications, information specific to the fascial technique to treat TrPs and restrictions associated with MPS is limited. The results of this study support the use of a fascial taping technique to increase pain pressure threshold (PPT) and decrease subjective pain associated with MPS. Although a small effect size, there was a significant decrease in perceived pain from pre-tape to 48 hours post-tape as well as an increase in PPT from pre-tape to initial application of tape. These data combined with a significant drop of PPT following tape removal is indicative the fascial taping technique is effective at treating TrPs.

Due to the pathophysiological and anatomical composure of myofascial TrPs, a fascial taping technique is indicated to correct the unorganized fiber formation and improper flow of neurotransmitters. In previous literature investigating kinesiology tape as the treatment option for MPS, the fascial layer of tissue is not considered. Instead, authors employ differing techniques[18,44] such as muscle inhibition[5,14,62] or facilitation[5,19] and space creation[76] in attempts to alleviate signs and symptoms of TrPs. The benefit of the fascial taping technique is highlighted from the lack of statistically and clinically meaningful results in the group that received the same application that did not specifically target the fascia. However, further research should be performed to compare the specific application described in this study to other suggested fascial techniques described by Kinesio® Tape.

Furthermore, there is a dearth of research investigating pain pressure threshold as a diagnostic tool or to determine a clinically significant change. Although averages of PPT have

helped determine standard values in some muscles, there is no defined quantity that distinguishes pathological tissue from healthy tissue.[22,24] However, some standards of pain tolerance have been established to form a benchmark bone to muscle tolerance ratio.[24] This involves determining a patients' PPT directly to bone, such as the forehead, then comparing the value to PPT of muscle, which if not pathological, should be higher than bone. If a patient's pain tolerance is generally low, this bone muscle ratio is helpful in determining if soft tissue hypersensitivity is present.[24] In the minimal research on pathological and clinically significant changes of PPT, healthy tendons were compared to tendons with tendonosis.[67,68] The same researcher conducted separate studies to determine a diagnostic level of PPT for patellar tendons (36.8 N)[68] along with a change considered clinically significant of PPT for patients with patellar tendinitis (19 N).[67] However, it is important to note these two related studies[67,68] evaluated pathological tendon as opposed to our study that involved fascial restrictions of the ITB.

Moreover, there are studies cited as determining a minimal clinically significant change in PPT of healthy muscle tissue.[69,70] From these protocols, two clinically meaningful changes in PPT were identified to be ≥10.78 N/cm^2 [69] and ≥11.38 N/cm,^{2} [70] respectively. Two PPT values in our study attained this level of change: 10-minutes post-tape to post-tape removal and 48-hours post-tape to post-tape removal with a decrease of 11.93 N/cm^2 and 11.85 N/cm^2, respectively. Certain PPT values in our study did not reach a change deemed clinically meaningful, however, PPT values from pre-tape to 10 minutes post-tape (+1.91 N/cm^2) were statistically significant ($t[43]=2.12$, $p=.040$, $d=0.14$). Lastly, wearing the tape for 48-hours, from the first session to the follow-up, there was an insignificant decrease in PPT of 0.08 N/cm^2. Therefore, our participants experienced a statistically significant improvement in PPT with the initial application, followed by no significant change over 48-hours. However, once the tape was removed, a clinically

significant increase in PPT occurred, indicating initial application and removal of the tape is effective at influencing PPT of TrPs within the ITB. Lastly, the significant decrease in VAS suggests the participants' perceived pressure applied to the TrP to be less painful following application of the Kinesio® Tape.

Further supporting the applicability of the results of this study, Walton et al. (2011)[72] reported important conclusions regarding PPT employed to detect change overtime. The authors state PPT may not accurately detect worsening or decreased PPT in patients whose baseline PPT is very low. Overall, PPT is more adept at identifying change when the baseline is higher to begin with, such as in asymptomatic patients.[72] Therefore, omitting 'symptomatic' as an inclusion criteria for the present study further supports the reliability of the PPT results in this study. The same researcher in a later observational study found algometry is more proficient at detecting change than ruling out change, thereby indicating the tool has a high specificity (0.92) and negative predictive value (0.86).[71] Overall, the diagnostic tool is suitable to determine minimally detectable changes and overall low or hypersensitive pain pressure threshold. Future research should seek to analyze algometry with the use of symptomatic and asymptomatic participants.

