Kinesio Tape has a positive effect on facilitation of the tibialis posterior muscle during walking gait

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**CONTEXT:** Excessive pronation is a common problem that may be linked to a variety of lower extremity pathologies. Kinesio Tape (KT) facilitation of the tibialis posterior muscle will act to supinate the foot and decrease navicular drop. **OBJECTIVE:** To determine if KT facilitation of the tibialis posterior muscle on participants with excessive pronation will decrease navicular drop, talar eversion, and calcaneal eversion during walking gait. **DESIGN:** Repeated measures pre-test/post-test. **PARTICIPANTS:** 25 participants with pronated feet (age = 20.39 ± 1.00 years), 11 male and 14 female. **INTERVENTIONS:** KT facilitation of the tibialis posterior muscle. Standard treadmill used for consistent walking surface at self-determined normal pace; Canon HD Vixia HF100 camera (Canon Inc.; Tokyo, Japan) recording 30 frames at 60i at a perpendicular angle to walking surface of treadmill in anterior, posterior, and medial views; recordings taken prior to taping (PT), immediately after taping (IP), after three days of wearing tape (3D), and immediately after tape removal (UT). **OUTCOME MEASURES:** Dartfish software (Dartfish Inc., Fribourg, Switzerland) used to assess dynamic navicular drop, talar movement, and calcaneal eversion; SPSS (Chicago, IL) using repeated measures ANOVA (α = 0.025). **RESULTS:** Dynamic navicular drop angle was significantly decreased ($F(2.4, 115.1) = 13.4, p = 0.000$); dynamic talar movement angle was significantly decreased ($F(2.3, 114.7) = 7.4, p = 0.001$); dynamic calcaneal eversion angle was significantly decreased ($F(2.1, 102.4) = 4.4, p = 0.013$). **CONCLUSIONS:** KT had a significant effect on decreasing dynamic pronation within the population from PT to IP, IP to 3D, PT to UT, and 3D to UT.

**Keywords:** tibialis posterior muscle, pronation, Kinesio tape
INTRODUCTION

Pronation is a necessary, shock absorbing motion at the ankle characterized by adduction and plantarflexion of the talus with eversion of the calcaneus while the foot is weight bearing.\textsuperscript{1-3} Pronation can reach excessive levels. Over pronation is indicated as excessive eversion of the calcaneus during stance, excessive internal rotation of the tibia, lowering of the medial plantar arch, and plantarflexion and adduction of the talus causing a medial bulge of the talar head. Apart from visual inspection, excessive calcaneal eversion during stance is verified by inward bowing of the Achilles tendon.\textsuperscript{1}

Some pronation is necessary to absorb shock placed on the foot by body weight during ground contact and for foot adaptation to the walking surface.\textsuperscript{1, 2, 4} It is when pronation becomes excessive, due to a structural or functional deformity, that it also may become pathological.\textsuperscript{1, 2, 4} Pronation in excess has been linked to a variety of lower extremity injuries located solely in the foot and ankle including but not limited to: stress fracture of the second metatarsal, hallux valgus due to hypermobility of the first ray, plantar fasciitis, posterior tibialis tendinosis, tarsal tunnel syndrome, Achilles tendinopathy, and medial tibial stress syndrome.\textsuperscript{3} Apart from being linked to lower leg pathologies, excessive pronation has also been associated with injuries up the kinetic chain, such as patellofemoral pain syndrome, iliobibial band friction syndrome, medial knee pain, and hip muscle imbalances.\textsuperscript{1-4} Prentice\textsuperscript{3} reported that over pronation causes excess subtalar eversion and adduction, leading to internal rotation of the tibia and femur, subsequently causing a valgus force at the medial knee that produces medial tracking of the patella. The tibialis posterior muscle plays a significant role in stabilizing the medial longitudinal arch (MLA) during gait and stance.\textsuperscript{2-6} Based on the line of pull of the tibialis posterior muscle, shortening of the muscle could supinate the rearfoot and raise the MLA of the foot.\textsuperscript{4}
Two ways to determine if a person has excessive pronation are a navicular drop test (NDT) and two-dimensional (2D) analysis of gait.\textsuperscript{6-11} A navicular drop value greater than 10 mm indicates excessive pronation.\textsuperscript{3, 7} The NDT is a reliable measure of static stance MLA deformation with an inter-rater reliability of 0.94 in a study by Lange et al.\textsuperscript{7, 11} To obtain a measure of dynamic navicular drop, 2D analysis of gait may be used. Although 2D analysis is a cheaper and less sophisticated analysis than three-dimensional analysis, it can be as reliable.\textsuperscript{6, 9} Additionally, Bencke et al\textsuperscript{6} found that 2D angles during walking gait had a high repeatability when measuring MLA deformation. Also, when MLA deformation was measured using 2D angles, the standard error of measurement was similar to the standard error of three dimensional analysis.\textsuperscript{6} Finally, the correlation between the three-dimensional measurements and 2D measurements was greater than the correlation between NDT and three-dimensional measurements in Bencke et al’s\textsuperscript{6} investigation as well, making 2D analysis more accurate at analyzing functional navicular drop than the NDT.

The theory behind correcting pronation is that by altering the alignment of the foot, it is possible to change activation timing of muscles of the proximal leg and properly align the rest of the lower leg.\textsuperscript{10, 12} This proper alignment and change in muscle activation can place the body in a position to minimize overuse injuries and reduce pain.\textsuperscript{10} Investigation into correction of excessive pronation has examined the effects of low-dye taping, augmented low-dye taping, shoes, and orthotics.\textsuperscript{3, 8, 10, 12-15} Low-dye taping has been found to reduce pronation for short periods.\textsuperscript{14} The goal of augmented low-dye taping, a variation of low-dye taping, is to support the MLA.\textsuperscript{3} Research using augmented low-dye taping has shown positive effects of the taping technique in biomechanical alteration of the foot and muscle activation at the foot, ankle, and hip.\textsuperscript{12-13} Foot orthoses have also had positive effects on decreasing symptoms and biomechanical
Lastly, shoes with adequate rear foot control have had positive effects by limiting pronation. Although there have been effective measures found to correct pronation, they are not always applicable. For example, barefoot athletes are unable to wear foot orthotics or shoes. Further, both low-dye and augmented low-dye taping have only had short term effects on correcting pronation.

A new form of tape called Kinesio Tape (KT) is made to mimic the qualities of the skin. The thickness of the tape is approximately the same as the epidermis of the skin so that body perception of the tape is limited. The participant does not perceive the tape approximately ten minutes post-application. The tape can be stretched longitudinally to 55-60% of its original length, and its elastic qualities allow it to be effective for 3-5 days after application. The cotton fibers of KT allow for evaporation of body moisture and quick drying so that the tape has better adhesive ability during exercise and can also be worn while swimming or bathing. Claims for KT state that proper application to the skin will assist the body to function normally. Meaning, that although the tape may not place the body in a position it is used to; its tension will place the body in a position so that its kinetics function normally to limit pain or injury. Kase et al claims that different applications of KT can facilitate or inhibit a muscle, limit edema and pain, or assist lymphatic drainage. The research examining these claims, especially muscle facilitation and inhibition, has had conflicting results. Research has supported the effect of KT on increasing strength of muscles. KT has also been found to aid in obtaining proper alignment in the body, increase the active range of motion in joints with weakened muscles, and affect the timing of activation of muscles. The effect of KT on the upper extremity has been well researched, but few studies have investigated the use of the tape on the lower extremity.
The purpose of this study is to investigate the effects of KT facilitation of the tibialis posterior muscle on participants with excessive pronation. I hypothesize that:

