AN ANALYSIS OF KINESIO® TAPE ON MITIGATION OF DYNAMIC KNEE VALGUM

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

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ABSTRACT

Kinesio® Tape has potential to be an intervention to mitigate dynamic knee valgum. This research project investigated the effect of Kinesio® Tape has on dynamic knee valgum through three-dimensional (3D) motion analysis in females with a history or current participation in competitive basketball or volleyball. Thirty volunteers preformed a Y-Balance test and drop jump landing (DJL) test with three different taping conditions. No tape, Kinesio® Performance Plus Tape for the facilitative gluteus medius application, and Kinesio® Tex Classic Tape for the spiral technique (ST). Results observed a statistically significant decrease in knee abduction valgum angle during 100 ms after initial contact on a DJL with application of the Kinesio® spiral technique. No significant results were observed between all three conditions during Y-Balance testing. Based off these findings we can conclude that applying the Kinesio® spiral technique mitigates dynamic knee valgum, therefore possibly decreasing the risk for ACL injury in females.

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LIST OF ABBREVIATIONS

ACL	Anterior Cruciate Ligament
ASIS	Anterior Superior Iliac Spine
PSIS	Posterior Superior Iliac Spine
DJL	Drop Jump Landing

1. INTRODUCTION

1.1. Overview of the Problem

Dynamic knee valgum is a common pathomechanic often leading to lower extremity injuries, including injuries to the anterior cruciate ligament (ACL).[1–45] Not only does dynamic knee valgum place excessive stress on the medial aspect of the knee, it also creates a mechanism affecting both the superior and inferior portions of the kinetic chain. To help mitigate the amount of valgum, clinicians have used multiple interventions that target both muscle weakness and structural abnormalities. These interventions include but are not limited to kinesiology tape,[671] initiation of strength programs,[8] and orthotics.[9] Clinicians continue to search for ways to improve patient outcome measures related to the amount of dynamic knee valgum experienced during jumping with the ultimate goal of decreasing the frequency of lower extremity injures.

One strategy implemented to help mitigate the effects of dynamic knee Valgum is the use of Kinesio® Tape. Kinesio® Tape has grown in popularity since the premiere of the product in the 1980s and is now produced under several brand names by competitive companies.[6,10] Kinesio® tape was founded by Dr. Kenzo Kase with the goal to enhance the function of tissues and physiologic systems through elastic properties, which create tactile stress on the tissues.[6,10] Although multiple benefits of the tape are proposed, there is a lack of evidence in therapeutic effects and consistency in the research application methodology.

To analyze joint kinematics, three-dimensional (3D) motion analysis has been proven to be a reliable and valid intervention and is considered the gold standard in the evaluation of biomechanical risk factors.[5,11] Through the use of high-speed cameras and markers, specific body segments can be analyzed during dynamic movements. Employment of 3D motion analysis is reliable during many functional tasks and can accurately determine multi-planar and dimensional kinematics, including rotational forces across joints.[11] By using 3D motion analysis to assess dynamic knee valgum, a better understanding can be gained by clinicians on its effects on the lower extremity kinetic chain.

1.2. Statement of Purpose

The purpose of this study was to analyze the effects of two different Kinesio® Tape applications and a control condition to mitigate effects of excessive knee valgum in female jumping athletes.

1.3. Research Questions

1. What are the within subject changes in knee valgum angles as measured during a drop jump landing (DJL) when comparing Kinesio® Tape applications?
2. What are the within subject changes in dynamic lower extremity control when measured via Y-Balance Test when comparing Kinesio® Tape applications?

1.4. Dependent Variables

The dependent variables in this study include dynamic knee valgum measured by the drop jump landing (DJL) test, as well as dynamic knee control measured by the Y-Balance Test.

1.5. Independent Variable

The independent variables in this study include the Kinesio® Tape application utilized to prevent dynamic knee valgum including Kinesio® Performance Plus Tape for the facilitative gluteus medius application and Kinesio® Classic Tape for the tibial torsion spiral technique (ST).

1.6. Limitations

Due to multiple variables, this study was not completed without limitations. First, participants included were females between 18 and 40 years old, which limits the generalizability of the findings to only one biological sex and specific age range. No exclusion criteria were established for upper or lower limits of knee valgum, thus resulting in the potential for a large degree of variance. Although markers were placed on each participant prior to the start of testing and were not removed until the end, some markers fell off during DJL test trials and had to be replaced. Replacement of the marker could have added a slight degree of change of location and measure of the joint angle. Finally, we did not have access to an FMS Y-balance testing unit. Therefore, the test had to be recreated with athletic tape and a tape measure, which may have affected the accuracy of the test due to human error placement.

1.7. Delimitations

Dynamic knee valgum can be found in both sexes; however, due to structural differences females are more prone to experience knee valgum during jump landing when compared to males.[12,13] Due to higher incidence rates of knee valgum in females, participants were only included if they were a female who previously or currently participates in competitive basketball or volleyball. No limit was placed on the length of time since they had participated in the sport. Thus, the time participants had performed these movements varied. The Y-balance test was included as a measure of superior chain stability as opposed to other balance tests due to ease of setup and access to equipment. Drop jump landings were completed at a height of 30 centimeters to mimic sport-specific movements.[4,14] Finally, this study was completed in one 90-minute session to provide information on the immediate effects of Kinesio® Tape on dynamic knee Valgum .

1.8. Assumptions

First, it was assumed participants answered the inclusion questions honestly related to injury history and current or past participation in volleyball or basketball. Additionally, it was assumed the participants maintained consistent jumping and landing mechanics to the best of their ability throughout the different trials and taping conditions.

1.9. Significance of Study

There is a lack of consistent evidence and proper use of Kinesio® Tape, especially as a treatment for dynamic knee valgum. Although there is a variety of current research on the causes of dynamic knee valgum, no gold standard for tape application has been ascertained. Finally, research has yet to be completed on the tibial torsion spiral technique using Kinesio® Tape. The results will guide clinicians to make evidence-based treatment decisions for the mitigation of dynamic knee valgum, thereby placing athletes in a better biomechanical position upon landing.

1.10. Definitions

Dynamic knee valgum: Movement of the patella medially relative to the anterior superior iliac spine (ASIS) and tibial tubercle and is often caused by deficits in proximal hip strength or neuromuscular control.[8,9]

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.[10]

Three-dimensional Motion Analysis: Movement analysis that uses camera systems to analyze markers placed on specific body parts during dynamic movements to analyze joint kinematics.[15]

2. LITERATURE REVIEW

2.1. Anatomy

A base knowledge of musculoskeletal anatomy in relation to the hip, thigh, knee, lower leg, and ankle is essential to understanding dynamic knee Valgum . Stemming from multiple disruptions in the lower extremity kinetic chain, this condition is complex in nature. Therefore, familiarity with the anatomical structures in the lower extremity enables clinicians to correctly diagnose and treat the various pathomechanics or muscle weaknesses that are associated with dynamic knee Valgum.

2.1.1. Bony Anatomy

The hip bone, more formally known as the innominate bone, is a large, flattened, irregularly shaped bone that forms the greater part of the pelvis.[16] The pelvis consists of three bones, the ilium, ischium, and pubis.[17] At birth these three bones are distinct from each other and separated by hyaline cartilage. At around age 25, as the body matures and grows, the bones fuse together into a single bone.[16,17] The intersection of these three pelvis bones, more specifically the lateral aspect of the pubis, superior ischium, and inferior ilium, form the acetabulum.[16,17] The acetabulum is a deep, cup-shaped depression that consists of a smooth surface known as the lunate surface.[16,17] The lunate surface articulates with the head of the femur to form the acetabulofemoral joint, which is more commonly known as the ball and socket joint.[17]

The acetabulofemoral joint plays several roles in hip mobility, stability, and movement in the lower extremity. Unlike other joints that are inherently unstable due to the shape of the structures, the acetabulofemoral joint is stable due to an almost complete bony socket enclosing the head of the femur, a strong articular capsule, various supporting ligaments, and dense muscular groupings.[17] The articular capsule, which is dense and strong, contributes extensively to stability of the hip joint.[17] The articular capsule extends from the lateral and inferior surfaces of the pelvic girdle to the intertrochantic line and intertrochantic crest of the femur enclosing both the femoral head and neck.[17] This arrangement helps keep the head from moving away from the acetabulum.[17] Four ligaments help to reinforce the articular capsule including, the iliofemoral, pubofemoral, ischiofemoral, and the transverse acetabular ligament.[17] Finally, the majority of hip stability originates from the volume of surrounding muscles that originate and insert on the bony surfaces of the acetabulum, femoral head, and femoral shaft. Due to the vast number of stabilizers, the acetabulofemoral joint rarely dislocates while also providing the movement needed for the lower extremity kinetic chain.

The femur is the longest, strongest bone in the skeletal system and is composed of a shaft and two extremeties.[16,17] The proximal extremity of the femur includes the femoral head, neck, and greater and lesser trochanter. The femoral head, coated in cartilage, articulates with the pelvis at the acetabulum while the neck connects the head to the shaft and serves as a source of mobility for the femur.[17] Finally, the greater and lesser trochanter serve as sites for multiple tendon attachments. Traveling distally along the femur includes medial and lateral condyles, which articulate with the tibia and fibula to form the two joints of the knee: the tibiofemoral joint and patellofemoral joint.[16,17]

When compared to other hinge joints, the knee joint is much less stable due to the degree of rotation that occurs in addition to flexion and extension.[17] Rotation at the joint during locking of the knee is known as the screw home mechanism and is caused by unequal sizes of the femoral condyles and tightness of the cruciate ligaments.[18] Since the medial femoral condyle has a larger surface area than the lateral condyle, in order to reach the final 30 degrees of knee extension, the tibia must externally rotate five to seven degrees on the femur to reach terminal extension.[18] While in terminal extension, the knee is at its most stable and locked position.

Together, these bony joints allow for essential movements of the lower body under the guide and stabilization of various soft tissue structures. Thus, having a thorough education of the bony anatomy of the hip and knee is crucial to understanding lower extremity valgum. By being able to evaluate how these structures might be malaligned or affected, clinicians can better mitigate knee valgum by placing patients in a more biomechanically correct position and decreasing the chance for injury.

2.1.2. Soft Tissue Anatomy

Originating at the hip is the gluteal complex that plays a key role in the biomechanics, stability, and neuromuscular control of the hip and knee.[17] The first, largest, and most superficial of these muscles is the gluteus maximus, which originates along the posterior gluteal line of the ilium and inserts on the iliotibial band of the fascia lata and the gluteal tuberosity.[16,17] Due to its size and strength, it is able to act almost independently to produce extension and lateral rotation of the hip.[17] The next muscles in the gluteal group include the gluteus medius and gluteus minimus, which work together to stabilize the pelvis during single-leg stance portions of gait. The gluteus medius is located on the outer surface of the pelvis originating on the gluteal surface of the ilium and inserting on the lateral aspect of the greater trochanter of the femur.[16,17] The gluteus minimus is the smallest and deepest of the three muscles also originating on the gluteal surface of the ilium and inserting onto the anterolateral aspect of the greater trochanter.

Due to the role of the gluteal complex in stabilizing the pelvis and controlling movements at the hip, weakness in any of these muscles can cause an increase in knee valgum, ultimately leading to increased risk for ACL injury.[7,8,19,20] Although all three muscles work collectively, arguments have been made that the gluteus medius plays the most crucial role in mitigating knee valgum.[7,20] This role is due to the gluteus medius's posterior fibers, which serve as a deep external rotator producing hip abduction and lateral rotation during open-chain kinetic movements.[7,20,21] Consequently, the posterior fibers are also responsible for slowing these motions through eccentric contraction, especially during single-stance phase periods as well as immediately prior to heel strike.[20] Therefore, weakness in the posterior fibers of the gluteus medius can lead to increased angles of knee valgum, decreased control during multi-planar hip and joint kinematics, and ultimately to an increase in ACL injury risk.[7,20,21] Thus, when determining how to mitigate knee valgum, clinicians need to take into consideration the gluteal complex, more importantly the gluteus medius, to create proper preventative programs.

2.2. Dynamic Knee Valgum

Dynamic lower extremity valgum often presents as a knocked-knee posture, specifically during deceleration in single and double-leg tasks.[8] Knee valgum posture is defined as movement of the patella medially relative to the anterior superior iliac spine (ASIS) and tibial tubercle.[8,9] Although multiple causes are reported for this pathomechanic, research suggests that it is often caused by deficits in proximal hip strength or neuromuscular control.[8,9] Dynamic lower extremity valgum has been affiliated with multiple injuries in the knee, but the most common is anterior cruciate ligament (ACL) injury.[5,8,19] Notably, knee abduction movement, which directly contributes to dynamic lower extremity Valgum , is a significant predictor for future ACL injury risk with 73% sensitivity and 78% specificity in young female athletes.[22] By increasing education on knee valgum, its etiology, and how it relates to ACL injury, clinicians can better understand how to implement preventative strategies possibly leading to a decrease in ACL injuries in both the male and female populations.

2.2.1. Etiology

In relation to posture, knee valgum is a form of a lower extremity pathomechanic that stems from dynamic lower extremity Valgum . Dynamic lower extremity valgum is defined as a combination of motions and rotations in the lower extremity, including hip adduction and internal rotation, knee abduction, tibial external rotation, anterior translation, and ankle eversion caused by deficits in proximal hip strength or neuromuscular control.[8] Due to the involvement of multiple joints, it is important to evaluate the entire kinetic chain when assessing dynamic knee valgum. Through kinetic chain analysis, clinicians can better understand the effects dynamic knee valgum has on joint alignment and how the pathomechanics lead to lower extremity injury.

Consequences of dynamic knee valgum on the lower extremity kinetic chain can first be observed at the pelvis. Clinical expertise and observation suggests excessive anterior tilt of the pelvis is associated with alignment changes in lower kinetic chain, specifically hip internal rotation, genu Valgum , and genu recurvatum, which is defined as hyperextension of the knee.[9] Due to the shape of the pelvis bones, it is normal to have a slight anterior tilt ranging from an 8º to 10º angle between the ASIS and PSIS relative to horizontal. Patients with knee valgum present with excessive anterior pelvic tilt, which is characterized by an angle between the ASIS and PSIS that is greater than 10º.[18]

When the pelvis sits in an excessive anteriorly tilted position, it changes the orientation of the acetabulum..[17] This surface is where the head of the femur articulates, meaning a change in orientation of the acetabulum creates a direct impact on the femoral position. Dorr et al[23] completed a study suggesting that pelvic tilt is directly related to acetabular anteversion, which is more commonly described as lean forward position. Through the employment of computer navigation on 35 patients, results indicated that for every 1º increase in anterior pelvic tilt, a reduction of acetabular anteversion between 0.7º -0.8º occurs.[23,24] Thus, as the angle of acetabular anteversion decreases, the resting position of the femoral head in the joint changes creating internal rotation.