The MSKHQ revealed notable instances of kinetic chain disturbances in participants. Of the N=49 participants, recreational runners (n=36) reported pain or discomfort in their lower extremities within the last 12 months. Further, n=19 reported knee pain and n=7 reported hip pain, which are both commonly affected areas secondary to TrPs within the ITB.[6] Overall, there were eight descriptions of 'lateral' pain of the lower extremities, which is also indicative of ITB fascial restrictions.[6] Moving distally along the kinetic chain, n=15 reported ankle or foot pain during the same time frame. Those who stated being diagnosed by a medical professional

commonly recounted Medial Tibial Stress Syndrome (n=6), tendonitis/tendinopathy (n=5), and Iliotibial Band Syndrome (n=4). Notably, three instances of referred pain were described by separate participants suggesting the presence of active trigger points.[1] Based on the data from the MSKHQ, it is evident to the researchers that myofascial restrictions in the ITB are commonly accompanied by other issues along the kinetic chain. Our findings are supported by past research on TrPs in the ITB and how they affect the surrounding soft tissue, such as pain in the lateral quadriceps and the knee.[6] Although the questionnaire revealed kinetic chain relationships, a full understanding of the impact ITB fascial restrictions have on the lower kinetic chain remains under-researched. Additional longitudinal studies need to be conducted investigating those who suffer from MPS of the ITB.

The lack of objective data observed in this study is an obvious limitation. While the analysis of patient-perceived outcomes, such as pain, is undeniably helpful to the treatment of pain disorders, the lack of objective data is an evident delimitation. Future research investigating pain pressure threshold of TrPs should seek to involve an objective data point, such as diagnostic sonography to visualize changes in the TrP. Combined with a doppler analysis of blood flow to the TrP, dimensions of the nodule would reveal if the treatment was successful in lessening the tissue restriction. Moreover, future researchers should consider applying a different brand of kinesiology tape with the same oscillating fascial taping technique to reveal any differences compared to Kinesio Tape® FP. Regarding the large drop of PPT following the removal of the tape, there are limitations noted by the authors, which could have influenced the significant change. First, it was the final PPT measurement; therefore, the participant could have prematurely reported pain in anticipation of the completion of the study. Additionally, there is a sensorimotor stimulus associated with tape on the skin, which could have a placebo effect on the

participants' pain, causing them to experience a heightened sense of pain threshold once the stimulus of tape was removed after 48 hours.

4.6. Conclusion

Applied with the oscillating fascial technique, Kinesio Tape® FP can be effective at decreasing patient-perceived pain associated with pressure on TrPs. Further, the statistically significant differences in PPT at four points, specifically the significant drop following tape removal, indicates the tape application can affect PPT of TrPs within the ITB. Due to the sham tape producing no significant variance between any PPT measurements, there is sufficient evidence to suggest the oscillating fascial technique is effective at manipulating PPT of TrPs. Overall, more pressure was needed to elicit pain and the TrPs became less symptomatic. Therefore, Kinesio Tape® FP should be considered by clinicians when treating pain secondary to TrPs within the ITB.

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APPENDIX. IRB APPROVAL LETTER

NDSU NORTH DAKOTA STATE UNIVERSITY

February 3, 2020

Dr. Katie Lyman
Health, Nutrition & Exercise Sciences

IRB Approval of Protocol #HE20151, "An Analysis of Kensio® Tape on Myofascial Pain Syndrome of the Iliotibial Band"
Co-investigator(s) and research team: Hanna Riegel
Protocol Reviewed: 1/9/2020
Protocol Status Update Due prior to: 1/8/2023

Research site(s): NDSU Funding Agency: n/a
Review Type: Expedited category # 1(a), 4
IRB approval is based on the protocol materials (received 1/27/2020). Please use the consent form submitted 1/27/2020.

Additional approval from the IRB is required:
o Prior to implementation of any changes to the protocol (Protocol Amendment Request Form).
o For continuation of the project beyond the approval period (Continuing Review Report Form). A reminder is typically sent approximately 4 weeks prior to the expiration date; timely submission of the report the responsibility of the PI. To avoid a lapse in approval, suspension of recruitment, and/or data collection, a report must be received, and the protocol reviewed and approved prior to the expiration date.

Other institutional approvals:
• Research projects may be subject to further review and approval processes.

A report is required for:
o Any research-related injuries, adverse events, or other unanticipated problems involving risks to participants or others within 72 hours of known occurrence (Report of Unanticipated Problem or Serious Adverse Event Form).
o Any significant new findings that may affect risks to participants.
o Closure of the project (Protocol Termination Report).

Research records are subject to random or directed audits at any time to verify compliance with human subjects protection regulations and NDSU policies.

Thank you for cooperating with NDSU IRB procedures, and best wishes for a successful study.

Sincerely,
Kristy Shirley
Kristy Shirley, CIP, Research Compliance Administrator

For more information regarding IRB Office submissions and guidelines, please consult https://www.ndsu.edu/research/for_researchers/research_integrity_and_compliance/institutional_review_board_irb/. This Institution has an approved FederalWide Assurance with the Department of Health and Human Services: FWA00002439.

INSTITUTIONAL REVIEW BOARD
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