<table>
<thead>
<tr>
<th>2D Analysis Hypotheses</th>
<th>Landmarks</th>
<th>Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dynamic Navicular Drop</strong></td>
<td>Endpoint: head of 1st metatarsal Apex: navicular tuberosity Endpoint: sustentaculum tali of calcaneus</td>
<td>Angle will decrease</td>
</tr>
<tr>
<td>(DND)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dynamic Talar Movement</strong></td>
<td>Endpoint: anterior apex of medial malleolus Apex: center of Talus Endpoint: anterior apex of lateral malleolus</td>
<td>Angle will decrease</td>
</tr>
<tr>
<td>(DTM)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dynamic Calcaneal Eversion</strong></td>
<td>Endpoint: middle of calcaneus Apex: apex of calcaneus Endpoint: middle of gastrocnemius</td>
<td>Angle will increase</td>
</tr>
<tr>
<td>(DCE)</td>
<td></td>
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</table>

Table 1: Description of angles measured and hypotheses of the effect of KT facilitation of the tibialis posterior muscle.

**LITERATURE REVIEW**

**Anatomy**

The foot contains twenty six bones and is divided into three regions, the forefoot, midfoot, and rearfoot.\(^1\,4\) For simplicity, the bones, articulations and ligaments will be discussed according to these three regions. The forefoot contains five metatarsals and fourteen phalanges, 5 distal phalanges, 4 middle phalanges, and 5 proximal phalanges.\(^1\,3,4\) The distal phalanges articulate with the middle phalanges at the distal interphalangeal joints.\(^1\,3\) The middle phalanges articulate with the proximal phalanges at the proximal phalangeal joints.\(^1\) Each interphalangeal joint is supported by a joint capsule and collateral ligaments.\(^1\) The proximal phalanges then join with the metatarsals at the metatarsophalangeal joints.\(^1\) The metatarsophalangeal joints are reinforced by the plantar fascia and the plantar ligament on their plantar aspect as well as medial and lateral collateral ligaments.\(^1\) Between the metatarsals are four proximal and distal
intermetatarsal joints that are formed by the bases and heads of adjacent metatarsals, respectively. The proximal intermetatarsal joints are supported by the interosseous, plantar, and dorsal ligaments whereas the distal joints are supported by the deep transverse ligament and the interosseous ligament.

The forefoot meets the midfoot at the tarsometatarsal joints, formed by the metatarsals and the distal tarsal bones. The first, second, and third metatarsals articulate with the first, second, and third cuneiforms, respectively. The cuneiforms lay side by side and also articulate with each other. The fourth and fifth metatarsals articulate with the cuboid. The cuboid also articulates on its medial side with the third cuneiform and navicular, and with the calcaneus posteriorly. The navicular articulates with the three cuneiforms anteriorly, the cuboid laterally, and the talus posteriorly.

The rear foot meets the midfoot at two joints. The first being the articulations of the navicular, calcaneus and talus at the talocalcaneonavicular joint. This joint is supported by the plantar calcaneonavicular ligament, that runs from the sustentaculum tali of the calcaneus to the inferior aspect of the navicular, and supports the MLA of the foot. The second joint is created by the articulation of the cuboid and calcaneus at the calcaneocuboid joint. This joint is supported by the dorsal and plantar calcaneocuboid ligaments, the long plantar ligament, and plantar fascia.

The foot contains three arches. The transverse metatarsal arch is formed by the lengths of the five metatarsals and the tarsal bones. The lateral longitudinal arch consists of the calcaneus, cuboid, and fifth metatarsal and is continuous with the MLA. The MLA consists of five bones: the calcaneus, talus, navicular, first cuneiform, and first metatarsal. Among these five bones, the navicular is considered to be the keystone of the MLA.
The rearfoot contains the calcaneus and talus.\textsuperscript{1,4} Aside from the navicular, the talus articulates with 4 other bones.\textsuperscript{1} The calcaneus and the talus articulate at the subtalar or talocalcaneal joint.\textsuperscript{1,3} The talocalcaneal joint is supported by the ligamentum cervicis and interosseous talocalcaneal ligament which run through the tarsal canal.\textsuperscript{1} It is also supported by the lateral talocalcaneal, medial talocalcaneal, and posterior talocalcaneal ligaments, parts of the deltoid ligament, which maintain the alignment of the two bones and support the joint.\textsuperscript{1} The talus also meets the medial malleolus, lateral malleolus, and the distal end of the tibia superiorly.\textsuperscript{1} The medial and lateral malleoli are part of the tibia and fibula, respectively.\textsuperscript{1} The two malleoli house the talus in what is called the ankle mortise or the talocrural joint.\textsuperscript{1} This joint is supported by a series of ligaments. The anterior talofibular ligament, located between the anterolateral surface of the lateral malleolus and the lateral talus, prevents anterior translation of the talus on the tibia and also resists inversion and internal rotation of the talus.\textsuperscript{1} The calcaneofibular ligament, attaching from the lateral portion of the lateral malleolus and the calcaneus, resists inversion.\textsuperscript{1} The posterior talofibular ligament is the deepest and strongest ligament, running from the posterior aspect of the lateral malleolus to the talus and calcaneus; it limits posterior displacement of the talus on the tibia.\textsuperscript{1}

On the medial ankle, the deltoid ligament complex provides the ligamentous support. The ligament complex is comprised of four ligaments.\textsuperscript{1} The anterior tibiotalar ligament attaches at the anteromedial malleolus and travels to the superior portion of the medial talus.\textsuperscript{1} The tibiocalcaneal ligament arises off of the apex of the medial malleolus and attaches at the posterior portion of the talus.\textsuperscript{1} The posterior tibiotalar ligament is located from the posterior aspect of the medial malleolus to the posterior portion of the talus.\textsuperscript{1} These three ligaments work together to resist eversion of the talus.\textsuperscript{1} The final ligament is the tibionavicular ligament which
travels from the medial malleolus to the medial navicular, it resists lateral translation and lateral rotation of the tibia on the foot.¹

Although muscles and ligaments provide stability, muscles also act to provide dynamic stability and initiate movement. The muscles in the foot that act on the phalanges and metatarsophalangeal joints include the abductor digiti minimi, abductor hallucis, adductor hallucis, flexor digiti minimi brevis, flexor digitorum brevis, flexor hallucis brevis, dorsal and plantar interossei, lumbricals, quadratus plantae, extensor hallucis brevis, and extensor digitorum brevis.¹ The muscles of the leg, which are more pertinent to this study and act on the ankle, foot, and digits are the flexor digitorum longus, flexor hallucis longus, gastrocnemius, peroneus brevis, peroneus longus, plantaris, soleus, tibialis posterior, extensor digitorum longus, extensor hallucis longus, peroneus tertius, and tibialis anterior.¹

The gastrocnemius and soleus muscles both attach to the calcaneus distally by the Achilles tendon on the calcaneal tubercle and are the primary muscles in plantarflexion.¹ ³ The gastrocnemius muscle consists of two proximal heads. The medial head attaches at the medial femoral condyle on the posterior side and the adjacent portions of the femur and knee capsule.¹ The lateral head attaches at the lateral femoral condyle on the posterior side and adjacent part of the femur and knee capsule.¹ The soleus muscle attaches proximally at the posterior fibular head and upper one third of its posterior surface as well as the posterior tibial shaft and middle one third of the medial tibial border.¹