As described above, an increase in hip internal rotation displaces the anatomical axes of the femur into adduction and the tibia into abduction, thereby increasing the tibiofemoral angle.[9] The tibiofemoral angle represents the angle formed by the anatomical axes (imaginary line running from anterior to posterior and perpendicular to the frontal planes) of the femur and tibia that would move the patella medially relative to the ASIS and the tibial tuberosity laterally.[25] As the tibiofemoral angle increases so too does the quadriceps angle (Q angle). The Q angle is the angle that is formed from two implied lines; the first is from the patient's ASIS to the midpoint of the patella, and the second from the tibial tuberosity to the midpoint of the patella.[25–27] This angle represents the direction of the quadriceps muscle force vector in the frontal plane.[25–27] Alignment of the pelvis also has a direct impact on both the tibiofemoral angle and Q angle. Subjects who have an increased anterior pelvic tilt angle have been noted to experience greater quadriceps and tibiofemoral angles.[9] Increases in both the tibiofemoral angle and Q angle have been shown to place more medial stress on the knee joint, which increases the amount of knee valgum possibly leading to a higher risk for ACL injury.

Inferior to the knee along the kinetic chain, subtalar joint pronation has also been labeled as a contributor to postural deviations of the knee.[9,18] Excessive pronation is characterized by adduction and plantar flexion of the talus and eversion of the calcaneus when the foot is weight bearing.[18] Two common observational methods used to measure pronated foot posture include longitudinal arch angle and navicular drop test.[18] To perform the longitudinal arch angle test, clinicians have the patient in a seated position with their subtalar joint in neutral. The clinician then uses a goniometer to measure the angle created by a line made from the head of the first metatarsal, navicular tuberosity, and the apex of the medial malleolus.[18] This measurement is then repeated while the patient is standing with the weight evenly distributed. Finally, the difference between measurements is calculated and compared. Angles ranging from 121 to 130 degrees would indicate pronation, where as an angle less than 120 degrees would equal a severely low arch and excessive pronation.[18]

To calculate a quantitative measure of foot pronation, clinicians use the navicular drop test. Testing is completed in both a weightbearing and non-weightbearing position. To begin testing, the patient is seated with both feet on a hard surface while the examiner is kneeling in front of the patient.[18] Next a mark is placed over the navicular tuberosity while the patient's foot is in a neutral position flat against the ground while non-weightbearing. An index card is placed alongside the medial longitudinal arch, and a mark is made on the card corresponding to the level of the navicular tuberosity.[18] Next, the patient stands with their body weight evenly distributed between both feet. The index card is placed alongside the medial longitudinal arch again, and a new mark is placed corresponding to the location of the navicular tuberosity.[18] Finally, the examiner measures the distance between the two dots in centimeters. A distance from 1.8 to 2.3 centimeters would indicate pronation, and any distance equal to or greater than 2.3 centimeters would indicate an excessive pronation.[18]

The foot posture index (FPI) was designed to improve the reliability and validity of classification of foot postures as supinated, neutral, or pronated.[18] In order to classify foot posture, the FPI uses palpation and inspection metrics with a patient in a relaxed stance as well as a five-point Likert-type scale which is represented in the table below.[18] Each of the five points is assigned a rating from -2 to +2 with negative values reflecting supinated positioning and positive values pronated positioning. The scores are added and then compared to set ranges for each foot position on the FPI score sheet. A score of +1 to less than +7 indicates neutral foot posture, whereas a scores of less than or equal to -3 or greater than or equal to +10 are considered pathological.[18] More specifically, a score of +7 to less than +10 would indicate that the patient is experiencing foot pronation.[18] As foot pronation increases, tibial internal rotation increases, thereby leading to adduction at the knee and larger valgum angles.[18]

Five-point Likert-type scale for each of the following items
1. Talonavicular congruence
2. Supra- and infralateral malleolar curvature
3. Calcaneal frontal plane position
4. Bulge in the region of the talonavicular joint
5. Height and congruence of the medial longitudinal arch
6. Abduction or adduction of the forefoot on the rear foot

Figure 2.1. Five-point Likert-type scale

Other than structural malalignments, another commonly cited factor that may lead to the development of knee valgum are defects in proximal hip strength and neuromuscular control.[7,8] The two main abductors of the hip include the gluteus medius and gluteus maximus. In addition to hip adduction, external rotation, and extension, the roles of these muscles are to stabilize the pelvis in both the frontal and transverse planes, maintain a level pelvis, and control rotation at the hip.[8,19] In the frontal plane, hip abductors produce torque to counteract the adduction force developed from the product of body weight and its larger external moment arm acting on the hip.[8] If abductors are weak or insufficient, hip stability decreases, thereby creating an inability to maintain neutral alignment of the hip and knee. This phenomenon can be observed especially during single limb weight-bearing movements. Therefore, attention has to be directed at correcting or improving hip strength or activation and its role in controlling dynamic lower extremity Valgum .[8]

Electromyography (EMG) studies have shown that the quadriceps muscles also play a role in increased non-contact ACL injury.[28] A narrative review was conducted to examine the significance of muscle activation of non-contact ACL injury with the main purpose to create proper preventative programs.[28] The majority of the studies investigated the gender differences in muscle activation patterns. Of these studies, multiple outcomes reported that females experienced increased quadriceps activation during landing and cutting maneuvers when compared to male athletes.[28] EMG readings from the studies also demonstrated that females' vastus lateralis was far more dominant when side cutting when compared to the other quadriceps muscles, whereas men are more vastus medialis dominate.[28] These findings are important because previous literature has shown that increased quadriceps activation during landing and cutting has been associated with increased anterior tibial shear forces leading to elevated non-contact ACL injury.[28] Likewise, elevated vastus lateralis activation when compared to vastus medialis has also been shown to increase the risk for non-contact ACL injury due to its association to increased knee abduction.[28] Linking these new findings with extensive previous research, clinicians determined that females are at a higher risk for non-contact ACL injury when compared to males. Furthermore, by creating a vastus medialis and hamstring focused prevention program the likelihood of injury can be decreased.

Dynamic knee valgum is unique in the fact that it can originate from a variety of structural pathomechanics or strength deficits in the lower extremity. As explained previously, knee valgum can involve multiple joints. A single alignment characteristic may interact with or cause compensations at other segments affecting the entire lower extremity kinetic chain.[29] Thus, clinicians need to account for the entire lower extremity rather than just a single segment when trying to determine the causes for dynamic knee valgum. Through a detailed evaluation and understanding of the etiology behind this postural malformation, clinicians can prescribe the correct treatment plan and mitigate the condition.

2.2.2. Gender Differences

When studying the effects of knee valgum between genders, the incidence rate of knee valgum is typically higher in females when compared to males.[12,13] Increases in valgum can occur due to a myriad of reasons including structural differences, biomechanics, and muscular strength. Structurally, females have a significantly larger quadriceps angle (Q angle), tibiofemoral angle, and a greater anterior pelvic tilt when compared to males.[9,26] Differences between genders can also be noted when analyzing biomechanics. Females often exhibit increased lower extremity valgum alignment and load compared to males during landing and pivoting movements.[12,13] Additionally, males have increases in hip strength during adolescent growth compared with no strength changes in females.[8] Due to the sex differences following growth and development, males have greater overall hip strength when compared to females, as well as less dynamic valgum experienced in the knee.

When assessing the lower extremity kinetic chain, gender differences can be observed at the pelvis, Q angle, and tibiofemoral angle. Multiple anatomical differences in pelvis size and structure are noted when comparing males and females. These differences occur due to adaptations for childbearing and variation in body size or muscle mass.[17] On average, smaller muscle mass for females cause the pelvis to be smoother and lighter with less prominent markings where muscles and ligaments attach.[17] Differences in structure with the intent to birth includes a relatively broad and low pelvis, ilia that project farther laterally, less curvature on the sacrum and coccyx, wider and more circular pelvic inlet, enlarged pelvic outlet, and broader pubic angle.[17] Generally, it is reported females present with larger pelvic anterior tilt angles than males.[9,26]

A larger anterior pelvic tilt creates a different orientation between the pelvis and femur resulting in greater quadriceps (Q angle) and tibiofemoral angles.[9] The Q angle is the angle formed by the direction of the combined pull of the quadriceps femoris muscle and the tendon connecting the patella to the tibia[27] A study was completed on 100 individuals (m=50, f=50) with no history of knee disorders to determine normative values and information regarding the relationship between Q angle, gender, and anatomical measurements.[27] To determine the mean Q angle measurements with respect to gender, researchers used calipers to measure hip widths and femur lengths of each subject. The mean Q angle discovered for women was 15.8 ± 4.5 degrees and for men 11.2 ± 3.0 degrees. This means that on average the mean Q angle for females subjects was 4.6 degrees greater than male subjects.[27] The tibiofemoral angle is directly related to the Q angle, thereby suggesting that as the Q angle increases so too does the tibiofemoral angle placing more Valgum stress on the knee. These anatomical differences place women at a disadvantage biomechanically, which potentially leads to increased dynamic knee Valgum and associated risk for injury. To understand how to combat these structural differences, clinicians need to gain a better understanding of how it affects landing techniques and neuromuscular control of the lower extremity.

A systematic review of literature related to landing tasks was performed to determine whether females have significant differences in knee frontal plane motion and moments when compared to males.[13] Researchers collected data from a total of 27 studies and reviewed the landing phase of four separate functional tasks: 1) drop landings, 2) stop jumps, 3) forward hops, and 4) drop vertical jumps. Researchers further divided drop landings into single- and double-leg landings. Six studies investigated single-leg drops and seven investigated double-leg landings. Of the six single-leg landing studies, one found no significant difference in abduction moment between gender from a 60-centimeter drop, but showed that males land with greater knee external adduction motion than females.[13] Three found females demonstrated greater knee abduction than males during drops from 13.5, 40, and 60 centimeters, and the last two stated that there were no sex differences during single leg landings.[13] Of the seven double-leg landing studies, six reported females demonstrated greater knee abduction angles when landing as compared to males during drops from 60, 52, 50, and 40 centimeters, and only one study reported no sex differences during double-leg landing.[13]

Four studies evaluated single-leg stop jumps, and only one found greater knee abduction angles in females when compared to males.[13] The drop vertical jump combined drop landing task with a maximum vertical jump in order to make the test more sports specific. Eight studies determined sex differences in this motion and five showed that females landed with increased knee abduction angles, while the other three reported no significant differences. Upon observation of the review, it can be determined that no major differences in knee abduction motion are found between genders during single leg landings and single-leg stop jumps. However, when comparing abduction motion during double-leg landing tasks, females land with significantly greater knee abduction motion when compared to males.[13]

Although valgum is found both during single- and double-leg landing techniques, evidence suggests that landing on a single limb is one of the most common ACL injury mechanisms and thus deserves particular attention.[30] Multiple studies have been conducted to investigate sex differences in valgum knee angle during single-leg drop landings. Recently a study by Ford et al recruited 22 collegiate athletes (m=11, f=11) and implemented 3D motion analysis to calculate differences in total coronal plane angular joint excursion (maximum-minimum).[31] Each participant was instructed to drop from a 13.5-centimeter block either medially or laterally for a total of 12 trials, three each leg for each direction.[31] A trial was marked successful if the subject dropped down and was able hold the landing position for two seconds before letting the contralateral limb touch the ground. Referring to the table below, results allowed researchers to conclude that female athletes demonstrate increased lower extremity coronal plane excursion when performing single-leg drop landing in both the medial and lateral direction when compared to height/weight matched male athletes.[31]

Table 2.1. Coronal plane hip, knee and ankle kinematics from Ford et al 2006[31]

	Lateral		Medial	
	Female	**Male**	**Female**	**Male**
Hip Adduction/adduction (º)				
Initial contact	-16.7	-15.2	-6.7	-6.7
Maximum Adduction (+)	1.9	-1.5	7.3	4
Maximum Abduction (-)	-17	-15.9	-7.6	-7.6
Knee Adduction/adduction (º)				
Initial contact	-2.4	1.7	-0.5	3
Maximum Adduction (+)	1.1	5	2.4	5.6
Maximum Abduction (-)	-4.9	0.1	-4.2	0.5
Ankle Eversion/inversion (º)				
Initial contact	-1.2	2.3	6.4	6.4
Maximum Inversion (+)	2.1	5.2	6.8	6.9
Maximum Eversion (-)	-15	-12.4	-19.2	-14.3

Similar to the study discussed previously, Russell et al. also analyzed knee valgum during single-leg landing.[30] Russell recruited 32 subjects (m=16, f=16) with an unknown activity level and employed a 10-camera Vicon motion analysis system to assess frontal-plane knee angles.[30] Subjects were asked to perform six drop landing tasks with their dominate leg from a 60-

centimeter box.[30] Similar to the previous study, a trial was labeled successful if the participant held his or her landing position for two seconds before letting the contralateral limb touch the ground. Following statistical analysis, researchers concluded that females experienced knee valgum angles on initial contact while men landed in knee varus (P<.025).[30] It was also observed that at maximal knee flexion both men and women were in a valgum position, but the magnitude of valgum was greater for women (P<.025).[30] Based off these results, researchers were able to conclude that women land in more knee valgum before and at impact when compared to men. This led researchers to believe that the increase in knee valgum angles during initial contact and at maximal knee flexion found in females may explain the sex disparity in ACL injury when compared to men.[30]

Although Russell and Ford's results were similar concerning gender differences in knee kinematics during single-leg drop landings, neither suggest what causes the differences. Further research needs to be completed to determine the reason for increased valgum during single-leg landing and the gender differences in this particular skill. Future research should investigate why females experience an increase in valgum during single-leg landing in comparison to men for clinicians to provide evidence-based preventative care specific to gender kinematics.

Researchers have suggested that there are gender differences during bilateral landings that may place females at greater risk of injury.[32] These differences include knee flexion and knee Valgum , normalized vertical ground-reaction force, unilateral landings in regard to hip adduction, and lower extremity muscle activity.[32] However, few studies have determined whether females and males land using different biomechanics during bilateral versus unilateral landings. Researchers investigated the effects of bilateral and unilateral landings and gender on kinetic, kinematic, and normalized electromyographic variables.[32] Subjects for the study included 16 males and 16 females between the ages of 20 and 40 who participated in recreational sports at least twice a week for a minimum of 45 minutes per practice session.[32] Each subject performed three bilateral and three unilateral landings from a 40-centimeter platform in randomized order. Data collection involved a motion analysis system used in conjunction with a force plate, and data were collected on only the right side because all subjects were right-side dominant.[32]

Gender differences between both types of landings confirmed previous research findings. When compared to males, females land with increased knee valgum and vertical ground reaction force (VGRF). At 40 degrees of knee flexion, females had 4.5º greater knee valgum and experienced 1.0 body weight higher VGRF during both types of landing.[32] Finally, both male and female athletes experienced increases in the biomechanical variables that are considered to place the lower extremity at risk for ligamentous injury during the unilateral landings. However, these implications may be more serious for female athletes since their increase in knee valgum and VGRF brings them closer to the threshold of injury.[32]

Although findings aligned with previous studies suggesting females landed with increased knee valgum when compared to males, they differed in the fact that the current study suggests this increase in valgum is not originating from the hip.[32] Researchers believe the main reason for the lack of valgum is the controlled environment subjects performed the tasks. Although environmental factors can affect the level of knee valgum experienced during a task, this result does not prove that valgum did not originate from the hip nor does it explain where it might be originating from instead.[32] Limitations may have also occurred due to motion analysis errors or movement of markers that led to a decrease in the amount of data received at the hip joint.[32] Future research needs to be conducted to see if current results are accurate, and if so what is causing the increase in valgum if it is not hip orientated as other research has suggested.