The peroneus longus muscle attaches at the lateral tibial condyle, fibular head and proximal two thirds of the lateral fibula and travels to insert on the lateral base of the first metatarsal, and lateral and dorsal parts of the first cuneiform.¹ This muscle works to pronate the foot and assist in ankle plantarflexion.¹ The peroneus brevis muscle attaches at the distal two
thirds of the lateral fibula and the styloid process of the base of the fifth metatarsal; it acts to pronate the foot and assist in ankle plantarflexion as well.\textsuperscript{1} Attaching at the distal one third of the anterior fibula and interosseous membrane and the dorsal surface of the base of the fifth metatarsal, the peroneus tertius muscle works to pronate the foot and dorsiflex the ankle.\textsuperscript{1}

The extensor digitorum longus muscle acts to extend metatarsophalangeal and interphalangeal joints two through five as well as assist in foot pronation and ankle dorsiflexion.\textsuperscript{1} The muscle attaches at the lateral condyle of the tibia, proximal anterior fibula and interosseous membrane and travels to the distal phalanges of digits two through five.\textsuperscript{1} The extensor hallucis longus muscle extends the first metatarsophalangeal and interphalangeal joints and assists in ankle dorsiflexion.\textsuperscript{1} The extensor hallucis longus muscle begins at the middle two thirds of the anterior fibula and the adjacent interosseous membrane and connects again at the base of the first distal phalanx.\textsuperscript{1} The tibialis anterior muscle dorsiflexes and supinates the foot; running from the lateral condyle and upper half of the tibia’s lateral surface and the interosseous membrane to the medial and plantar surface of the first cuneiform.\textsuperscript{1}

The flexor digitorum longus muscle flexes the interphalangeal and metatarsophalangeal joints two through five as well as assist in ankle plantarflexion and foot supination.\textsuperscript{1} This muscle attaches at the distal two thirds of the posteromedial tibia and the fascia of the tibialis posterior muscle and runs to the plantar base of distal phalanges two through five.\textsuperscript{1} The flexor hallucis longus muscle works to flex the first interphalangeal and metatarsophalangeal joints as well as assist in foot supination and ankle plantarflexion. Its attachments are on the distal two thirds of the posterior fibula and the plantar surface of the first proximal phalanx.\textsuperscript{1} The tibialis posterior muscle acts to supinate the foot and assist in ankle plantarflexion.\textsuperscript{1} Its proximal attachments include the interosseous membrane, the posteriolateral tibia, and upper two thirds of the medial
fibula. The tibialis posterior muscle attaches on the tuberosity of the navicular bone, and the sustentaculum tali of the calcaneus, the plantar surface of each of the three cuneiforms, the cuboid, and the bases of the metatarsals two through four.

Branches of the femoral, tibial, and peroneal nerves supply innervations to the lower leg and foot. The tibial nerve supplies the tibialis posterior, flexor digitorum longus, flexor hallucis longus, soleus, plantaris, and gastrocnemius muscles. The tibial nerve also supplies the plantar aspect of the foot. The tibial nerve branches into the medial sural nerve which supplies the skin of the posterior leg and lateral foot, and the lateral and medial plantar nerves which supply the plantar surface of the foot. The deep peroneal nerve innervates the extensor hallucis longus, extensor digitorum longus, and tibialis anterior muscles in the leg. The nerve then travels inferiorly to innervate the dorsal surface of the foot with the superficial peroneal nerve. The superficial peroneal nerve also innervates the peroneus longus and brevis muscles. Finally, the saphenous nerve, a branch of the femoral nerve, innervates the skin of the medial ankle and foot.

**Proprioception**

The nerves that supply motor and sensory signals contribute to proprioceptive neuromuscular control of the ankle. Proprioception is the use of sensory input from the eyes and inner ears as well as receptors found in muscle spindles, tendons, and joints to allow the body to distinguish joint position and movement. Pressure sensations elicited from the sole of the feet provide the brain with information regarding weight distribution between the feet as well as where the weight is distributed on a particular foot.

Kinesthesia, also known as position sense, is often coupled with proprioception and is defined as the awareness of the body in space or dynamic joint motion. Kinesthetic signals in
response to body movements and tensions with in tendons arise from sensory receptors found in muscles, tendons, and joints.\textsuperscript{3, 27} This conscious and unconscious awareness that occurs with proprioception and kinesthesia is crucial to motor learning, muscle function, and reflex stabilization.\textsuperscript{3, 27}

There are two types of neuromuscular control.\textsuperscript{3} The first is feed-forward control which involves the ability to plan movements that are based on sensory information from past experiences.\textsuperscript{3} Feed-forward control provides preparatory muscular activation.\textsuperscript{3} The second type of neuromuscular control is feedback.\textsuperscript{3} Feedback is constantly regulating muscle activity through reflex pathways.\textsuperscript{3} This type of control provides reactive muscle activity.\textsuperscript{3} If sensory and motor pathways are stimulated frequently, feed-forward and feedback neuromuscular controls can enhance the dynamic stability.\textsuperscript{3} This regular stimulation will create a memory of the signal so that the movement can be easily recalled.\textsuperscript{3, 27} Callaghan et al\textsuperscript{28} investigated the effect of a constant stimulus on proprioception through the use of patellar taping and its effect on proprioception at the knee. Callaghan et al\textsuperscript{28} found that there was an increase in brain response during proprioceptive activities during the taped condition versus the un-taped condition. The findings of the study show that the brain does react to a constant stimulus, although the researchers did not investigate the recall of the movement.\textsuperscript{28} Apart from easy recall of movement, increased muscle activation will also increase the stiffness of the muscle, which in turn will improve stretch sensitivity of the muscle.\textsuperscript{3} Increased stiffness of muscles provide for a more effective resistance to joint displacement, as a result a joint that is supported by regularly activated muscles will have a decrease in dynamic range of motion.\textsuperscript{3}
Biomechanics

To talk about the motions that occur at the ankle during walking gait, it is easiest to separate the gait cycle into phases. The gait cycle is separated into two distinct phases, stance and swing. These phases are then subdivided into parts. The stance phase begins with loading response, which starts the instant the heel hits the ground and ends when the opposite foot’s toe leaves the ground. Midstance follows, starting when the opposite foot leaves the ground and ending when all of the body weight is over the support limb. The next part of stance phase is terminal stance. This subphase begins when the weight is directly over the support limb and ends when the limb in swing phase touches the ground. The swing phase is subdivided into three parts. Pre-swing phase begins when the opposite limb touches the ground and ends when the limb in swing phase leaves the ground. Initial swing follows, starting when the foot leaves the ground and ending when the foot of the swing limb is adjacent to the foot of the stance limb. The mid-swing occurs from when the foot is adjacent to the support limb until the tibia is vertical with the ground. The final part is terminal swing, starting with the tibia vertical to the ground and ending just before the swing limb makes heel contact and starts the loading response of the gait cycle.

In order for the gait cycle to move fluidly, different motions occur at each joint throughout the cycle. During the loading response phase, the hip is in slight external rotation and flexed to approximately 30 degrees. The gluteus maximus and hamstring muscles are eccentrically contracting to slow hip flexion during this phase. The knee is also flexed to approximately five degrees and continues to flex until reaching the next phase of stance. The quadriceps muscles are contracted to control knee movement during acceptance of weight in this phase. The tibias anterior, extensor digitorum, and extensor hallucis muscles are eccentrically
contracting to decelerate plantarflexion that is happening at the talocrural joint. The tibialis posterior muscle is working to decelerate pronation caused by the peroneal muscles and maintain the subtalar joint’s inverted position. The first metatarsophalangeal joint is slightly extended.