Due to anatomical differences, deceased levels of strength, and lack of neuromuscular control, females demonstrate increased dynamic knee valgum compared to males during athletic maneuvers.[12] These differences place females at a biomechanical disadvantage during pivoting and jumping sports causing them to have a higher risk of suffering ACL injuries. Furthermore, females who participate in pivoting and jumping sports suffer ACL injures at a rate of four to six times greater rate than males who participate in the same sports.[22] Keeping these differences in mind, research needs to be completed to address divergent treatment options that place females in a more biomechanically correct position potentially decreasing the chance for injury.

2.2.3. Diagnosis and Treatment

Dynamic knee valgum is prevalent in the active population and there are several ways this condition may be diagnosed. The most common diagnosis methods are observation and measurement. Upon postural observation, a patient who presents with knee valgum will have medial collapse of the knee, otherwise known as knock-kneed posture. Postural analysis for knee valgum is completed by observing if the knees are visibly closer together than the ankles during stance.[18] Observation techniques can also be used to assess dynamic instead of static knee valgum. Dynamic knee valgum involves analysis of medial collapse of the knee during functional movements instead of stance phases. Common examples include drop jump landing, single-leg landing, single-leg squat, and lunges.

In instances of dynamic knee Valgum , the patient will present with greater medial collapse of the knee and an increase in valgum angle during athletic movements compared to stance observations. For a static diagnosis, clinicians measure knee valgum by measuring the patient's Q angle.[18] As stated above, the Q angle is the angle that is formed from two lines, the first is from the patient's ASIS to the midpoint of the patella, and the second from the tibial tuberosity to the midpoint of the patella. [25–27] Measurements are completed during normal stance for structural Valgum . However, to measure dynamic knee valgum, technologically complex motion analysis systems need to be employed to assess valgum angles throughout the movement.

Although some causes of dynamic knee valgum are structural and genetic, studies have shown success in mitigating dynamic knee valgum allowing patients to participate in athletic tasks with decreased risk. There are three main forms of treatment to mitigate dynamic knee Valgum . These forms include initiation of strength programs, orthotics, and application of kinesiology tape, which will be discussed later in the Kinesio® section.

The first treatment option for dynamic knee valgum is initiation of a strength program. It has been observed that the inability to eccentrically control hip adduction and internal rotation may lead to greater dynamic lower extremity valgum commonly seen during landing, squatting, and running.[8] Strength programs that focus on hip neuromuscular exercise interventions have gained considerable attention by researchers and clinicians over the years for addressing dynamic lower extremity Valgum .[8] Ford et al.[8] designed a review to identify hip focused exercise interventions that aimed to strengthen and activate hip musculature leading to a reduction in dynamic lower extremity valgum. The duration and volume of hip-focused programs varied considerably with all programs occurring two to three times a week, but ranging from four to 12 weeks in duration.[8] Exercises also varied within programs between non-weight-bearing hip exercises (side-lying hip abduction, prone hip extension, clam-shells, and seated hip external rotation) and a combination of non-weight-bearing, weight-bearing, and functional exercises (single limb squats and deadlifts, lunges, forward and lateral step-ups, and resisted hip external rotation).[8]

When comparing results from the studies, although implementation methods of the programs were variable, each program consistently produced improved measures of hip extension, abduction, and external rotation strength.[8] The largest gains in strength were found in the programs that mainly focused on isometric strength. However, as stated earlier, eccentric strength may be of the most importance in controlling dynamic lower extremity valgum during jumping or cutting. Thus, a prevention exercise program should focus on both attributes.[8] Finally and most importantly, strength gains resulting from hip focused interventions have translated to improved biomechanics at the hip and knee during athletic activities.[8]

Table 2.2. Components, strength, and biomechanical outcomes of hip-focused intervention programs

Study	**Program Components**					**Outcome Measures**		
	NWB	WB-S	WB-F/T	BAL	TS	↑ Hip Srength (ABD, ER, EXT)		
Baldon	x	x	x		x	15%* Ecc	0% Ecc	NT
Dolak	x	x	x			21%* Iso	29% Iso	NT
Earl and Hoch	x	x			x	12%* Iso	17%* Iso	NT
Ismial	x	x				41%* Con	33%* Con	NT
						15%* Ecc	29%* Ecc	
Khayambashi	x					32%-42%* Iso	37%-56%* Iso	NT
McCurdy		x				NT	NT	NT
Myer		x	x	x	x	15-17%* Con	NT	NT
Nakagawa	x	x	x		x	15% Ecc	6% Ecc	NT
Sterns and Powers		x		x	x	7% Iso	NT	8%* Iso
Willy and Davis	x	x	x			42%* Iso	24.1%* Iso	NT

Note: *Reported as statistically significant changes in strength.
Abbreviations: ABD, abduction; ER, external rotation; EXT, extension; Ecc, eccentric; Con, concentric; NWB, non-weight-bearing; WB-S, weight-bearing sagittal plane; WB-F/T, weight-bearing frontal/transverse plane; BAL, ballistic; TS, trunk stabilization; NT, not tested; Iso, isometric.

The next form of treatment used to mitigate dynamic knee valgum is the use of orthotics. It has been cited that pronation at the subtalar joint is the most commonly linked variable to lower extremity injuries.[9] Since foot and knee motions act together in the kinetic chain during weightbearing functions, evidence exists for a link between foot pronation and knee valgum.[2,18] Multiple studies have found a correlation between athletes who experience increased knee valgum during athletic movements and ankle pronation.[2] Therefore, it is hypothesized that limiting the amount of pronation experienced at the foot will translate to decreased dynamic knee Valgum . Researchers recruited 10 female NCAA Division I volleyball and basketball athletes and inserted a 5º medial heel wedge in their shoe to limit pronation and eversion.[2] Subjects then completed six drop jumps, three with the medial heel wedge and three without, and mean values for each condition were calculated.[2]

Significant differences were observed in both knee and ankle measurements at initial contact and maximum values. Trials completed with the medial wedge condition showed significant decreases in knee valgum and pronation at initial contact (1.24º, $P<.01$) and maximum angle values (1.21º, $P<.01$).[2] This decrease in valgum can result in less medial pressure placed on the knee during landing movements, thus placing the athlete in a more biomechanically correct position and decreasing chance for injury.

Although often undiagnosed, dynamic knee valgum is a common condition in both recreational and competitive athletes and can lead to various injuries in the lower extremity. Unique in the fact that the valgum angle can be affected by many variables at multiple joints, treatment options need be detailed and diverse. Strengthening of hip abductors, employment of regular neuromuscular training, and the use of orthotics have been shown to produce beneficial effects on the angle of knee valgum. Another beneficial tool for decreasing knee valgum is the use of a modality, more specifically Kinesio® Tape. Kinesio® Tape has been employed to assist with immediate neuromuscular control, facilitate the muscles, or act as a medial stabilizer. These three benefits could make it a tool for clinicians to consider based on the demographic they are treating.

2.3 Kinesio® Tape

First developed by Dr. Kenzo Kase in the late 1970s, Kinesio® Tape differs from traditional athletic tape in both structure and function.[10] Traditional athletic tape is made of a thick, firm material, which provides little to no stretch with the intent to restrict an athlete's joint and muscle range of motion for the purpose of pain reduction.[6,10] By contrast, Kinesio® Tape is an elastic, cohesive, and lightweight tape capable of stretching up to 150% of its original length.[6,10] The manufacturer suggests that these elastic and lightweight properties of Kinesio® Tape enhance the function of tissues and physiologic systems. Kinesio® Tape may be applied for various purposes including muscle facilitation, muscle inhibition, mechanical support, increased proprioception, decreased pain sensation, and increased lymphatic drainage.[1,33] With these various claims, Kinesio® Tape has become a popular treatment choice for rehabilitation and treatment of musculoskeletal pathologies.

2.3.1. Characteristics

Although the exact materials and structure of Kinesio® Tape are not made public by the manufacturers, understanding the properties of the tape is important with respect to correct application to achieve desired outcomes. Of the available consumer information, reports indicate kinesiology tapes are generally composed of woven fabrics with a high degree of elasticity on one side with an adhesive layer covered with a silicone paper that acts as an adhesive repellant on the opposite side.[6] The use of cotton-based, woven fabric gives kinesiology tape a high degree of elasticity allowing it to extend longitudinally approximately 140-160% of its unstressed length. Although components have not been made readily available to the public, it can be assumed that the elastic properties of Kinesio® Tape generates tactile stress on the body surface that could provide therapeutic benefits. These potential benefits include decrease in pain, accelerated repair process, and correction of biomechanical motion patterns.[6] Since this information is not commonly published by the Kinesio® manufacturer, researchers investigated TEMTEX® Tape, which claims to be an imitation of Kinesio® Tape.[6] TEMTEX® Tape, like Kinesio® Tape, is made of an elastic material with a woven pattern and an adhesive backing.[6] To further analyze mechanical properties, researchers deconstructed TEMTEX® Tape to analyze yarn type, adhesive and thermophysical properties, mechanical function, porosity, and permeability to air and water.[6]

Upon dissection, researchers found TEMTEX Tape was comprised of woven fabric made of two types of yarn, warp and weft.[6] Warp yarns are core spun using 73 dtex elastane filament and traditional cotton fibers, whereas weft yarns are 100% cotton spun.[6] By weaving these two yarns together, the tape's parallel fibers are able to stretch up to 140-160%. Longitudinal stretching of the tape is also assisted by its adhesive backing that is 100% acrylic, heat activated, and applied on the tape in a wave-like pattern. This wave-like pattern assists with lifting the skin, supports longitudinal elasticity, and allows for water vapor and air transportation in free zones where the adhesive is not applied.[6] An increase in longitudinal stretching of the tape leads to a rise in the size and number of pores per unit area, which broadens permeability properties.

Porosity of the fabric has a direct impact on air and water vapor permeability. When tape was tested at 0% tension and elasticity, porosity was 1.95%, air permeability was 232 l/m2/s, and water vapor permeability was at 42.2%. As tension was increased to 50% and tape was elongated, there was an increase in porosity (15%), air permeability (1474 l/m2/s), and water vapor permeability (49.9%).[6] Finally, it was suggested when tape tension increased, thereby increasing air and water vapor permeability, that the thermophysical properties of the tape decreased. Decrease in thermophysical properties is caused by the higher amount of air trapped in the created pores during tensioning, which positively affects comfort for the patient.[6]

When comparing the mechanical properties of kinesiology tapes, similarities can be found in the basic materials used. These materials include a mixture of cotton, polyurethane synthetic fiber, and hypoallergenic thermo-active acrylic adhesive.[34] However, as both clinicians and lay public have increasingly used the product, different manufacturers have implemented new materials to enhance the tension and adherence properties of the tape in an attempt to create significant therapeutic effects.[34] As a clinician, it is important to understand mechanical differences between tapes, their strengths and weaknesses, and how those will affect the desired tape outcomes. To compare the mechanical properties of several therapeutic tapes used in sports and clinical practice, researchers collected 50 samples of elastic tapes and divided them into five groups (10 samples per group). Manufacturer groups included Kinesio Tex Gold®, Kinesio Tex Gold-FP®, Kinesio Sport®, Rock Tape®, and Premium Kinesiology 3 NS Tex®.[34] Five test samples for each taping group were submitted to a mechanical assay composed by longitudinal traction for rupture and surface adherence analysis. Then, data from each sample group were recorded for maximal deformation, maximal load, maximal tension, and relative stiffness.[34]

Table 2.3. Maximum tension for each group, during the traction testing[34]

	Group A	Group B	Group C	Group D	Group E
Maximum tension during traction assay- Pascal					
Maximum	294.24	307.49	281.24	266.64	272.53
Minimum	270.09	285.54	245.51	229.22	256.24
Mean	282.59	301.42	269.59	241.41	263.14
SD	10.59	10.64	8.53	15.3	6.35
Maximum deformation during traction assay (%)					
Maximum	256.12	248.25	209.59	196.79	228.63
Minimum	235.01	179.1	197.71	180.98	224.07
Mean	244.83	203.98	204.43	187.44	225.85
SD	8.38	26.84	4.67	5.86	1.7
Maximum Load during traction assay- Newtons					
Maximum	210.74	224.48	201.42	175.4	195.19
Minimum	193.44	204.5	185.15	164.17	183.52
Mean	202.39	215.87	193.08	168.6	188.46
SD	7.58	7.62	6.11	4.27	4.55
Stiffness traction assay- Newtons/mm					
Maximum	4.04	5.75	4.53	4.32	4.09
Minimum	3.69	4.4	4.41	4.1	3.85
Mean	3.9	5.14	4.45	4.24	3.96
SD	0.13	0.53	0.05	0.09	0.1

Group A: Kinesio Tex Gold; Group B: Kinesio Tex Gold e FP; Group C: Kinesio Sport; Group D: Rock Tape; Group E: Premium Kinesiology 3 NS Tex. SD: Standard deviation.

When comparing results from the traction test, significant differences were recorded among the five brands. Kinesio Tex Gold-FP® presented the best results for maximum tension, maximum load, and stiffness when compared to the other tapes.[34] When using tape application for mechanical correction, tape is placed over a joint to support or prevent pathomechanics during the range of motion.[34] Regarding the desired outcomes, tape stiffness is a key element to success in application. Therefore, compared to the four other tape manufactures, Kinesio Tex Gold-FP® is the best choice for mechanical correction.

Additionally, adherence is an important consideration when taping for athletic participation as perspiration can become problematic. Often when applying a tape with a low adherence, clinicians will use an adhesive spray in attempts to improve longevity of the tape throughout the competition. Although effective, adhesive spray can cause skin irritation or other allergic reactions.[34] When comparing results from the adhesive test between the five tapes, Premium Kinesiology 3 NS Tex® presented with highest mean adherence (1.45 N) and Kinesio Tex Gold® presented with lowest mean adherence (0.34 N), suggesting that when taping for a sporting event Premium Kinesiology 3 NS Tex® should be used.[34] When assessing homogeneity, Kinesiology 3 NS Tex® had the greatest degree of homogeneity, which describes the characteristics and quality throughout the entire length of tape.[34] Kinesio Tex Gold-FP® was the least homogeneous making it likely to have discrepancies in the manufacturing of tape.[34] The final comparison between tapes was maximal deformation, which refers to the rigidity of the tape. No significant differences in deformation were found between the groups upon comparison. Due to the elastic qualities of kinesiology tapes, it can be assumed that it has a higher deformation than traditional athletic tape.[34]

As kinesiology tape continues to grow in popularity, it is clinically important to understand the mechanical differences between tapes, including strengths and weaknesses, and how they affect the desired therapeutic outcomes. The dissection of the physical and mechanical aspects of TEMTEX® Tape grants a better knowledge to clinicians regarding the mechanisms of the tape. Comparison of several manufactured kinesiology tapes addressing various material discrepancies enhanced or limited the desired outcome for therapeutic treatment. Based on the significant differences amongst all five manufacturers, it is suggested that tape brands are effectually dissimilar and should not be used interchangeably.

2.3.2. Methods of Application

Kinesio® Tape is an adhesive and pliable material, differing from classical tape in both physical characteristics and clinical application.[6] The application of Kinesio® Tape diverges from traditional athletic tape in usage and treatment goals. The purpose of Kinesio® Tape application is to grant therapeutic benefits without the loss of mobility through the use of traction, whereas traditional athletic tape is used to restrict range of motion to protect the muscle or joint [35,36] Kinesio® Tape application involves a combination of pulling tension longitudinally and positioning the target muscle on a stretch to initiate traction. The traction promotes an elevation of the epidermis and reduces the pressure on the mechanoreceptors situated below the dermis. Reduction in pressure on the mechanoreceptors leads to reduction in nociceptive stimuli, improvement of blood and lymphatic circulation, reduction in pain intensity, realignment of joints, and change in the recruitment activity patterns of the treated muscles.[35]

Lymphatic drainage can be achieved through multiple different Kinesio® Tape applications. The main purpose of this application is to increase the space beneath the soft tissue to facilitate the circulation of blood and lymph fluid as well as increase the rate of healing.[10] Researchers investigated the effectiveness of kinesiology taping compared to manual lymphatic drainage (MLD) in reducing postoperative edema, pain, and lower extremity functions in the early stage after total knee arthroplasty.[37] Researchers recruited 40 patients who underwent total knee arthroplasty and randomized them into three groups, a kinesiology taping group, a MLD group, and a control group. Each patient completed the same postoperative rehabilitation program, which included early mobilization and physical therapy twice a day. However, patients in the kinesiology group received the lymphatic correction taping method on the second day after surgery, and patients in the MLD group received a 30-minute treatment.[37] Circumference measurements were taken preoperatively, then on the second, third, fourth day, and sixth week after surgery for each patient. Results from the study included a significant effect on edema difference (*P*=.047) and pain levels (*P*=.006) in both the kinesiology taping and MLD group when compared to the control group. No significant difference was found when comparing the kinesiology taping group and MLD group (*P*=.933).[37]

Results from the study led researchers to believe kinesiology taping can be used instead of or with MLD to increase lymphatic drainage and decrease pain levels in patients during the early stages of total knee arthroplasty surgery.[37] By using the application of kinesiology tape for lymphatic drainage, clinicians can provide evidence-based treatments. Patients are also able to experience a decrease in lymphatic congestion, and subsequently pain, outside of the clinic setting.

To understand how the use of Kinesio® Tape can inhibit muscle and aid in correction of possible articular malalignments, researchers used a biomechanical approach. Based on the structure and mechanical properties of kinesiology tape, it can be assumed Kinesio® Tape generates tactile stress on a body surface, which affects activity of mechanoreceptors in skin and proprioceptors in the muscles. The Golgi tendon organ is the main mechanoreceptor affected by this tactile force. Located at the muscle-tendon junction, the Golgi tendon organ is sensitive to changes in muscle tension and when triggered, inhibits the muscle and excites the antagonist.[10] Kinesio® Tape techniques can be applied with the goal of inhibiting an overactive muscle or facilitating a weak muscle. For muscle inhibition, the tape is applied from insertion to origin at 15-25% tension, while muscle facilitation is applied from origin to insertion at 15-35% tension.[10]

To evaluate the effects of a Kinesio® Tape (KT) application to the quadriceps muscles, researchers analyzed isokinetic muscle strength, gait, and functional parameters in patients who had suffered from a stroke.[38] Recruitment included 24 patients with subacute, chronic stroke and allocated them into a sham or KT group. Both the KT and sham group participated in identical rehabilitation programs five times a week for four weeks.[38] The only difference between the groups was the KT group received tape application on their bilateral quads during the four weeks while the sham group did not.

Tape application for the study included Kinesio® Tex Gold, which was applied to each subject's bilateral vastus medialis, vastus lateralis, and rectus femoris muscles with a muscle facilitation technique. Tape was applied to each muscle individually using Y-cuts from origin to insertion and was changed every three to seven days.[38] For the rectus femoris, tape was applied without tension from 10 centimeters below the anterior superior iliac spine to the superior edge of the patella.[38] Then, the tape was crossed from the edges of the patella, with maximum tension, and fixed below the inferior edge of the patella while the knee was flexed.[38] For the vastus lateralis, the tape was applied without tension from the great trochanter to the lateral edge of the patella. The tape was then crossed with maximum tension from the lateral edge of the patella and fixed below the inferior edge of the patella while the knee was in flexed position, and then another piece of tape was fixed over the fibular head.[38] For the vastus medialis muscle, KT was applied without tension from the middle third of the medial thigh to the medial edge of the patella.[38] Next, the tape was crossed with maximum tension from the medial edge of the patella and another piece of tape was fixed over the tibia.[38]

Following the study, researchers observed an increase in peak torque values ($P < .05$) for limbs with and without paralysis (paretic and nonparetic) in both the KT and sham group when compared to baseline measurements. However, assessing the raw data from the table below, change levels were significantly higher in the KT group when compared to the sham group suggesting the application of KT tape increases muscle strength.[38]

Table 2.4. Paretic and nonparetic side peak torque values before and after treatment and change levels between groups.[38]

Isokinetic Parameter	PT Before Treatment	PT After Treatment	Change Level	p-Value
		Paretic		
Knee Extension 60°/s AV				
KT	46.8 ± 20.8 40.0	65.7 ± 25.5	18.9 ± 15.5	0.04
Control	40.0 ± 26.2	47.7 ± 29.5	7.7 ± 4.8	
Knee Flexion 60°/s AV				
KT	19.0 ± 11.0	29.5 ± 16.3	6.4 ± 1.8	0.02
Control	12.1 ± 8.0	14.4 ± 9.6	1.9 ± 0.5	
Knee Extension 180°/s AV				
KT	33.8 ± 11.3	40.7 ± 16.9	10.3 ± 8.1	0.06
Control	25.5 ± 7.0	29.7 ± 7.3	4.4 ± 1.6	
Knee Flexion 180°/s AV				
KT	11.9 ± 3.3	18.7 ± 7.1	8.0 ± 5.7	0.02
Control	14.7 ± 9.5	19.9 ± 8.0	3.5 ± 1.8	
		NonParetic		
Knee Extension 60°/s AV				
KT	64.1 ± 26.5	82.5 ± 32.7	17.7 ± 10.0	0.03
Control	64.9 ± 28.0	73.9 ± 27.3	8.9 ± 5.4	
Knee Flexion 60°/s AV				
KT	37.0 ± 26.1	43.0 ± 26.3	6.0 ± 5.2	0.6
Control	24.6 ± 13.5	31.5 ± 14.5	6.9 ± 2.4	
Knee Extension 180°/s AV				
KT	44.2 ± 22.2	56.8 ± 26.6	12.5 ± 9.0	0.04
Control	40.2 ± 22.9	46.0 ± 23.9	5.8 ± 2.5	
Knee Flexion 180°/s AV				
KT	21.6 ± 15.0	28.0 ± 17.2	6.4 ± 4.4	0.19
Control	15.0 ± 4.6	19.5 ± 6.2	4.4 ± 2.4	

Data presented as mean ± standard deviation

Subjects in the KT group also showed prominent improvements in isokinetic strength of both the knee flexors and extensors. Increase in knee flexor strength can be attributed to strengthening of the knee extensors paired with the mechanical support of the KT produce better knee control.[38] Results from gait, balance, mobility, quality of life, and functional parameter tests were compared to baseline measurements in both the KT and sham group. When analyzing both groups separately, both the KT and sham group had significant improvements (all $P < 0.05$). However, when comparing outcomes from the KT group to the sham group, changes in levels did not reveal one group suggesting stronger outcomes over the other ($P > 0.05$).[38] Researchers predict the lack of significant changes could be due to lack of developed muscle strength or because functional parameters are related to several other factors, such as proprioception and balance. As a result, researchers suggested that KT be applied for longer periods of time.[38]

Limitations from the study arose due to incorrect application of the Kinesio® tape. Application was correct in the fact that to facilitate a muscle a clinician should apply the tape from muscle origin to insertion. However, the amount of tension used and the location of tension was incorrect. For rectus femoris, vastus lateralis, and vastus medialis, researchers applied tape with no tension along the muscle belly then maximum tension along the musculotendinous junction. In the Kinesio® Taping Assessments book Dr. Kenzo Kase instructs that for proper muscle facilitation, 15-35% tension needs to be applied in the therapeutic zone and go as far as the musculotendinous junction. By applying no tension along the muscle researchers did not actually facilitate the correct area, possibly mitigating the beneficial effects of the tape.

Regarding the use of Kinesio® taping for pain relief, several researchers state taping with the insertion to origin technique significantly reduced pain following application.[10] This effect on pain may be associated with gate control theory. When Kinesio® Tape is applied to the skin, it causes stimulation of afferent receptors, which then activates the glial cells in the spinal cord changing the transmission of pain inhibited to the brain.[10] Current research disregards how Kinesio® Tape affects gate control theory, and some researchers consider Kinesio® Tape's effect on pain control to be mainly placebo.[10]

To determine the effects of Kinesio® Tape (KT) on pain modulation, researchers examined a total of 13 knees with patellar tendinopathy from seven active, college-aged females.[39] Testing was conducted with functional activities including single-leg squats, maximum vertical jump test, and isometric knee extension.[39] Each participant completed the functional activities under three conditions: no tape, Kinesio® Tape (KT), and sham tape in randomized order with each session separated by a minimum of three but no longer than seven days.[39]

Kinesio Tex Tape® was used for both the KT and sham conditions, and out of the seven active college aged females, 13 symptomatic knees were taped total (six bilateral, one unilateral). For the KT condition, the participant was instructed to flex her knee to 30 degrees. A tendon corrective I-strip was applied with the middle third of the KT tape stretched to 75-100% tension over the patellar tendon; then, the two outer thirds served as anchors and were laid at 0% tension along the lateral and medial aspects of the thigh.[39] Finally, for the vastus medialis obliques (VMO), a facilitative Y-strip was divided into thirds; the first third was designated as the tail and the remaining two-thirds were split longitudinally to create the Y-divisions.[39] The tail of the Y was placed with 0% tension, also known as the anchor, at the proximal origin of the VMO. The Y-divisions were applied medially and laterally around the VMO with 25-35% tension, ending with 0% tension at the anchors.[39] For the sham condition, tape was applied in an identical pattern on the involved extremity with 0% tension and no stretch.[39]

Pain level for each subject was obtained using the Numeric Pain Scale (NPS) ranging from zero to ten with zero representing no pain and ten representing unbearable pain.[39] Data analysis through a one-way ANOVA indicated no significant difference between baseline pain level and isometric knee extensor strength at each condition (P=.05). When analyzing pain during functional tasks for each condition, pain scores were significantly lower during the maximum vertical jump test for the KT condition (3.38 ± 1.26) when compared to the NT condition (4.54 ± 2.22). No significant difference was found between conditions for reported pain score during the single-leg squat test (P= .67) or the knee extensor strength test (P= .34).[39]

Based on the reported results, the researchers suggest the effects of KT tape on pain cannot be wholly explained by gait control, and the KT tendon corrective strip may have worked in a similar fashion to an infrapatellar tendon strap.[39] Subsequently, further research is indicated to investigate the mechanism of KT effects on pain in patients with patellar tendinopathy.

Depending on the desired outcome, there are various methods of tape application that can be utilized by clinicians. However, there is limited research that validates the claimed effects of taping methods and how they can be applied to treat certain pathologies. As kinesiology tape continues to increase in popularity and function, more research needs to be done on the effects and function of the tape to determine if it is a valid treatment option for clinicians.

2.3.3. Kinesiology Tape and Knee Valgum

A deficiency in neuromuscular control of the hip has been identified as a cause of medial knee collapse.[7] Although under researched, a commonly referenced method to combat poor neuromuscular control and subsequently knee valgum is Kinesio® Tape, which claims to aid muscle facilitation.[10] Due to the dearth of research regarding the use of Kinesio® Tape to mitigate dynamic knee valgum, only a few methods of application are employed in the literature. Thus, no gold standard of taping technique has been established leading to clinical recommendations without appropriate evidence.

The Gluteus medius is an important hip stabilizer and one of the primary abductors of the hip. A decrease in strength or neuromuscular control of the gluteus medius can cause excessive adduction and internal rotation leading to increases in dynamic knee Valgum .[7] One of the ways to combat this result is the use of Kinesio® Tape application for muscle facilitation. Utilizing the Kinesio® Tape Y-strip to facilitate the gluteus medius, researchers conducted a study to investigate whether Kinesio® Tape on hip abductor muscles could reduce dynamic knee valgum

(DKV) and improve its function in collegiate athletes when compared to sham Kinesio® Tape. Participants included 40, college-level athletes between the ages of 18 and 28 with a presence of dynamic knee valgum (DKV) (>8º for men and >13º for women) who were currently participating in sports.[7] Participants were placed by block randomization into one of two groups: Kinesio taping (KT) or Sham control (SC). An equal number of participants were randomized into each group and the participants were blinded to their treatment assignment.

For the KT group, Kinesio® Tape was applied with the patient in a side lying position with 90 degrees of hip flexion, adduction, and internal rotation. The Y-strip was applied on the gluteus medius from insertion to origin. The base of the Y-strip was attached to the lateral surface of the greater trochanter with no tension. The anterior tail went towards the anterior superior iliac spine (ASIS) and the posterior tail went toward the posterior superior iliac spine (PSIS). Each tail was applied beginning with 15-25% tension and ending with no tension for the last 1-2 inches.[7] The SC group's tape application was applied with the same technique listed above with the only difference being a lack of tissue stretch by taping the participants in neutral hip position. All outcome measures for DKV and the Donnatelli Drop Leg Test (DDT) were obtained at three different times: pre-tape application, immediately after tape application, and three days post tape application.