As the body moves into midstance the hip internally rotates and extends as the gluteus maximus muscle contracts. The knee extends as the quadriceps muscles contract and the tibia internally rotates. The soleus and gastrocnemius muscles contract eccentrically to control movement at the talocrural joint as the ankle plantarflexes, adducts, and inverts as the plantar surface of the foot touches the ground. The ankle then dorsiflexes, abducts, and everts as the body weight moves to be directly over the support limb. The subtalar joint goes through a rapid eversion of the calcaneus following heel contact until the body reaches midstance. During midstance the subtalar joint begins to invert, and this inversion continues through the terminal stance. The tibialis posterior and peroneal muscles continue to counteract each other during subtalar motion. The first metatarsophalangeal joint is in a neutral position during midstance.

During terminal stance, the hip continues to extend to approximately 10 degrees and the femur is externally rotating. The iliopsoas muscle is eccentrically contracting to slow hip extension. The knee flexes again as the heel leaves the ground and the tibia rotates externally. The ankle reaches maximal dorsiflexion just when the heel leaves the ground. There is a major contraction from the gastrocnemius and soleus muscles to plantarflex the ankle. The subtalar joint continues to invert as the tibialis posterior muscle contracts until the limb enters the swing phase. The first metatarsophalangeal joint begins to extend as the heel leaves the ground as well.

As the body enters the pre-swing phase, the hip is at full extension and the femur is externally rotated. The iliopsoas and sartorius muscles contract and the hip begins to flex and
reaches neutral position as the pre-swing phase ends at toe off. The knee is flexed to approximately 35 degrees. The ankle continues to plantarflex due to the contraction of the gastrocnemius and soleus muscles. The tibialis posterior muscle is still contracting to cause the subtalar joint to be inverted maximally at toe-off. The first metatarsophalangeal joint is extended.

The iliopsoas and sartorius muscles continue to concentrically contract and the hip flexes past the neutral position during initial swing and the femur internally rotates. The knee flexes to approximately 60 degrees to clear the foot from the ground and the tibia internally rotates. The talocrural joint dorsiflexes due to contraction of the tibialis anterior, extensor digitorum, and extensor hallucis longus muscles until it reaches the neutral position in order to clear the toe. The subtalar joint remains slightly inverted and the first metatarsophalangeal joint is now in a neutral position due to extensor digitorum and extensor hallucis longus muscle contraction.

As the body enters the final phase of the gait cycle, the sartorius muscle is still contracting and the hip is continuing to flex and internally rotate. The gluteus maximus muscle begins contraction to decelerate hip flexion as the hip reaches maximal flexion just before heel contact. The femur continues to internally rotate. The quadriceps muscles activate and the knee extends almost to full extension, then flexes again as the hamstring muscles contract and the limb prepares to accept weight during heel contact. The tibialis anterior muscle continues contracting as the talocrural joint dorsiflexes and prepares for heel contact and the subtalar joint remains slightly inverted. The first metatarsophalangeal joint is extending slightly as the foot prepares for heel contact due to contraction of the extensor digitorum and extensor hallucis longus muscles.
**Pronation and Injury**

A variety of lower extremity injuries are often associated with excessive pronation.\(^1,3\) Those occurring at the foot and ankle include but are not limited to: stress fracture of the second metatarsal, hallux valgus due to hypermobility of the first ray, plantar fasciitis, posterior tibialis tendinosis, tarsal tunnel syndrome, Achilles tendinopathy, and medial tibial stress syndrome.\(^1,3,29,30,31,32\) Excessive pronation creates a hypermobile MLA.\(^4\) This hypermobile arch creates an increase in stress on the forefoot as a result of ground reaction forces acting on the foot to force the forefoot and midfoot into a supinated position.\(^4\) This increased repetitive stress on the structures of the forefoot and decreased ability to dissipate loads causes stress fractures and the pathology of hallux valgus.\(^1,4\) Jurgel\(^29\) reported that a decrease in plantar pressures in the fourth and fifth metatarsals and an increase in plantar pressures in the medial forefoot has been shown in people with excessive pronation. Glasoe et al\(^30\) proposed that excessive pronation places the first metatarsal in an adducted position. The increased pressure in the medial foot coupled with a more adducted first metatarsal would put a varus stress on the first phalanges leading to hallux valgus of the joint.\(^29,30\) The repetitive deformation of the MLA often leads to plantar fasciitis, again because of the hypermobility of the arch.\(^1\) The plantar fascia acts as a bowstring on the normal foot by pulling the calcaneus toward the metatarsals to create a “bow” or arch in the foot.\(^1\) When the MLA is hypermobile, the plantar fascia is stressed causing inflammation of the structure, or in some cases, the structure begins to pull away from its origin on the calcaneus.\(^1\) Excessive rearfoot varus creates a non-uniform tension on the Achilles tendon which could lead to the degenerative changes and pain seen in Achilles tendinopathy.\(^31\) Posterior tibialis tendinosis and medial tibial stress syndrome are linked to a dysfunction between the force couple created by the tibialis posterior and tibialis anterior muscles, although the effect of the
dysfunction on the pathologies should be further investigated.¹ Rearfoot varus with excessive pronation increases the internal rotation of the tibia.¹ When this is combined with a hypermobile MLA, increased stress is placed on the tibial nerve which may cause tarsal tunnel syndrome.¹

Further up the kinetic chain, excessive pronation has been related to injuries such as: patellofemoral pain syndrome, iliotibial band friction syndrome, medial knee pain, and hip muscle imbalances.¹⁻⁴ Excessive pronation creates an increased internal rotation of the tibia and in turn a more adducted femur.¹⁻⁴ Chueng and Ng³² reported that increased internal rotation creates a delay in external rotation of the tibia creating an altered alignment between the tibia and femur. The change in alignment of the tibia and femur alters the contact area of the patella on the patellofemoral groove.⁴ This may create maltracking of the patella or patellofemoral pain syndrome.⁴ The rearfoot eversion associated with pronation causes a valgus stress at the knee, creating medial knee pain as well as laxity or increased risk of injury to the medial collateral ligament.⁴ This valgus stress also creates a more adducted femur causing the hip adductor muscles to be tighter and the hip abductor muscles to be weaker.⁴