DKV was measured using 2D video analysis. Markers were placed on participants' bilateral lower extremities at the proximal thigh along a line from ASIS, midpoint of femoral condyles, and midpoint of ankle malleoli prior to testing. After markers were placed, drop jump landing trials were videotaped using a camera located 10 meters from the test box, and video was uploaded to the Quentic software V29 for analysis.[7] Researchers used the initial landing from the step to analyze DKV. Finally, to measure gluteus medius strength, the Donnatelli Drop Leg Test

(DDT) was performed. For the DDT, the participant was instructed to lie on his or her non-involved limb while the tester stood behind. Then, the tester passively abducted the patient's leg and placed it into 20 degrees of extension. Finally, the patient was asked to maintain the leg in the abducted and extended position for 7-10 seconds. To be diagnosed as suffering from a weak gluteus medius, the leg would drop 2-12 inches.[7]

Results included a decrease in dynamic knee valgum in the KT group immediately post-tape application in males (4.0º, 95% CI 3.5-4.5, $P < .001$) and females (4.3º, 95% CI 3.5-5.2, $P < .003$), but not on the third day of tape application males (1.4º, 95% CI 1.1-1.7, $P = .08$) and females (1.7º, 95% CI 1.1-2.2, $P = .07$). Participants in the SC group presented with no significant differences in DKV either immediately after application or on the third day of application.[7] DDT analysis revealed there was a significant improvement in gluteus medius strength for both the KT and SC group immediately after tape application and on the third day of tape application.[7]

Results from the study determined that Kinesio® Tape applied for gluteus medius facilitation using the Y-strip can have immediate positive effects in decreasing DKV and increasing gluteus medius strength. However, researchers reported employing a facilitation taping technique by pulling tension from insertion to origin on the gluteus medius in the KT group; this technique is incorrect and is purported to inhibit muscle activity. If the desired result was to facilitate the muscle fibers, opposite direction of application is indicated. By pulling from insertion to origin, the researchers, in fact, applied an inhibition taping technique. Due to the improper technique, results from the study are invalid, and further research is required to determine if Kinesio® Tape application for glute medius facilitation can mitigate dynamic knee valgum.

Another taping technique researchers employed in an attempt to improve pathomechanics during a drop vertical jump was the anterior cruciate ligament (ACL) Kinesio® technique.[1] Twenty healthy male participants with no history of lower limb injury within the previous six months or history of ACL injury were recruited to take part in the study. All participants were blinded to the experimental condition, and participants performed testing with both the ACL Kinesio® taping condition (ACL-KT) and a placebo condition (PT). Testing was separated by three days and the same physiotherapist, who was a certified KT practitioner (CKTP), applied the tape. For the ACL-KT condition, participants received the standard Kinesio® Taping technique for ACL injury. This technique used five-centimeter width Kinesio® Tex tape and was applied at the tibial tuberosity to the medial and lateral condyle of the femur with 75% tension to limit anterior translation of the tibia. The PT group had the same technique for application, but it was applied with a non-stretched Kinesio® Tape at 10% of resting tension.[1]

Knee joint angles were measured at initial contact using a 10-camera, 3D motion analysis system. Although specific placement of the reflective markers was not discussed in detail, it was stated 44 total markers were placed on each participant's feet, upper and lower legs, pelvis, and trunk.[1] After markers were placed on the body, participants were asked to perform three DVJs. Comparisons were made of peak knee joint angles moments and knee joint angle at initial contact (IC). Between-conditions were analyzed using paired sample *t*-tests.

Results from the study included a significant decrease in knee abduction angle at IC found in the ACL-KT condition (P=.04). However, there was no significant difference in knee flexion angle at initial contact or peak knee flexion when comparing abduction and rotation angle between the ACL-KT and PT conditions ($P > .05$).[1] Based on these results, standardized Kinesio® Tape application for ACL injury prevention applied with 75% tension can create significant changes in knee valgum angle during initial contact when performing a DVJ in injury-free, male participants.

Table 2.5. Mean (SD) of the knee joint angle at IC and peak knee joint angle between KT and PT conditions

Kinematic (degree)	KT	PT	Effect Size	p-value
Knee flexion at IC (-)	-27.39 (10.96)	-30.96 (11.73)	0.28	0.337
Knee abduction (-)/ adduction (+) at IC	1.43 (2.12)	-1.24 (2.42)	1.06	0.036*
Peak knee flexion (-) /extension (+)	-96.22 (11.67)	-90.93 (11.08)	0.55	0.599
Peak knee abduction (-) /adduction (+)	-2.00 (6.59)	-4.25 (5.93)	0.44	0.126
Peak knee external (-)/ internal rotation (+)	6.77 (8.96)	6.71 (8.81)	0.10	0.974

(Data are expressed as mean standard deviation. IC, initial contact. *Significant effect of taped, $p < 0.05$)

Results from both studies suggest that application of the Y-strip for gluteus medius application, as well as the standard Kinesio® taping technique for ACL injury, is successful at mitigating dynamic knee valgum in patients. However, the gluteus medius tape application was applied incorrectly using the inhibition technique instead of a facilitation technique making those results invalid. Gluteus medius application also indicated that tactile feedback generated by the Kinesio® Tape is not enough to maintain muscle power in healthy athletes for long periods of time. These results indicate that for the best prolonged results in decreasing DKV, researchers suggested pairing the Y-strip for gluteus medius facilitation with routine hip girdle muscle strengthening.[7] Due to these limitations, more research needs to be conducted to determine the effectiveness of Kinesio® Tape on mitigating dynamic knee valgum and a gold standard tape application.

The next study incorporated two separate ergogenic aids with the goal of improving lower extremity joint alignment during a lunge, thus reducing injury risk.[40] Researchers chose to incorporate a lunge because when athletes decelerate or cut, the lunge movement is utilized.[40] Therefore, researchers rationalize that if the movement is performed incorrectly, there exists a higher risk of injury. Eight male participants with no existing lower extremity injuries were recruited for the study.[40] Each participant was randomly assigned the order in which he would receive each of the ergogenic aids prior to arrival. The ergogenic aids chosen for the study were a compression garment, Kinesio® Tape, and a control condition that included no aid. Kinesio® Tape was applied following instructions stated by Dr. Kenzo Kase for the gluteus medius, patellar tracking, tibialis anterior, and peroneus longus.[40] While the authors report that they applied tape to three separate muscles, they neither provided the details nor whether they facilitated or inhibited the muscle fibers. A lack of attention to methodological reporting results in analyses that could lead to incorrect clinical use. Compression garments used a pair of CW-X® Support Web compression leggings in accordance with the manufacturers recommendations. Garments covered the participants' pelvis, knees, and upper ankles.[40]

Upon arrival each participant was instructed to complete a five-minute warmup on the treadmill at low intensity.[40] Following the warmup, 14 retroreflective markers were placed on the lower extremity, and the height from the ground to the participant's greater trochanter was measured used to standardize the participant's lunge length.[40] Electrical tape was placed on the floor marking the lunge direction and was positioned along the x-axis to identify the sagittal plane. While not wearing shoes, the participants were asked to perform three rotational lunges by stepping forward with their dominate leg along the x-axis and then lowering their trunk until the non-dominant knee was approximately 3 centimeters above the ground.[40] After preforming the lunges, each participant completed a 10-minute treadmill run at 70% of their perceived maximum intensity. Following the run, participants repeated the lunge trials again with the same condition, thus completing the first testing session.[40] Following completion of testing for the first condition, participants were asked to rest and then let researchers know when they were ready to start the next condition testing. The same procedure was repeated for each condition, and the participant ran at the same speed as set by the first testing procedure.[40]

Data collected from the markers included maximal lateral pelvic tilt, maximal knee Valgum , and maximal ankle eversion/inversion during each lunge.[40] Lower extremity kinematics were statistically analyzed using PASW software and a repeated measures ANOVA was employed to assess differences across the three ergogenic aids.[40] Results for the greatest lateral pelvic tilt prior to and post exercise bout included no significant differences between ergogenic aid conditions.[40] The greatest knee Valgum angle prior to exercise bout was in the control condition (8.5°±4.6), followed by the compression garment (7.1°±4.0) and the Kinesio Tape® condition (6.5°±3.3); however, there was no significant difference between ergogenic aid conditions.[40] Following the exercise bout, maximal knee Valgum increased by 1.2º within the Kinesio® Tape condition, possibly indicating that there was a reduction in the support provided by the tape following exercise.[40] No other significant differences were found in maximal knee Valgum between the control and compression garment condition.

Researchers inferred that lower extremity joint alignment remained unaffected with the application of all ergogenic aids prior to exercise.[40] This result suggests that if an athlete has no pre-existing lower extremity injuries, he or she does not need to use Kinesio® tape or a compression garment as a preventative measure. Following the bout of exercise, evidence suggested that Kinesio® Tape actually increased knee joint malalignment if worn for more than 10 minutes of exercise. However, limitations can be found in the tape application process. Researchers stated that they followed tape application instructions stated by Dr. Kenzo Kase for the gluteus medius, patellar tracking, tibialis anterior, and peroneus longus. However, they did not state if a certified Kinesio® Tape practitioner (CKTP) applied the tape to each participant, or if the taper was consistent throughout the study. Also, it was not stated if a rest period was given after tape application to allow the tape to totally adhere and activate the targeted muscles. Finally, rest periods between conditions for each participant were based on their own personal fatigue. This method led to a lack of consistency between each participant's rest period and could also have played a role in the results.

Due to the lack of consistency in the research involving Kinesio® Tape and gluteus medius applications for mitigating knee valgum, it is difficult to come to a conclusion regarding its utility as a therapeutic tool. Of the studies available, multiple limitations can be found in lack of consistency of tapers as well as application errors. More research needs to be done using a consistent CKTP with the correct gluteus medius application to determine its effects on knee valgum. Until then no firm conclusions can be made about the application or if clinicians should incorporate it as a preventative tool or not.

2.4. 3D Motion Analysis

Three-dimensional (3D) motion analysis is used for analyzing joint kinematics (the description of motion) and kinetics (the explanation of motion).[11] Due to its ability to measure joint kinematics in different planes and reliability for measuring functional tasks, 3D motion capture systems are considered the gold standard in the evaluation of biomechanical risk factors when preformed in a laboratory-based setting.[11] To collect data, 3D motion analysis incorporates camera-based systems to track surface makers on the body during activities and synchronizes with force plate data to calculate the intersegmental forces and movements with an inverse dynamics approach.[15] Computational biomechanical models are then used to calculate joint kinematics and kinetics.[15] Data collected by 3D motion analysis systems can aid clinicians in diagnosing gait abnormalities, assisting with patient treatment and intervention plans, evaluating the effectiveness of interventions, and developing products to improve patients' quality of life.[15]

2.4.1. Reliability and Validity

As stated above, laboratory-based 3D motion capture systems are considered the gold standard in the evaluation of biomechanical risk factors.[5,11] These systems are reliable during many functional tasks and can accurately determine multi-planar and dimensional kinematics, including rotational forces across joints.[11] However, multiple factors remain a negative influence in the reliability of 3D motion analysis including the system utilized, application and placement of the electromagnetic sensors, force plate errors, and inability to recreate athletic-specific movement.[11] Variability can also be affected during repeated motion analysis testing from factors such as marker-placement errors, referenced static alignment, task difficulty, and neuromuscular development of the population.[41] Errors in any of these factors can result in inaccurate data, which can affect a clinician's ability to provide proper patient care. Therefore, it is important to determine the reliability and validity of the 3D motion analysis system.

When evaluating biomechanical risk factors utilizing 3D motion analysis, reliability and validity are relevant factors in mitigating collection error. To test the reliability and validity of 3D motion analysis researchers recruited four motion analysis laboratories where clinical care and research studies are routinely performed. The laboratories had differing motion capture systems, cameras, force plates, and biomechanical models. Each laboratory performed three different tests, which evaluated the accuracy of the motion capture system, the integration of the force plate and the motion capture system, and the strength of the biomechanical model used to calculate rotational kinematics.[15] Through the results of these tests and a comparison of each laboratory, researchers aimed to evaluate the reliability of 3D motion analysis systems and biomechanical models.

The separate laboratories independently completed three mechanical tests to ensure the different configurations of the motion capture equipment and biomechanical models produced consistent, reliable, and comparable data. To test motion analysis markers, researchers used the Gait and Clinical Movement Analysis Society Standards Council (GCMAS) proposed motion system accuracy testing protocol. This protocol tracked moving markers, evaluated marker locations if obscured by some cameras, and evaluated marker position as markers pass close to each other.[15] Integration of the force plates with the motion capture system was tested by applying a direct force to the force plate using a rod with markers attached. Last, a physical model representing the human pelvis and right leg and foot was involved to assess the accuracy of the biomechanical model. Researchers at the respective laboratories attached markers specific to their biomechanical model and kinematic data at the hip and knee were calculated and compared to the known rotations. [15] Known rotations included single-hip rotations, single-knee rotations, hip rotations for combined knee and hip rotations, and knee rotations for combined knee and hip rotations.

Results from the mechanical tests for all four laboratories showed that error between the measured and calculated distances within markers was less than 2 mm and 1° for marker separations, which ranged from 24 mm to 500 mm.[15] Results from the force plate integration tests demonstrated errors in center of pressure calculation less than 4 millimeters across all labs, despite varied force plate and motion system configurations.[15] Finally, errors across laboratories for single-joint rotations and for combined rotations at the hip and knee were less than 2° at the hip and less than 10° at the knee.[15] These results led researchers to believe that 3D motion analysis reliability and validity can be obtained from a variety of different motion analysis laboratories with varying motion capture systems, types and numbers of cameras, force plates, and biomechanical models.

Motion analysis techniques are commonly utilized to identify potential risk factors for knee injuries; however, a majority of the investigations are limited to cross-sectional comparisons between groups.[41] Even though cross-sectional comparisons can be important to the overall understanding of poor biomechanics related to injury risk, the biomechanical findings are not typically coupled with injury outcomes. Incorporation of longitudinal experimental designs into prospective injury risk factor studies may allow for the combination of both epidemiological and biomechanical techniques to address important sports medicine and orthopedic problems.[41]

To address lack of longitudinal data, a study was completed to determine the reliability of 3D motion analysis on lower extremity kinematic and kinetic variables during landing in young athletes. Subjects included middle and high school aged soccer (f=58, m=71) and basketball (f=65, m=71) athletes. All groups tested prior to the start of their sport season and athletes who participated in both soccer and basketball (f=3,m=8) were tested prior to the start of each sport, approximately 7 weeks apart, to determine the within- and between-session reliability of lower extremity biomechanical variables.[41] Prior to testing, 37 markers were placed on the subjects to collect data for 3D motion analysis. Markers were placed on the sacrum, left posterior superior iliac spine, sternum, and bilaterally on the shoulder, elbow, wrist, anterior superior iliac spine, greater trochanter, midthigh, medial and lateral knee, tibial tubercle, mid shank, distal shank, medial and lateral ankle, heel, dorsal surface of the midfoot, lateral foot (fifth metatarsal), and toe (between the second and third metatarsals).[41] For the first trial, the subject was instructed to stand unmoving while neutral alignment was measured. Next, the subject completed three trials of drop vertical jump (DVJ) from a 31-centimeter box.

For data analysis, lower-extremity kinetics and kinematics were qualified during DVJ and the mean of the three trials bilaterally were used for between-session reliability. Discrete variables included maximum joint movement in addition to maximum and minimum joint angle for the hip, knee, and ankle. Each variable was calculated for both sides during the stance phase of the DVJ and used for within-session reliability.[41] Finally, to examine with-in and between-session reliability coefficient of multiple correlations, researchers used interclass correlation coefficients and typical error analysis.[41]

Table 2.6. Within- and between-session reliability measures of both discrete and waveform data

	Within Session			**Between Session**		
	CMC	ICC	TE	CMC	ICC	TE
Joint Angles (°)						
Hip flexion	0.971	0.956	2.9	0.95	0.595	5.5
Hip adduction	0.712	0.955	1.6	0.689	0.791	2
Hip internal rotation	0.721	0.934	2.9	0.652	0.699	3
Knee flexion	0.989	0.933	3.2	0.982	0.616	4.2
Knee abduction	0.799	0.993	0.9	0.65	0.855	2.3
Knee internal rotation	0.696	0.971	1.4	0.706	0.872	1.9
Ankle dorsiflexion	0.986	0.955	1.6	0.991	0.922	1.3
Ankle eversion	0.881	0.966	1.9	0.806	0.835	2.3
Joint Moments (N·M·KG -1)						
Hip flexion	0.927	0.904	0.23	0.942	0.8	0.19
Hip abduction	0.71	0.778	0.14	0.739	0.766	0.08
Hip internal rotation	0.824	0.882	0.1	0.828	0.655	0.1
Knee flexion	0.954	0.926	0.15	0.957	0.843	0.13
Knee abduction	0.692	0.931	0.12	0.711	0.87	0.1
Knee internal rotation	0.654	0.666	0.08	0.766	0.592	0.05
Ankle dorsiflexion	0.908	0.925	0.12	0.939	0.825	0.19
Ankle eversion	0.848	0.779	0.1	0.864	0.748	0.06

CMC = Coefficient of multiple correlation, comparing within- and between-session waveform data. ICC = intraclass correlation coefficient, for the peak measure of each variable. TE= typical error, in the measurement unit for the peak measure of each variable.

Findings from the study indicate the majority of the kinematic and kinetic variables in youth athletes during landing have excellent to good reliability.[41] The within-session reliability of discrete variables was higher than between two extended sessions, which supports the researchers' first hypothesis that biomechanical variables quantified during a DVJ in youth athletes would be reliable when assessed in longitudinal sessions.[41] The results of the current study contradict previous studies analyzing running.[41] No between-day intraclass correlation coefficients (ICC) differences were found during a DVJ in peak angle, initial contact, or total angular excursion measures. Joint moment reliability in the sagittal plane was higher than in the secondary planes, and the sagittal plane joint moments exhibited greater reliability than the sagittal plane peak angles. However, further analysis of the data demonstrates the within-session reliability of the kinetic data was high in all three planes.[41] From these results, researchers were able to conclude 3D motion analysis has the ability to reliably quantify lower extremity biomechanical errors and variables in young athletes during dynamic tasks over extended intervals and may aid in identifying potential mechanisms related to injury risk factors.[41]

2.4.2. 3D Motion Analysis and Knee Valgum

When employing video analysis to assess kinematics, the majority of studies use either two-dimensional (2D) or three-dimensional (3D) analysis. Equipment costs for 2D video analysis are inexpensive when compared to 3D and less time is needed to collect and analyze data, making it a more common testing method. However, for assessing knee Valgum , studies stated 2D motion analysis was limited regarding accurate values of angle displacement.[4] In addition, researchers recommended 3D motion analysis be used in future studies investigating ACL etiology and its relationship to excessive dynamic knee valgum.[4,42] When gauging lower extremity kinematics and dynamic knee valgum through 3D motion analysis, a variety of cameras, retroreflective markers, and force plates are employed.

To conduct an experiment using 3D motion analysis, researchers must know the characteristics of the signal they are collecting, more specifically the frequency content of the signal they are collecting.[43] Knowledge of signal frequency, specifically the highest frequency and appropriate sample rate, is crucial when selecting compatible equipment for data collection. Types of cameras used, such as high-speed cine camera, have a variable setting for the frame rate, allowing researchers the opportunity to adjust the sampling rate of the camera to meet the requirements of the signal under inspection in the experiment.[43] However, many biomechanics laboratories have switched from using a high-speed cine camera to videography, which has a fixed sampling rate, presenting a challenge when it comes to matching sampling needs.[43] In general, video cameras and recorders have a fixed sampling frequency or frame rate of 60 Hertz (Hz), whereas high-speed video cameras have a sampling frequency of 120-500 Hz.[43] In addition to 60 Hz cameras being inexpensive compared to high-speed cameras and sufficient in collecting data for human movement analysis, they tend to be more prominent in biomechanics laboratories. The number of cameras and Hz used to assess dynamic knee valgum varies and often depends on budget, access to equipment, and the frequency content of the signal researchers are collecting. One study collected data with a 10-camera system at a sampling rate of 200 Hz, another incorporated six cameras at 200 Hz, and two studies employed eight cameras at 240Hz.[1,3,44,45]

To assess landing force at various points in the studied movement, researchers pair 3D motion analysis cameras with force plates set at contrasting amounts of Hz. Four studies assessing dynamic knee valgum used two force plates, but collected data at different Hz, 1000Hz,1600Hz, and 1200Hz.[1,3,44,46] By synchronizing the data collected from the force plates with the motion analysis system, researchers are able to determine how much force the knee is experiencing at different points in the studied movement, which is critical when assessing dynamic knee Valgum .

The number of retroreflective markers used, as well as placement of the markers, depends on the joint angles the researcher wants to assess. Dynamic knee valgum is linked to dynamic lower extremity Valgum , which is defined as a combination of motions and rotations in the lower extremity, including hip adduction and internal rotation, knee abduction, tibial external rotation, anterior translation, and ankle eversion caused by deficits in proximal hip strength or neuromuscular control.[8] From this definition we can assume dynamic knee valgum can be affected by three different joints, the hip, knee, and ankle. Therefore, an accurate assessment of the cause of dynamic knee valgum requires researchers to employ markets that assess multiple joints in the lower kinetic chain.

In an appraisal of gender differences for knee valgum kinematics, one study utilized 23 retroreflective markers on the sacrum and bilaterally on the shoulder, ASIS, greater trochanter, mid-thigh, medial and lateral knee, mid shank, medial and lateral ankle, as well as heel and toe (between second and third metatarsals).[45] A second study evaluated knee joint adduction and abduction through the use of 10 retro reflective markers that were placed on the right and left anterior-superior iliac spines, mid-thigh, medial and lateral femoral epicondyles, mid-shank, medial and lateral malleoli, heel and 2nd metatarsal.[3] A final study measured trunk, hip, and knee angles and used thirty-five reflective markers that were placed on the 7th cervical vertebrae, 10th thoracic vertebrae, clavicle, sternum, right back, shoulders, lateral epicondyles of the elbow, medial wrists, lateral wrists, second metacarpal heads, anterior superior iliac spines, posterior superior iliac spines, lateral thighs, lateral epicondyles of the knee, lateral thigh tibias, lateral malleoli, second metatarsal heads and heels.[44] The reliability and validity of 3D motion analysis can be negatively affected by maker-placement errors, especially when the study includes reapplication of the markers between testing days.[41] These errors may lead to measurable differences in angles and moments creating false data collection and inaccurate research conclusions making it important to decrease inconsistent marker placement.

Various details are involved during employment of motion analysis for assessing dynamic knee Valgum . Most times each variable depends on the goals of the research project, movement tested, and angles assessed. However, cost and budget limitations often play a larger factor when it comes to deciding what equipment is used often restricting researchers from using the gold standard method for measuring dynamic knee Valgum , 3D motion analysis. No matter the equipment used, reliability and validity can still be affected so accuracy and precision must be used when implementing different analysis strategies.

2.5. Conclusion

In conclusion, although dynamic knee valgum is a common pathomechanic, future research is still necessary to determine the best treatment options. Past research has been conducted on the use of kinesiology tape,[671] initiation of strength programs,[8] and orthotics,[9] and results demonstrated beneficial effects at mitigating dynamic knee valgum. However, the lack of research, inconsistency of methodology, and occasional errors in tape application still create question for clinicians. More specifically, limited research has been conducted to examine if different applications of Kinesio® Tape has a positive effect on knee valgum. Since it has been shown to be a positive tool for correcting joint positioning and facilitating muscles, Kinesio® Tape can be assumed to have a likely positive effect on mitigating knee valgum. Therefore, it is necessary for research to be conducted to investigate if Kinesio® Tape can be used as an intervention to mitigate knee valgum, ultimately leading to a decrease in ACL injury.

3. METHODOLOGY

The purpose of this study was to analyze whether Kinesio® Tape applied with two different taping conditions as well as a control condition mitigates dynamic knee valgum during jumping. Current literature is inconclusive regarding a gold standard application of kinesiology tape to correct knee Valgum . However, the majority of studies utilize a gluteus medius facilitation application in attempt to limit dynamic knee Valgum .[1,7] This chapter outlines the participants included in the study, data collection procedures, and subsequent data analysis.

3.1. Participants

For this research study, recruitment was completed via email listserv. Inclusion criteria for this study required a history of or current participation in competitive basketball or volleyball. Exclusion criteria for the study comprised any present pain with jumping or landing, history of lower limb surgery within the last 12 months of the study, or any contraindications to Kinesio® Tape such as allergy to adhesive, diabetes, malignancy/cancer site, cellulitis, skin infection, open wounds, or fragile skin. Participants were informed of the inclusion and exclusion criteria during the recruiting process both verbally and through email to ensure they qualified, and a total of 30 females between the ages of 18 and 40 were ultimately recruited to participate. Informed consent was obtained from each participant prior to the start of the study.

3.2. Setting

This study was completed in the Biomechanics Laboratory room 16 of Bentson Bunker Fieldhouse on the North Dakota State University campus located at 1301 Centennial Blvd. Fargo, ND 58102.

3.3. Equipment and Instrumentation

The Y-Balance Test is a functional screening tool, which can be used to assess lower extremity stability, monitor rehabilitation progress, understand deficits after injury, and identify athletes at high risk for lower extremity injury.[47] The Y-Balance Test consists of a stance platform with three pipes extending in three directions: anterior, posteromedial, and posterolateral. The participant stands in a single-leg stance on the platform and is instructed to push the reach indicator three times as far as possible in all three directions along the pipe with the non-weightbearing leg. For the trial to count, the reach foot is not permitted to touch the floor and the hands had to remain stationary on their pelvis. If the participant fails to meet the testing criteria, the trial is repeated.[47]After the trial is completed, the clinician measures the distance of the reach indicator, which is marked in five-millimeter increments. Equipment is then reset for the participant to repeat the test on the opposite leg.[47–49]

Since a functional movement screening (FMS) Y-Balance platform was not available, the test was recreated with white athletic tape and tape measure. To assemble the test, three strips of athletic tape measuring 40 inches were placed on the floor in a Y-shape.[50] The anterior strip was placed in a straight line, with the posterior medial and posterior lateral strips connecting to it to create a 135-degree angle.[50] A 90-degree angle was made between the two posterior lines.[50] Next, a reach direction line was marked at the zero point where the three tape strips connected in the middle.[50] This line served as a starting point for the tape measure and to help position the participant's foot.

For the anterior direction, the participant was instructed to line her toes behind the reach direction line facing forward. For the posterior direction, the participant remained facing in the anterior direction but moved her foot in front of the line so that the heel was aligned with the direction line. Since no reach indicator was used, the participant was instructed to reach out as far as possible and tap the tape with a toe. Distance was measured with a tape measure in inches starting at the anterior reach line for the first direction, then the posterior reach line for the posterior medial and posterior lateral directions. For the trial to count, the reach foot needed to tap the tape line, but was not permitted stay on the floor long enough for weight to be distributed from the stance leg to the tapping leg. Hands also needed to remain stationary on the pelvis. Three trials were completed in all three directions on the dominant leg, and a mean score was calculated for each direction.

The second test employed in this study was the drop jump landing (DJL) test, which was the movement pattern used to evaluate dynamic knee Valgum .[7] The DJL clinical test has a high reliability (95%) to screen for lower limb injury, including a high specificity (46.07%) and sensitivity (95.04%) to predict ACL injury.[1,51] The DJL test is typically performed off of a 30-centimeter box onto a force plate and often used in conjunction with a 2D or 3D motion analysis.[4,14] The test can be completed with different techniques to test various outcomes, such as double-leg stance, single-leg stance, counter jump, and maximum vertical jump.[1,3,4,42,44,45] Previous study protocols include three DJL practice trials followed by three testing trials.[4,14]

Three-dimensional (3D) motion analysis was employed to analyze measures of knee valgum during the DJL tests. Lower body position data were recorded with an eight-camera motion analysis system (Vicon Motion Systems Ltd., Oxford, England) recording at 200 Hz. A custom lower body model was created for this study using 40 spherical, 14mm retroreflective markers on both legs. Five clusters of four markers each were placed on the sacrum, bilateral thighs, and bilateral shanks. Twenty single markers were placed on the bilateral ASIS, PSIS, lateral epicondyle of the femur, medial epicondyle of the femur, lateral malleolus, medial malleolus, calcaneus, base of the second metatarsal, head of the second metatarsal, and head of the fifth metatarsal. Kinematic measures were calculated for the hip, knee, and ankle joints from the landing of the initial countermovement during the DJL tests with Vicon Nexus 2.12 and Vicon ProCalc 1.5. Marker trajectories were labeled, gap-filled using the spline and rigid body fill, and trimmed to include the frames of interest.

The final instrument applied in this study is kinesiology tape. Kinesio® Tape is a therapeutic tape, which has proposed benefits in the prevention and treatment of sports injury.[1] The tape is designed to enhance function of tissues and physiologic systems, and the tape may be applied for various purposes including muscle facilitation, muscle inhibition, mechanical support, increased proprioception, decreased pain sensation, and increased lymphatic drainage.[33] The Kinesio® Tape application utilized to prevent dynamic knee valgum included Kinesio® Performance Plus Tape for the facilitative gluteus medius application and Kinesio® Classic Tape for the spiral technique (ST). All tape applications were applied by the same Certified Kinesio® Tape Practitioner (CKTP).

3.4. Procedures

Females who participate in pivoting and jumping sports suffer ACL injuries at a rate of four to six times greater rate than males who participate in the same sports. Additionally, an estimated 38,000 ACL injuries occur in female sports in the United States annually.[22] For females, the increase in non-contact ACL injury incidences have been predicted as a result of lower extremity pathomechanics and hip weakness.[8] Lower extremity pathomechanics in females often presents with increased knee valgum during landing and jumping tasks from a variety of heights and landing techniques.[8,13] Therefore, the first 30 females who met inclusion criteria of being between the ages of 18-40 with a history of or current participation in competitive basketball or volleyball were included in the study. For this research study, participants were recruited via email listserv and word-of-mouth in the Fargo-Moorhead metroplex. Data collection was conducted in the Biomechanics Laboratory room 16 of Bentson Bunker Fieldhouse at North Dakota State University. Upon arrival and prior to any participation, informed consent was obtained and signed by both the participant and researcher.

Participants reported once for data collection for a 90-minute session. They were instructed to wear loose-fitting shorts so the Certified Kinesio® Tape Practitioner (CKTP) could access the participant's thigh and buttock for tape application. It was strongly advised not to wear lotion prior to the session so that tape and 3D markers could adhere to the skin. Finally, participants were told to bring shoes they perform their activity or sport in.