Previous Research

2D Analysis of Walking Gait and NDT

A NDT is a measure of MLA deformation during static weight bearing; however, two types of dynamic measurements, three-dimensional and 2D, can be used to study excessive pronation during movement.⁴ Where 2D measurements account for movements that occur in the sagittal and frontal planes, three-dimensional measurements take into account sagittal, frontal, and transverse planes.⁴ During three-dimensional analysis of the foot and ankle, movements such as internal and external rotation can be accounted for in addition to dorsiflexion, plantarflexion, eversion, and inversion.⁴
Few studies have investigated the validity of NDT, however many studies use the test as criterion for participation.\textsuperscript{7, 8, 10} Bencke et al\textsuperscript{6} investigated the validity of the NDT as it related to dynamic MLA deformation. The researchers\textsuperscript{6} also investigated the validity of two clinical measurements of MLA deformation. Bencke et al’s\textsuperscript{6} study used male participants who had not suffered lower leg or foot pathologies nor any lower extremity orthopedic injury within the past six months.\textsuperscript{6} The study required one static NDT measurement and two dynamic measurements of each MLA.\textsuperscript{6} The NDT was modified to incorporate a force plate and tandem stance; an average of three repeated measurements were reported as the NDT data.\textsuperscript{6} The dynamic tests required three markings on the foot that were defined as the MLA: the medial aspect of the head of the first metatarsal bone, the medial tuberosity of the navicular, and a point on the medial surface of the calcaneus found using a measuring tool created by the researchers.\textsuperscript{6} For the 2D analysis, Bencke et al\textsuperscript{6} used a pressure mapping mat and a standard digital video camera placed at a 90 degree angle to the walking path with a frame rate of 50 Hz. From the video, the angle of MLA was determined at five different points of the gait cycle.\textsuperscript{6} These points included at initial heel strike before a load was placed on the arch, at the instant load was applied to the arch, at midstance, at the initial point that the heel leaves the ground, and finally at toe off.\textsuperscript{6} For three-dimensional analysis, the same foot markings were used as 2D with the same points in walking gait being measured as well.\textsuperscript{6} The three-dimensional angle was modified to be in the vertical plane so that the heel was incorporated into the measurement.\textsuperscript{6} An eight-camera video system recording at 100MHz was used for the three-dimensional recordings.\textsuperscript{6} Five trials were completed for the 2D and the three-dimensional measurements and the average values were taken for each foot.\textsuperscript{6} The examiners\textsuperscript{6} defined the actual arch deformation angle as the difference between the angle measured at the initial point that the heel leaves the ground and the angle
measured during initial heel contact. The researchers calculated reliability of the MLAD angles from 2D and three-dimensional measurements as well as the difference between the two analyses. Results showed that 2D angles were significantly lower than three-dimensional measurements, and that reliability of three-dimensional MLA deformation evaluation was most accurate. The three-dimensional test was only moderately correlated with the NDT, researchers speculate that this may be from a difference in loading during walking and standing. The researchers also found a significant difference between three-dimensional and 2D measurements. However, repeatability for both measurements was high and the correlation between 2D measurements and three-dimensional measurements was higher than the correlation to NDT. The study only examined the MLA deformation in 2D compared to three-dimensional measurements; it did not incorporate more than one 2D measurement.

Nielson et al looked at the effects of foot length, gender, age, and body mass index on navicular drop during walking. The researchers used a metric ruler to measure foot length, from the posterior aspect of the calcaneus to the tip of the longest toe, of the participants in centimeters. Nielson et al used three landmarks for video analysis on the foot, the navicular tuberosity, the medial aspect of the first metatarsal head, and a mark on the medial calcaneus 2 cm above the floor and 4 cm from the most posterior aspect of the calcaneus as markings for video analysis. The participants walked barefoot on a treadmill at a self-selected speed for six minutes prior to taking a 20 second recording. Nielson et al used a 2D motion analysis to measure navicular drop during walking; defining navicular drop as the perpendicular distance between the navicular tuberosity and the straight line formed by the metatarsal head and heel marker. The average navicular drop was calculated from the 20 recorded steps. This method of 2D analysis had a 0.95 within day and 0.94 between days test/retest values. The researchers
found that only foot length was correlated with dynamic navicular drop. A positive correlation between foot length and dynamic navicular drop was found in the participants, with the majority of the healthy, pathology free participants having a navicular drop of less than 8.5 mm. They found that as foot length increases, dynamic navicular drop increases, but does not exceed 10 mm in either male nor female participants. The researchers compared their 0.94 intra-class correlation coefficient (ICC) of 2D analysis to a previous study which stated three-dimensional analysis had a 0.86 ICC value when using the same skin marker positioning; this demonstrated that 2D analysis can be at least as reliable as three-dimensional analysis.

**Taping**

A literature analysis conducted by Franetovich et al explored the physiological and psychological bases of anti-pronation tape that have been proposed. Franetovich et al found that immediately after low-dye taping, calcaneal eversion in static standing was reduced and navicular height was increased. Augmented low-dye taping was reported to have a greater and longer lasting increase in navicular height than low-dye taping. Augmented low-dye taping was found to increase navicular height through 10-20 minutes of jogging; however low-dye taping was only effective for 10 minutes of walking. Low-dye taping was also found to reduce peak plantar pressures under the medial midfoot and forefoot, and to increase the plantar pressure at the heel and lateral midfoot in several studies found by Franetovich et al. Augmented low-dye taping was reported to reduce the activity of the tibialis posterior, tibialis anterior, peroneus longus, and soleus muscles.

A study conducted by Lange et al examined the immediate effects of low-dye taping application on peak plantar pressure maximums within step and mean plantar pressures within each of ten zones of the foot surface for one step in both male and female participants with a
positive NDT. The researchers set exclusion criteria that participants could not participate if they had any sort of symptoms or pathology of the foot or lower limbs in the six months before the study. The researchers chose to alternate whether the participants walked taped or untaped first so that sequence did not affect the outcomes. The participants were taped by the same researcher every time using ten strips of 5 cm Leuko tape that was applied with one layer of longitudinal strips along the plantar fascia and one layer of transverse strips across the MLA. Participants were allowed five minutes to practice walking before both trials so that they felt comfortable walking onto the platform. The researchers divided each set of footprints into ten zones so that comparisons would be easier. These zones included: the first toe, second toe, toes three-five, lateral forefoot, middle forefoot, medial forefoot, lateral midfoot, medial midfoot, medial heel, and lateral heel. Lange et al found that peak and mean plantar pressure in the lateral midfoot, and all toes were higher when participants walked with the tape than when they walked without the tape. However, peak and mean plantar pressure in the medial and lateral heel, medial forefoot and middle forefoot were lower when the participants walked with the tape. The results demonstrated that low-dye taping does have an immediate effect on plantar pressures in participants with positive NDT. However, that study’s results cannot be extended to mean that low-dye taping corrects excessive navicular drop, only that it has effect on plantar pressure. The study had a limitation in that it only investigated immediate effects of low-dye taping and not the effect of the taping over time.

Another study conducted by Kelly et al focused on investigating the effect of augmented low-dye taping on muscle activation in the lower limb. The researchers used control taping, augmented low-dye taping, and a no taping condition for each participant’s right foot. For each condition, peak plantar pressure was measured as well as the electrical activity of
the vastus lateralis, vastus medialis, and gluteus medius muscles.\textsuperscript{12} The participants were recorded for 20 strides in each condition; during these 20 strides the electrical signal amplitude, onset time, and total burst duration of muscle activity were recorded as well as peak plantar pressures.\textsuperscript{12} Kelly et al\textsuperscript{12} found that there was a significant increase in lateral midfoot peak plantar pressure in the augmented low-dye taping condition compared to the no tape and control taping conditions. The researchers\textsuperscript{12} also found that the application of augmented low-dye taping caused a delay in muscle activity onset in the vastus lateralis, vastus medialis, and gluteus medius muscles.