To begin, participants completed a warm-up on a stationary bike for five minutes at 40-60 revolutions per minute.[52] Once the warmup was completed, participants performed three practice trials of the double-leg jump landing test to become comfortable with the movement prior to testing. The DJL test was performed using double-leg stance to mimic movement patterns for volleyball and basketball athletes. The DJL tests were completed with the participants wearing shoes normally worn during their activity or sport. Jumps were performed from a 30-centimeter box in a double-leg stance position with the feet approximately shoulder-width apart.[14] When verbal instructions were given, they dropped down from the box, leading with either foot, and landed with both feet concurrently. Immediately, a vertical jump was performed with a final landing in double-leg stance with the knees slightly flexed. For the trial to count, the participants needed to maintain the landing posture for at least two seconds. If they were unable to do so the trial was repeated.[4] Throughout the DJL, arms were swung for momentum and to mimic a sport-specific movement.

After the completion of three practice trials of the DJL test, practice trials of the Y-Balance Test were completed. For this study, the Y-Balance Test was employed to assess dynamic knee control. Each participant completed the Y-Balance Test three times, once for each taping condition. The test was completed without shoes to eliminate any additional balance or stability shoes may provide[53] and allowed researchers to measure the position of the athlete's foot more accurately.[49] Prior to the first Y-Balance test practice trial, each participant watched an example demonstrating how to perform the test. Following the example, six practice trials were completed in each direction on their dominate leg.[47,49,53] Trials began standing on the dominant leg, reaching with the non-dominant six times in the anterior direction, posteromedial direction, then posterolateral direction.[4] For the trial to count, the reach foot needed to tap the tape line, but was not permitted stay on the floor long enough for weight to be distributed from the stance leg to the tapping leg. Hands had to remain stationary on the pelvis throughout each trial. If the participant failed to meet the testing criteria, the trial was repeated until the participant could perform three repetitions correctly.[47] At the end of the trial, each testing direction distance was recorded and a mean score was calculated.

Upon completion of the practice trials of the DJL test and Y-Balance Test, the first taping condition was applied. Each participant received three taping conditions to the dominant leg: a gluteus medius facilitation using the snowflake technique (GM), a spiral technique (ST), and no tape (NT). The order of conditions was randomized by a random number generator for each participant. For each technique, the Kinesio® Tape was applied by the same Certified Kinesio® Tape Practitioner (CKTP). Prior to application of tape, the skin was cleaned with an isopropyl alcohol wipe and any excess hair was trimmed.

The facilitative gluteus medius application snowflake technique was applied from origin to insertion of the muscle, as specified by Dr. Kase. The subject was positioned side-lying with the dominant leg facing up, knee and hip flexed to approximately 90 degrees. The CKTP cut a four block I-strip of Kinesio® Performance Plus Tape with two sets of double lengthwise slits the same distance applied from the participant's ASIS to the greater trochanter of the femur. The tape was anchored at the gluteal surface of the ilium with no tension. Then, the I-strip was applied, following the fibers of the muscle, towards the greater trochanter with 10-20% tension. At the greater trochanter, the insertion of the muscle, the I-strip was adhered again with no tension. Before activating the adhesive, the lengthwise slits were spread out with minimal tension throughout the application. Following application, the participant was instructed to remain in a position of comfort for 10 minutes before continuing with the study protocol.

The second taping condition utilized was the spiral technique (ST), applied with Kinesio® Classic Tape. Participant positioning included standing in a close-packed, double-leg stance with feet approximately hip width apart. First, the CKTP measured the length of the tape needed for the participant's leg, wrapping it around the dominate leg from the medial tibia, laterally to the posterior knee, around the medial knee, and finally ending at the lateral thigh. The CKTP anchored an I-strip of tape with no tension on the participant's medial aspect of the distal 1/3 of the tibia. With a stabilizing hand on the anchor, the practitioner pulled the tape with 75-100% tension and applied towards the lateral aspect of the tibiofemoral joint. Then, with no tension, the tape was adhered to the posterior aspect of the tibiofemoral joint, from lateral to medial. When the tape crossed diagonally over the popliteal fossa, the CKTP again employed at 75-100% tension from the medial femoral condyle middle of the lateral thigh. The tape was then secured to the lateral thigh with an anchor at 0% tension. Thus, the tape created a spiral shape around the participant's leg. Again, the subject was directed to rest comfortably in a non-weight bearing position for 10 minutes.

The use of a no tape condition acted as a control for both the DJL test and the Y-balance test. For this condition, no tape or intervention of any kind was applied to the subject before completing either task. Subjects received all three taping conditions during their testing session and conditions were randomized with a random number generator. Regardless of the order of randomly assigned taping condition, the participant rested 10 minutes in a position of comfort before completing a round of testing. During the 10-minute rest, 40 3D retroreflective markers were placed on the participant's lower extremity to assess dependent levels of knee valgum. After the sensors were applied, the first follow-up Y-Balance Test was completed.

Testing Trials for the Y-Balance Test began on the participant's dominate leg, reaching with the non-dominant leg three times in the anterior, posteromedial, then posterolateral direction.[4] Following the first Y-Balance test, three DJL tests were performed. The DJL test was considered adequate if the final landing position was held for at least two seconds.[44] If the participant was unable to complete the trial correctly without mistake, the trial was repeated. Once the participant completed three approved trials, the first taping condition was removed and the CKTP applied the second randomized taping technique.

Once the second taping condition was applied, the DJL test was repeated with the same protocols. The participant rested for 10 minutes in a position of comfort with the tape. After 10 minutes, the participant performed a second round of the Y-Balance Test with the same testing protocols stated above. Participants then performed another three DJL. Once three trials were complete with the second taping condition, the taping condition was removed and the CKTP applied the third and final randomized condition.

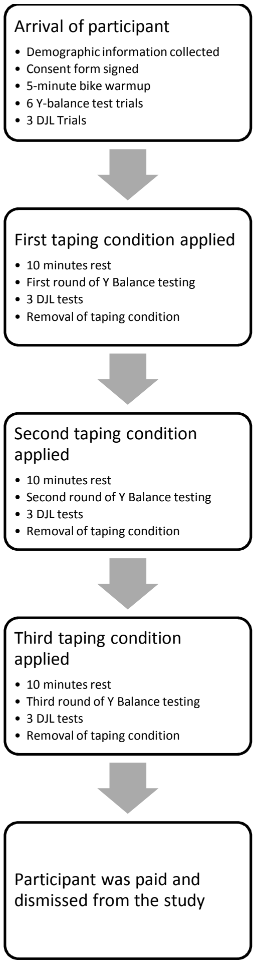

Figure 3.1. Study procedure

After the application of the third taping technique, the participant rested for another 10 minutes in a non-weight bearing position. Subsequently, the participant completed a third round of the Y-Balance Test. Each distance was recorded for the anterior, posteromedial, and posterolateral directions, and a mean score was calculated for each. Finally, the subjects performed three DJL tests. Tape and sensors were removed, and the participant was paid and dismissed from the study.

3.5. Data Analysis

To analyze Y-Balance test data, the three testing distances for anterior, posteromedial, and posterolateral directions and a mean score was calculated. Comparisons will be within subject between taping techniques and the participant's contralateral leg. The application with the highest average Y-Balance score will show which taping method had the greatest effect on dynamic knee control.

DJL will be analyzed by calculating the overall knee valgum angle for each taping condition during the first countermovement landing phase. Kinematic measurements were calculated in all three dimensions for the hip, knee, and ankle joints from the landing of the initial countermovement during the DJL tests with Vicon Nexus 2.12 and Vicon ProCale 1.5. Marker trajectories were labeled, gap-filled using the spline and rigid body fill and trimmed to include frames of interest. Knee valgum angle will be calculated as the distance between knee and ankle joint centers. Comparisons will be with-in subject between taping techniques and the participant's contralateral leg.

Prior to each DJL session, static and functional trials were recorded for processing purposes. The standing static trial was used to calibrate the auto-labeling of the DJL trials and as a reference posture for DJL trial normalization. Participants started the functional trial in a standing static pose, and then performed lower body movements including the star-arc pattern used to identify hip joint centers.[54–56] The optimal common shape technique was used to reduce the effect of skin artifact, and then the symmetrical center of rotation estimation determined right and left hip joint centers.[54,57,58] Pelvis origin was established as the midway point between two points that bisect the ASIS and PSIS markers, respectively. Knee and ankle joint centers were defined as the midpoint between lateral and medial epicondyles and malleoli, respectively. Initial contact (IC) was defined as the point when the velocity of the 2nd metatarsal head reached zero for both feet.[59] If one foot landed first, the second of the zero velocity events was selected as IC. Since ACL injuries likely occur the instants following IC, data from IC plus 100ms was utilized as a time point.[60] The deepest point of the initial countermovement landing was defined as the lowest vertical point of the pelvis origin. Pelvis origin was established as the midway point between two points that bisect the ASIS and PSIS markers, respectively.

Joint angles and knee to ratio were recorded for the three times points in each condition. The global coordinate system was such that the participants' anteroposterior axis was the x-axis, y-axis was mediolateral, and z-axis was superior-inferior. The local coordinate system for the pelvis, thigh, shank, and foot segments was made in accordance with the International Sociality of Biomechanics.[61] Hip, knee, and ankle joint angles were calculated as Euler angles with the distal segment in reference to the proximal segment, and the y-axis (flexion/extension) first, x-axis (abduction/adduction) second, and the z-axis (internal/external rotation) last. For the hip and knee joint angles, positive values reflect flexion, adduction and internal rotation. Similarly for the ankle angles, dorsiflexion inversion, and forefoot adduction are positive values. Knee to ankle ratio, which has been used in prior research is a measure of knee valgum, was calculated as the horizontal distance between knee joint centers divided by the horizontal distance between ankle joint centers.[62] Model outputs were filtered with a low-pass, zero-lag Butterworth filter (fourth order) at a cutoff frequency of 10 Hz. Kinemaic data were exported and combined into Microsoft Excel with a custom Matlab program.

Data were analyzed using the R statistical environment and the *rstatix* package (Kassambara, 2021)[63,64]. For each measurement, a repeated-measures ANOVA model was estimated with the three taping conditions as the primary factor of interest and each participant serving as her own control for a total of 24 statistical models. Tables 4.2 and 4.4 report the mean and standard deviation for each measurement in each condition.

The ANOVA code in the *rstatix* package automatically conducts Mauchly's test for sphericity and applies the Greenhouse-Geisser correction to the degrees of freedom, as needed. Tables 4.2 and 4.4 present the associated F-statistic and p-value for each ANOVA. In two cases (AKratio and AnkleSep) the results were statistically significant at the 5% level, while the model for KneeSep was statistically significant at the 10% level (P=.058). None of the other measurements differed across taping conditions to a statistically significant degree.

3.6. Conclusion

The purpose of this study was to analyze whether Kinesio® Tape applied with three different taping conditions decreased the amount of dynamic knee valgum. Published literature has demonstrated that increased knee valgum can lead to increased risk for ACL injury.[1–45] Furthermore, due to biomechanical disadvantages, females experience larger valgum angles when compared to males increasing their risk.[12,13] Multiple treatment methods have been tested to decrease valgum. However, published research specific to Kinesio® Tape as the mitigating tool to treat knee valgum is limited. Further complicating the issue is that existing literature often reports incorrect applications and methodologies for measuring knee valgum. Thus, research targeting the etiology of knee valgum with Kinesio® Tape as the treatment is indicated before clinical recommendations can be made.[1,6,7]

Three-Dimensional motion analysis has been proven to be the gold standard in the evaluation of biomechanical risk factors.[5,11] 3D motion analysis is often used during dynamic motions to analyze ACL injury risk. For all the above reasons, we hypothesized that if we used 3D motion analysis to investigate the applications of a spiral technique (ST) in combination with muscle facilitation of the gluteus medius, we would observe a decrease in dynamic knee valgum during a DJL.

4. MANUSCRIPT

4.1. Introduction

Although injuries to the anterior cruciate ligament (ACL) occur in both genders, female athletes experience ACL injuries with a 4- to 6-fold greater incidence when compared to males while participating in the same landing and cutting sports.[22,42,65] Furthermore, injury mechanisms include both contact and non-contact events; however, 70% are noncontact episodes involving actions such as deceleration, lateral pivoting, and landing tasks.[22,42,65] Several theories have been researched attempting to explain differences between gender that may cause the fluctuation in ACL injury rates, however the main cause still remains unclear.[22,66,67] Further research is needed to explore the discrepancies between genders in injury rates such that mitigation strategies can be created to prevent ACL sprains.

One of the more commonly researched precursors to ACL injury is dynamic knee valgum. Dynamic knee valgum is defined as movement of the patella medially relative to the anterior superior iliac spine (ASIS) and the tibial tubercle.[8,9] Although origin of this pathomechanic can vary per patient, dynamic knee valgum is often caused by deficits in proximal hip strength or neuromuscular control.[8,9] Knee valgum, otherwise known as knee abduction movement, has been identified to be a significant and reliable predictor for future ACL risk in young female athletes with 73% sensitivity and 78% specificity.[22] Athletes with an ACL injury had significantly greater knee abduction angles and abduction moments than uninjured athletes during vertical drop jumps[42] Drop vertical jumps are common reoccurring movements in sports such as volleyball and basketball. When compared with all other injuries that occur in these sports, ACL tears are the most common. [68–70] A study was completed comparing ACL injury data across 15 sports from 2004 to 2013.[69] During this time there were a total of 162 ACL injuries that occurred in women's basketball with an overall injury rate of 0.22 per 1000 athlete exposures (95% CI, 0.19-0.25).[69] More specifically, it was found that 15% of female athletes entering the WNBA had experienced an ACL injury.[70] Contrasting from basketball in the fact that volleyball is considered a non-contact sport, ACL injuries are still common due to repetitive drop jump landings from hitting and blocking. A recent study established that in women's volleyball, the incidence of knee injury is 0.27 injury per 10,000 hours of exposure to sport of which 16% were ACL/PCL rupture.[68] Therefore, treatment methods for mitigating ACL injury in female athletes need to address knee abduction angles, especially during drop jump moments.

Although conventional strategies have been published related to rehabilitation of weak gluteal muscles, that approach takes time and consistent effort on the part of the athlete. Multiple studies and reviews have been done to identify exercise interventions aimed to strengthen and activate hip musculature leading to a reduction in dynamic lower extremity valgum.[8,20,71] Despite varying in duration, volume, and exercise type, each program consistently produced improved measures of hip extension, abduction, and external rotation strength.[8] After reviewing the literature, researchers acknowledged that a linear relationship between improved strength and improved biomechanical variables cannot be made.[8] In fact, they suggested that although hip-focused exercises generally have a positive effect on knee abduction angles, controlling dynamic lower extremity valgum is complex and involves a combination of tools including some type of feedback.[8]

Kinesio Tape® applications have been shown to be effective in decreasing degrees of valgum due to its various purposes including muscle facilitation[7,10,38], mechanical support[1], and increased proprioception.[1,33] Studies have employed multiple techniques to decrease valgum including gluteus medius facilitation and an ACL technique.[1,7] Although results indicated that both applications mitigated dynamic knee valgus in patients, published methodologies were incorrect and inconsistent thereby hindering broad recommendations. Therefore, in order to establish a preferred tape application to reduce the amount of knee valgum, further research needs to be completed.