**KT**

Hsu et al\textsuperscript{33} investigated how scapular kinematics, muscular strength, and electromyographic activity were affected by KT in baseball players with shoulder impingement. The researchers\textsuperscript{33} used placebo taping and KT of the lower trapezius muscle in their study, with each participant receiving both taping treatments that were separated by at least three days.\textsuperscript{33} Participants could participate if they were a baseball player that showed at least two positive shoulder impingement screening tests.\textsuperscript{33} The researchers\textsuperscript{33} used three-dimensional kinematic video of scapular motion and EMG recording of the serratus anterior, lower trapezius, and upper trapezius muscles. Hsu et al\textsuperscript{33} used a dynamometer to test lower trapezius strength before and after taping.\textsuperscript{33} Muscle strength, EMG, and scapular motion were measured for both taping conditions.\textsuperscript{33} The participant practiced moving the arm through scaption with a pole according to an eight second metronome pace.\textsuperscript{33} The participant performed three successive scaption movements with a weight in hand while data was collected.\textsuperscript{33} The participant received a three minute rest between the EMG and kinematic data collection, and then was asked to perform three reference voluntary contraction tasks with one minute rest between.\textsuperscript{33} The average of these three
tasks was used as EMG normalization data of dynamic scaption tests. The participant’s lower trapezius muscle was then manual muscle tested by a blinded examiner to assess muscular strength. The subject was given three minutes after the baseline tests before the lower trapezius muscle was taped and the testing procedure was performed again. Hsu et al found that posterior tilt of the scapula at 30 and 60 degrees of humeral elevation, defined as scaption 30 degrees anterior to the frontal plane, increased with KT application. KT also increased lower trapezius muscle activity during the last third of scaption motion; however, both tapings decreased the muscle’s activity during the first two-thirds of motion. KT also increased upper trapezius muscle activity during 90-120 degrees of scaption, even though the muscle was not taped. The researchers further found the strength of the lower trapezius increased after KT application, but this result was not statistically significant.

Schneider et al studied KT effect on decreasing fatigue of forearm extensors in healthy collegiate tennis athletes. The participants participated in both conditions, but were randomly assigned to either the control or KT condition to start the study. The “Y” technique of KT was used to inhibit muscle function of the common wrist extensor muscle group. Schneider et al tested the force of wrist extension using a hand-held dynamometer. Participants attended two testing sessions, one for each condition. Prior to each session, the participants’ performed a dynamometer test to record strength. A ball machine was used to dispense balls and the participant was asked to hit 65 single-handed backhand strokes and 75 forehand hits with a dynamometer test being completed and a five minute rest between the two series of hits. Schneider et al found that KT helps to maintain muscle strength in forearm extensors.

Although, the majority of KT studies involve the upper extremity, some research has been conducted on the lower extremity. Vithoulk et al studied KT’s effect at the thigh
and hip, showing a positive increase in strength. Vithoulk et al\textsuperscript{18} used healthy non-athlete women to investigate KT effect on the quadriceps muscle group strength during maximum eccentric and concentric isokinetic testing. Three conditions were used by the researchers: no taping, placebo taping, and KT.\textsuperscript{18} KT was applied to the rectus femoris, vastus medialis, and vastus lateralis muscles to facilitate their contraction.\textsuperscript{18} The placebo taping consisted of two strips of KT applied transverse to the muscle group.\textsuperscript{18} Participants participated in all three conditions which were separated by three days.\textsuperscript{18} During the sessions participants were asked to perform isokinetic testing with a ten minute cycling session for warm-up.\textsuperscript{18} This was followed by three sub-maximal and two sets of five maximal trials on the isokinetic device.\textsuperscript{18} Vithoulk et al\textsuperscript{18} found an increase in peak torque during eccentric isokinetic testing of the quadriceps muscle group in the KT condition compared to the other conditions. No significance was found during concentric quadriceps muscle group contraction between the conditions.\textsuperscript{18}

Briem et al\textsuperscript{21} studied the effect KT on muscle activity of the peroneus longus muscle. Briem et al\textsuperscript{21} found that KT did not have an effect on muscle activity. On the contrary, Wong et al\textsuperscript{34} examined the difference in isokinetic knee performance with and without KT application. The researchers\textsuperscript{34} used the muscle facilitation technique of KT to facilitate the vastus medialis muscle of the quadriceps complex. The researchers\textsuperscript{34} recruited from a local public hospital staff club. Participants were excluded from the study if they had any known cardiopulmonary or musculoskeletal injuries or active joint pain in the past 12 months.\textsuperscript{34} The participants had to attend two testing sessions of isokinetic knee exercises.\textsuperscript{34} Each participant performed in both the taped and un-taped conditions; however, the treatments were assigned to participants in random order by a coin toss.\textsuperscript{34} The treatments were separated by seven days so that the researchers avoided carry-over affect.\textsuperscript{34} The tape positioning was established using manual muscle testing.
before the tape was applied. The taped session involved KT application to the vastus medialis muscle of the dominant leg of the participants at 75% of its max stretch as instructed by Kenzo Kase. Stretch of the tape was confirmed by measuring the tape before stretch, calculating how much 75% would be, and then measuring the tape during stretching. The researchers used an isokinetic dynamometer with a testing range from 0-100 degrees to measure maximal concentric knee extension and flexion. Zero degrees in this study was at anatomical zero, or the knee at neutral extension. The participant was seated with the hip flexed to 100 degrees and the axis of the lever arm aligned with the test knee. The dynamometer was recalibrated prior to each data collection. Each participant performed five minutes of low-resistance cycling as a warm-up and rested one minute before completion of the isokinetic knee exercises. The researchers took measurements at 60, 120, and 180 degrees per second for ten repetitions at each angle. Prior to taking the measurements the participants were asked to complete three trials of sub-maximal effort to familiarize themselves with the exercise. The participants received scripted verbal encouragement and were allowed to see their performance on the monitor screen. The participants were given a one minute rest period between each set. The results showed no significant difference in peak torque or normalized work done for flexion and extension between the conditions, meaning the contraction of the muscle was not stronger between the conditions. However, the time to reach peak torque in knee extension was significantly shortened in the KT condition at all three testing angles, meaning the knee reached peak torque at a faster rate than the un-taped condition. Time to peak torque was unchanged between the conditions for knee flexion.

Bicici et al investigated the use of different methods of taping on functional performance in male basketball athletes with chronic inversion ankle sprains. The researchers
used the Cumberland Ankle Instability Tool to classify the functional ankle instabilities of the participants. The researchers investigated four taping techniques including placebo, no tape, athletic taping, and KT taping; each taping had a one week interval between trials. The athletic taping method was a standard ankle taping using two-inch athletic tape: two anchor strips were placed at the base of the gastrocnemius muscle over prewrap, followed by two stirrups, heel locks and figure of eight strips were used as well. The KT method facilitated the peroneus longus and brevis muscles and supported the tibiofibular ligament. The placebo taping was performed using athletic tape that was cut into ‘I’ strips. For each taping trial, the participant had to complete six agility tests including single leg hop, single leg hurdles, vertical jump, standing single leg heel rise, the star excursion balance, and Sport KAT. Each agility test was performed following a 20 minute warm-up that was created by the athlete. Results revealed that there was not a statistically significant effect on the subject completion of the hopping, single leg hurdle, dynamic balance, and star excursion test. The results did show a statistically significant decrease in performance in the vertical jump when participants wore the athletic tape, however, no difference was shown when using KT. There were other differences in performance between KT and athletic tape between conditions however no differences of statistical significance.

**METHODS**

This study was a repeated measures pre-test/post-test design that assessed multiple measures.

**Participants**

Participants were recruited from Marietta College through referral to the study by certified athletic trainers at Marietta College and by giving speeches during classes, team meetings and to groups on campus. Participants were between 18 and 23 years old. After
recruitment, participants met with the researcher and received information about the study. After the meeting the participants read and signed a Statement of Informed Consent approved by the Marietta College Human Subjects Committee.

**Inclusion and Exclusion Criteria**

In order to ensure eligibility for the study, participants completed a brief medical history questionnaire. A NDT was also performed to ensure that foot eligibility was met. Participants were excluded from the study if they had suffered a lower limb injury in the three months prior to participation or exhibited a negative NDT on one or both feet.

This study used 25 participants who met the criteria for age \((m=20.4\, \text{yrs},\ sd=1.00\text{yrs})\) as well as for bilateral NDT \((m=18.6\text{mm},\ sd=3.3\text{mm})\), giving a total of 50 feet used in the study.

**NDT**

The lowering of the medial arch was verified through the NDT (See APPENDIX A).\(^1\) To perform the NDT subtalar neutral was found by having the participant stand with the foot lightly touching the ground without weight bearing.\(^1\) The foot was inverted and everted by the researcher while palpating the talar dome just anterior to the most inferior portions of the lateral and medial malleoli of the ankle.\(^1\) Subtalar neutral was found when the talus was equally palpable by the thumb and forefinger of the researcher.\(^1\) The researcher held the participant in the subtalar neutral position then located and marked the navicular tuberosity in black marker.\(^1\) An index card was held up to medial aspect of the foot with the flat edge parallel to and touching the floor, the height from the floor to the navicular tuberosity was marked on the index card.\(^1\) The participant distributed their weight evenly between the feet with the researcher no longer maintaining the foot in subtalar neutral, the navicular tuberosity was palpated again and marked. The height of the navicular tuberosity was marked on the card again.\(^1\) The distance between the
two marks on the card was measured using a metric ruler, a distance of 10 mm or greater indicated excessive pronation.\(^1\)

**Video and 2D analysis**

The participant’s foot was dot-marked with permanent black marker on the following landmarks: the talar dome, the anterior apex of the lateral and medial malleoli, the posterior apex of the calcaneus, the medial apex of the first metatarsophalangeal joint, the sustentaculum tali of the calcaneus, and the navicular (See APPENDIX B). In addition, the participant was asked to lay prone while a line was drawn bisecting the gastrocnemius from the apex of the calcaneus to the popliteal fossa, and the calcaneus was bisected from the superior to inferior aspect from the apex to the base.

The participant was instructed to walk on a treadmill at a speed that matched their normal walking pace. The participant was given three minutes to acclimate themselves to the treadmill and to select their normal walking pace by increasing the treadmill speed. A Canon HD Vixia HF100 camera (Canon Inc.; Tokyo, Japan) recording 30 frames at 60i was used to record at a perpendicular angle to the walking surface. The video recording began after three minutes of walking and the participant reporting a normal walking pace had been found. Thirty second videos were taken from the anterior, posterior, and medial views. The videos were uploaded to the software, Dartfish (Dartfish Inc., Fribourg, Switzerland). Using the Dartfish software (Dartfish Inc., Fribourg, Switzerland), angles were drawn between marked locations and measured. All angles were measured at 5 midstances throughout the trial. The mean values for each angle was calculated by Microsoft Excel (Microsoft Corp., Washington, United States).

Midstance in the medial view was classified as the point at which the tibia was perpendicular to the walking surface and the navicular had dropped the most. In the anterior and
posterior views, midstance was determined by the point at which the medial malleolus of the non-weight bearing leg crossed the tibia of the weight bearing leg. The angles were measured in an effort to gain knowledge of foot and ankle motion that occurs in people with excessive pronation.

**Taping Technique**

Application of KT was performed according to description by Kase et al.\(^\text{16}\) The skin was cleaned and free of oils and lotions.\(^\text{16}\) The skin was shaved of hair on the leg either entirely or partially along the path the tape traced, depending on participant preference.\(^\text{16}\) The participant was asked to hold the foot everted and dorsiflexed which stretched the tibialis posterior muscle.\(^\text{16}\) The “I” technique of application was used to facilitate the tibialis posterior muscle. A strip of KT was cut so that it was approximately 2 inches shorter than the tibialis posterior muscle.\(^\text{16}\) The ends were rounded to prevent catching of square corners and to allow for longer wear time.\(^\text{16}\) The tape started two inches above the tibialis posterior muscle origin at the proximal two-thirds of the posterior tibia, just above the soleal line.\(^\text{16,31}\) The end of the tape was applied without stretch.\(^\text{16}\) The backing was removed and the tape was stretched to approximately 40% of its available tension and applied to the skin.\(^\text{16}\) The stretch was calculated by measuring the length of the tape prior to application, multiplying the measurement by 0.4, then adding the number to the initial measurement. The tape was placed on a stretch as it traced the tibialis posterior muscle down the lower leg, posterior to the medial malleolus, and ended at the plantar aspect of the navicular.\(^\text{16,31}\) The tape then was applied with no stretch tension across the rest of the plantar aspect of the foot so that it ended on the dorsal aspect of the foot. This endpoint of the tape was chosen so that the end was not on a surface of high friction in order to prevent early removal of the tape. The tape was then rubbed with the hands to produce heat activation of the adhesive.\(^\text{16}\)
The participant waited 20 to 30 minutes before performing physical activity so that the adhesive had adequate time to activate.\textsuperscript{16}

After KT application, the participant was given an instructive paper with the following directions:

1) Do not remove the tape for 3-4 days unless skin irritation begins to occur.

2) Bathing and swimming are allowed, however, the tape should be patted dry with a towel.

3) DO NOT use any type of heat device to dry the tape, the adhesive is heat activated and this will increase the tape’s adhesiveness to the skin, making removal potentially painful.

4) If the ends of the tape begin to peel off or the entire taping peels off, notify the examiner immediately.

5) If orthotics are normally worn, discontinue use for next 3 days.

6) Refrain from wearing heels for the next 3 days to avoid peeling of the tape.

7) If at any time you feel discomfort or wish to discontinue participation in the study, contact the researcher immediately. Do not attempt to remove the tape yourself as this could cause skin irritation.

8) A rash may occur in people with sensitive skin; contact the researcher immediately if this occurs.

**Procedure**

After inclusion criteria were confirmed, each the participant completed a video-taped walking session that lasted approximately ten minutes. After the initial data were collected the participant was taped with KT according to the tape application described above. Immediately following the application, a second ten minute video-taped walking session was completed.
Upon return three days later, a third ten minute videotaped walking session was completed prior to KT removal. Tape removal was performed according to Kase et al.\textsuperscript{16} The tape was moistened with cool water.\textsuperscript{16} The most proximal end was peeled away slightly, then tension was applied between the skin and tape, the skin was pushed away from the KT.\textsuperscript{16} Upon removal the participant was asked to perform a final ten minute video-taped walking session.

In cases that the KT peeled off of the participant prematurely or the participant removed the KT, the participant’s initial taped data was discarded, and new measurements were performed prior to a new three day wear period.

A repeated measures ANOVA with a Greenhouse Geiser correction for sphericity (p ≤ 0.025) was performed using SPSS (Chicago, IL) to compare the DND, DTM, and DCE angle measurements in four different conditions: pre-tape (PT), immediately after being taped (IP), after three days of wearing the tape (3D), and after tape removal (UT).

RESULTS

A significant effect was found when comparing the mean DND angle measurements between the four conditions \((F(2.4, 115.1) = 13.4, p = 0.000).\) Follow-up protected \(t\)-tests revealed that DND angle decreased significantly from PT (mean \((m) = 160.1,\) standard deviation \((sd) = 8.8\)) to IP \((m=157.3, sd=8.3)\), from PT to UT \((m = 157.2, sd = 8.4)\), and increased significantly from 3D \((m = 156.1, sd = 8.4)\) to UT. The angle decreased from IP to 3D but this decrease was not significant.

A significant effect was found when comparing the mean DTM angle measurements between the four conditions \((F(2.3, 114.7) = 7.4, p = 0.001).\) Follow-up protected \(t\)-tests revealed that DTM angle decreased significantly from IP \((m = 170.0, sd = 9.4)\) to 3D \((m = 167.8,\)
The angle decreased from PT to IP and from 3D to UT, however this was not significant.

A significant effect was found when comparing the mean DCE angle measurements between the four conditions ($F(2.1, 102.4) = 4.4, p = 0.013$). Follow-up protected $t$-tests revealed that DCE angle increased significantly from PT ($m = 173.3, sd = 4.7$) to IP ($m = 174.5, sd = 4.8$) and decreased significantly from 3D ($m = 174.8, sd = 5.1$) to UT ($m = 173.8, sd = 4.8$).

The angle increased from IP to 3D and from PT to UT, however this was not significant.

**DISCUSSION**

KT facilitation of the tibialis posterior muscle decreased navicular drop, talar eversion, and calcaneal eversion over time. The DND decreased during the taped conditions, then increased upon removal of the tape but still did not return to baseline. The DTM angle decreased throughout the conditions. DCE angle increased overtime, but again showed a decrease when the tape was removed.

The findings of this study are consistent with previous research in KT’s effect on facilitation of muscles.$^{18, 23, 28, 30}$ Previous research has examined KT’s effect on other muscles, but no previous study has examined KT on the tibialis posterior muscle.$^{18, 21, 23, 26, 28, 29, 30}$ Research that has been conducted at the lower extremity primarily involves muscles of the quadricep and hamstring muscle groups.$^{18, 26, 29}$ Vithoulk et al$^{18}$ concluded that KT may increase eccentric muscle strength of the vastus medialis, lateralis, and rectus femoris muscles in healthy adults. This relates to the current study in that the tibialis posterior muscle is eccentrically contracting against gravity during gait as the foot pronates to adapt to the walking surface. KT is facilitating a concentric contraction of the muscle, so this could aid in slowing any eccentric contraction, thus decreasing pronation during gait. Further, Chen et al$^{26}$ found that KT had an
effect on changing the timing of vastus medialis muscle activity during stair climbing. Wong et al\textsuperscript{29} and Chen et al\textsuperscript{26} reported that the vastus medialis muscle was active earlier when taped with KT than without. Both of these researchers\textsuperscript{26,29} proposed that cutaneous receptors played a part in proprioception and easier recruitment of motor units. This same phenomenon could be present in the current study. Although the current study did not investigate muscle activity, an earlier onset of tibialis posterior muscle activity could have played part in producing the significant results that were found. One study, by Briem et al\textsuperscript{21} found that KT facilitation of the peroneus longus muscle was ineffective in activating the muscle during sudden ankle inversion movement. This may have been because the KT had to be altered in order to accommodate the surface electrode, and also because the stretch of the tape was not reported to be calculated therefore an inaccurate stretch for facilitation could have been used. The current study did not alter the tape and calculated the stretch of the KT so that it was consistent between participants.

Previous studies\textsuperscript{7,12,13} have investigated the use of other taping methods on excessive pronation. Kelly et al\textsuperscript{12} found that augmented low-dye taping decreased plantar pressure in the medial foot as well as increased plantar pressure on the lateral foot. Lange et al\textsuperscript{7} reported similar findings using the low-dye taping. However, Franettovich et al\textsuperscript{13} completed a literature review of anti-pronation taping studies and the consensus involving low-dye and augmented low-dye anti-pronation taping is that static calcaneal eversion is reduced and static medial longitudinal arch height is increased immediately after tape is applied; yet, both do not last for more than 20 minutes of jogging using augmented low-dye taping and no more than 10 minutes of walking when using low-dye taping. The high-dye anti-pronation taping is also reported to decrease DCE, but the low-dye technique has not been found to affect calcaneal eversion during treadmill walking or running.\textsuperscript{13} Franettovich et al\textsuperscript{13} also reported that researchers have found augmented
low-dye taping to reduce the peak activity of the tibialis posterior and tibialis anterior muscles. This could be potentially counterproductive because these muscles are key muscles in foot supination.\textsuperscript{1} The current study found that KT was effective in decreasing DCE, DND, and DTM during treadmill walking for three consecutive days; suggesting that it could potentially be used for a more long term control of excessive pronation ($p < 0.025$).

**Limitations**

The findings of this study can only be generalized to populations with excessive pronation between the ages of 18 and 23. The participants in this study were not monitored during the three days of wearing the tape, therefore it cannot be known if the participants maintained their normal activity. Likewise, a potential observer effect could have occurred during treadmill walking due to the participants not being blinded in the study. Further, the video analysis was not ideal because three-dimensional analysis is preferred to 2D. The position of the camera during taping of the treadmill walking was a limitation because there was no tripod available to maintain consistent camera angles. Also, the stride length of the participants was often inconsistent and was uncontrollable by the researcher. Finally, the researcher was not certified in KT application and the tibialis posterior muscle location was difficult to trace exactly due to anatomical differences between participants.

**CONCLUSION**

The purpose of this study was to investigate the effects of KT facilitation of the tibialis posterior muscle on participants with excessive pronation. Significant changes in calcaneal eversion, navicular drop, and talar movement of the participants were found. Analysis of the data indicates the KT facilitation of the tibialis posterior muscle is effective in decreasing DND, DCE, and DTM. This finding indicates that the taping method is effective in decreasing
pronation for up to three days. This study could be the basis of future research investigating a more long-term correction of excessive pronation.

**Future Research**

Future research should take a three-dimensional approach to evaluating the effectiveness of KT on decreasing excessive pronation in order to obtain more accurate evidence. Other research could also examine the effects of KT facilitation of the tibialis posterior muscle on running gait as well as its effect on participants with lower extremity pathologies such as plantar fasciitis, patellofemoral pain syndrome, or low back and hip pain. Studies in the future could also expand the participant pool by using children, adolescents, adults, and elderly participants. Other research could also investigate the effect of KT over a time period lasting more than three days.


APPENDIX A: NDT

1. Palpate subtalar neutral with foot non-weight bearing:

2. Mark the height of the navicular on an index card aligned parallel to and touching the ground while holding the participant in subtalar neutral:

3. Allow the participant out of subtalar neutral and instruct to distribute weight evenly between the feet, palpate and mark the height of the navicular on the index card that is align parallel to and touching the ground:

4. Measure between the two markings on the index card. A measurement greater than or equal to 10 mm indicates excessive pronation.
APPENDIX B: Dot markings and views for 2D analysis

Anterior View:
- Anterior apex of the lateral malleolus
- Center of the talus
- Anterior apex of the medial malleolus

Medial View
- Sustentaculum Tali
- Navicular tuberosity
- Medial apex of the first metatarsophalangeal joint

Posterior View
- Bisected gastrocnemius
  - End point: center of popliteal fossa
- Apex of calcaneus
- Bisect calcaneus
  - End point: middle of calcaneus

Weight Bearing  Non-Weight Bearing
APPENDIX C: Graphical Representation of Statistics

Figure 1: The mean DND angle for all participants for the 4 conditions: PT, IP, 3D, and UT

Figure 2: The mean DTM angle for all participants for the 4 conditions: PT, IP, 3D, and UT
Figure 3: The mean DCE angle for all participants for the 4 conditions: PT, IP, 3D, and UT