Research has labeled dynamic knee valgum as a possible pathomechanic for females that increases their risk for lower extremity injuries, including injuries to the anterior cruciate ligament (ACL).[1–45] Although multiple mitigation techniques for dynamic knee valgum have been studied, including strength programs and Kinesio® Tapping applications, additional variables must be explored to provide clinicians with options that meet the needs of each athlete. Therefore, the purpose of this study was to compare two separate Kinesio® Tape conditions and their effects on joint angles during a dynamic movement.

4.2. Methods

4.2.1. Study Design and Population

Thirty, healthy female participants (age = 21.15 ± 2.50, height = 1.75 ± 0.17 m, body mass = 66.81 ± 6.05 kg) who all had a history of or current participation in competitive basketball or volleyball participated in this study. Because we were interested in joint angles with a drop jump landing, we excluded any participants who had pain or lower limb surgery in the previous 12 months. In addition, we excluded participants who had a contraindication to Kinesio® Tape such as allergy to adhesive, diabetes, malignancy/cancer site, cellulitis, skin infection, open wounds, or fragile skin. Informed consent was obtained from each participant prior to the start of the study both verbally and through email.

4.2.2. Instrumentation and Biomechanical Model

The Y-Balance Test is a functional screening tool, which can be used to assess lower extremity stability, monitor rehabilitation progress, analyze deficits after injury, and identify athletes at high risk for lower extremity injury.[47] The Y-Balance Test consists of a stance platform with three pipes extending in three directions: anterior (A), posteromedial (PM), and posterolateral (PL). Research has suggested that performance on the Y-Balance Test, specifically in the Anterior coordinate, correlates to a reduced risk of injury in non-contact sports.[72] Furthermore, researchers determined 94 cm of asymmetry is the optimal cut point for predicting injury (sensitivity 59%; specificity 72%).[72]

To analyze the measures of knee valgum during the DJL trials, data were collected with an eight-camera three-dimensional (3D) motion analysis system (Vicon Motion Systems Ltd., Oxford, England) recording at 200 Hz. A custom lower body model was created for this study using 40 spherical, 14mm retroreflective markers on both legs. Five clusters of four markers were placed on the sacrum, bilateral thighs, and bilateral shanks. Twenty single markers were placed on the bilateral ASIS, PSIS, lateral epicondyle of the femur, medial epicondyle of the femur, lateral malleolus, medial malleolus, calcaneus, base of the second metatarsal, head of the second metatarsal, and head of the fifth metatarsal. Kinematic measures were calculated for the hip, knee, and ankle joints from the landing of the initial countermovement during the drop jump landing tests with Vicon Nexus 2.12 and Vicon ProCalc 1.5. Marker trajectories were labeled, gap-filled using the spline and rigid body fill and trimmed to include the frames of interest.

4.2.3. Taping Application

The facilitative gluteus medius application Snowflake technique was applied from origin to insertion of the muscle with the subject positioned side-lying, dominant leg up with knee and hip flexed to approximately 90 degrees. A four block I-strip of Kinesio® Performance Plus Tape with two sets of double lengthwise slits was applied with the tape anchored at the gluteal surface of the ilium with no tension. Then, the I-strip was applied, following the fibers of the muscle, towards the greater trochanter with 10-20% tension. At the greater trochanter, the I-strip was adhered again with no tension. Before activating the adhesive, the lengthwise slits were spread with minimal tension throughout the application.

The spiral technique (ST) was applied with Kinesio® Classic Tape. The participant stood in a close-packed, double-leg stance with feet approximately hip width apart. The CKTP anchored an I-strip of tape with no tension on the participant's medial aspect of the distal 1/3 of the tibia. With a stabilizing hand on the anchor, the practitioner pulled the tape with 75-100% tension and applied towards the lateral aspect of the tibiofemoral joint. Then, with no tension, the tape was adhered to the popliteal fossa, from lateral to medial. When the tape crossed diagonally over the fossa, the CKTP again employed at 75-100% tension from the medial femoral condyle middle of the lateral thigh. The tape was then secured to the lateral thigh with an anchor at 0% tension.

4.2.4. Procedures

Participants reported to a biomechanics laboratory at a mid-sized university for one, 90-minute data collection session. After demographic information was collected and the consent form was signed, a five-minute warmup was completed on a stationary bicycle. Following the warmup, three practice trials of the double-leg jump landing (DJL) test were performed. Participants stepped off a 30-cm box with a self-selected foot, landed in a double leg stance, then immediately performed a vertical jump with the final landing in a double-leg stance with knees slightly flexed. Six trials of the Y-Balance test followed. Y-Balance testing required that participants' shoes were removed, and the participant reached in all directions while standing on the dominate leg with hands on hips.

Next, the first taping condition was applied to the participant's dominate leg. The three conditions were gluteus medius facilitation (GM), spiral technique (ST), and no tape (NT). Condition order was determined prior to the start of the study via a random number generator. Following application, participants rested for 10 minutes to allow the tape to take effect. Following applications, the participants remained in a non-weight bearing position to allow the tape to take effect as well as allow the researchers to place 40, 3D retroreflective markers on the participates lower extremity.

Following the rest period, three testing trials of the Y-Balance test were performed as well as three DJL trials. Upon completion of the trials, the next taping condition was applied, and the process was repeated. Once the participant completed all three conditions, sensors were removed, payment was given, and they were dismissed from the study.

4.2.5. Data Analysis

To analyze Y-Balance test data, mean scores from the three testing directions A, PM, and PL was calculated. Comparisons were within subject between taping techniques and the participant's contralateral leg. The application with the highest average Y-Balance score will show which taping method had the greatest effect on dynamic knee control.

DJL was analyzed by calculating the overall knee valgum angle for each taping condition during the first countermovement landing phase. Kinematic measurements were calculated in all three dimensions for the hip, knee, and ankle joints from the landing of the initial countermovement during the DJL tests with Vicon Nexus 2.12 and Vicon ProCale 1.5. Marker trajectories were labeled, gap-filled using the spline and rigid body fill and trimmed to include frames of interest. Knee valgum angle will be calculated as the distance between knee and ankle joint centers. Comparisons were with-in subject between taping techniques and the participant's contralateral leg.

Prior to each DJL session, static and functional trials were recorded for processing purposes. The standing static trial was used to calibrate the auto-labeling of the DJL trials and as a reference posture for DJL trial normalization. Participants started the functional trial in a standing static pose and then performed lower body movements including the star-arc pattern used to identify hip joint centers.[54–56] The optimal common shape technique was used to reduce the effect of skin artifact, and then the symmetrical center of rotation estimation determined right and left hip joint centers.[54,57,58] Pelvis origin was established as the midway point between two points that bisect the ASIS and PSIS markers, respectively. Knee and ankle joint centers were defined as the midpoint between lateral and medial epicondyles and malleoli, respectively. Initial contact (IC) was defined as the point when the velocity of the 2nd metatarsal head reached zero for both feet.[59] If one foot landed first, the second of the zero velocity events was selected as IC. Since ACL injuries likely occur the instants following IC, data from IC plus 100 ms was utilized as a time point.[60] The deepest point of the initial countermovement landing was defined as the lowest vertical point of the pelvis origin. Pelvis origin was established as the midway point between two points that bisect the ASIS and PSIS markers, respectively.

Joint angles and knee to ankle ratio were recorded for the three times points in each condition. The global coordinate system was such that participants' anteroposterior axis was the x-axis, y-axis was mediolateral, and z-axis was superior-inferior. The local coordinate system for the pelvis, thigh, shank, and foot segments was made in accordance with the International Sociality of Biomechanics.[61] Hip, knee, and ankle joint angles were calculated as Euler angles with the distal segment in reference to the proximal segment, and the y-axis (flexion/extension) first, x-axis (abduction/adduction) second, and the z-axis (internal/external rotation) last. For the hip and knee joint angles, positive values reflect flexion, adduction and internal rotation. Similarly for the ankle angles, dorsiflexion inversion, and forefoot adduction are positive values. Knee to ankle ratio, which has been used in prior research is a measure of knee valgum, was calculated as the horizontal distance between knee joint centers divided by the horizontal distance between ankle joint centers.[62] Model outputs were filtered with a low-pass, zero-lag Butterworth filter (fourth order) at a cutoff frequency of 10 Hz. Kinemaic data were exported and combined into Microsoft Excel with a custom Matlab program.

4.3. Results

Data were analyzed using the R statistical environment and the *rstatix* package (Kassambara, 2021)[63,64], which automatically conducts Mauchly's test for sphericity and applies the Greenhouse-Geisser correction to the degrees of freedom, as needed. For each measurement, an ANOVA model was estimated with the three taping conditions (no tape, spiral, and glute tapings) as the primary factor of interest and each participant serving as her own control. All analyses were repeated with BMI as a covariate in the repeated measures ANOVA model. The results were qualitatively similar for each model, and BMI was never a statistically significant factor. Therefore, summary statistics and results are presented for models that do not include BMI.

For the Y-balance data, the three dependent variables were A, PM, and PL with data always collected on the dominant (taped) leg only. There was essentially no observable difference among the results across the three taping techniques. Table 4.1 provides summary statistics and *F*-tests of the three ANOVA models.

Table 4.1. ANOVA models for Y-balance testing

	No tape	**Spiral**	**Glute**	***F[2, 58]***	***p***
A	26.4	26.1	26.1	0.510	0.603
	3.47	3.08	3.41		
PM	28.8	28.7	28.4	0.831	0.441
	3.55	3.81	3.85		
PL	25.8	25.5	25.2	0.789	0.459
	3.70	4.34	4.54		

In the DJL experiment, the distance was measured between both the knees and ankles, and the ratio was computed as a measure of valgum. That ratio was used as the dependent variable in an ANOVA model to compare results among the three taping techniques. Descriptive statistics and results of the statistically significant model appear in Table 4.2. Follow-up paired *t*-tests were conducted to describe in more detail the observed differences. The spiral taping technique resulted in greater measurements than both glute taping (*p*=.038) and no tape (*p*=.059), while the difference between untaped and glute taping was not statistically significant. While the observed differences are slight, the spiral tape resulted in the least valgum.

Table 4.2. Measurements of valgum between the three taping conditions

	No tape	**Spiral**	**Glute**	***F[2, 38]***	***p***
Knee-Ankle Ratio	0.883	0.899	0.874	3.31	0.047
	0.148	0.144	0.129		

The DJL data included measurement of 9 additional dependent variables: three dimensions each for ankle, hip, and knee. Measurements were collected at three points in time (initial contact, 100 ms later, and at the low point of the DJL) and for both the dominant (taped) leg and the non-dominant (untaped) leg. ANOVA models for each of the nine dependent measurements were estimated with taping technique and leg (dominant or non-dominant) as independent factors; each participant served as her own control.

The nine models were estimated separately for each of the three time periods, and the results were qualitatively similar. The statistics presented here are for the measurements collected 100 ms after initial contact. Table 4.3 gives summary statistics for the 9 measurements, distinguishing between dominant and non-dominant leg as well as taping technique.

Table 4.3. Comparison of valgum measurement angles at 100 ms after initial contact, dominant vs non-dominant leg

	Dominant			**Non-dominant**		
	No Tape	**Glute**	**Spiral**	**No Tape**	**Glute**	**Spiral**
AnkleX	94.3	93.6	94.4	87.5	87.7	87.4
	8.2	8.3	7.7	8.0	8.1	6.3
AnkleY	-1.6	-1.2	-0.9	0.6	0.6	0.3
	3.0	2.7	2.8	3.3	2.8	3.0
AnkleZ	2.1	-1.0	1.8	4.6	4.0	3.8
	5.4	12.8	6.2	6.2	6.0	5.1
HipX	54.4	54.5	55.8	56.5	57.0	57.0
	13.4	13.7	14.3	12.3	13.5	14.9
HipY	-5.8	-5.5	-5.1	-5.5	-4.1	-4.7
	4.8	5.4	5.1	4.9	4.1	3.4
HipZ	-3.6	-3.9	-2.4	-3.1	-2.1	-3.3
	5.2	5.7	5.9	7.9	6.6	7.8
KneeX	48.9	48.5	50.6	49.4	49.0	48.6
	11.6	11.5	11.4	11.3	11.6	12.6
KneeY	0.1	0.7	1.0	0.3	0.4	1.2
	4.4	3.6	5.0	5.2	5.0	6.3
KneeZ	4.4	2.9	3.1	2.1	2.0	1.9
	3.6	3.4	3.3	3.7	4.4	3.8

Ankle: +X (dorsi flexion), -X (plantar flexion), +Y (foot adduction), -Y (foot abduction), +Z (internal rotation), -Z (external rotation)

Hip/Knee: +X (flexion), -X (extension), +Y (adduction), -Y (abduction), +Z (inversion), -Z (eversion)

Results of the ANOVA models are summarized in Table 4.4, with statistically significant results appearing in bold print. The statistics show that there was an observed difference between dominant and non-dominant leg in all of the ankle measurements. However, in no case did the differences among the tape techniques result in a statistically significant difference.

Table 4.4. Results of ANOVA models between dominant, and non-dominant legs

	Tape	**Dominance**	**Interaction**
	F[38, 2]	***F[19, 1]***	***F[38, 2]***
AnkleX	0.440	**29.164**	0.646
	0.583	**<.001**	0.053
AnkleY	0.225	**4.773**	0.965
	0.800	**0.042**	0.365
AnkleZ	0.172	**4.871**	0.209
	0.842	**0.040**	0.813
HipX	1.485	**9.614**	3.074
	0.239	**0.006**	0.058
HipY	1.294	1.265	0.678
	0.286	0.275	0.514
HipZ	0.269	0.118	2.348
	0.766	0.735	0.109
KneeX	0.870	1.918	2.239
	0.400	0.182	0.120
KneeY	0.770	0.010	0.665
	0.470	0.921	0.520
KneeZ	0.090	2.476	0.731
	0.914	0.132	0.488

Ankle: +X (dorsi flexion), -X (plantar flexion), +Y (foot adduction), -Y (foot abduction), +Z (internal rotation), -Z (external rotation)

Hip/Knee: +X (flexion), -X (extension), +Y (adduction), -Y (abduction), +Z (inversion), -Z (eversion)

It was observed that eight of the participants actually landed in varus at the moment of initial contact (KneeY > 0). As further exploration of the data, the models were estimated again on two subsets, splitting the data from the twenty participants into subsets of the 12 who landed in valgus and the 8 who landed in varus. The results were qualitatively similar and are consequently not reported here.

4.4. Discussion

Researchers have concluded dynamic knee valgum as a possible pathomechanic for females that increases their risk for lower extremity injuries, including injuries to the anterior cruciate ligament (ACL).[1–45] Development of adequate mitigation strategies is crucial for clinicians to expand individualized approaches for each athlete. Multiple techniques to address knee valgum are cited in the literature including orthotics[2], strength programs[8,20,71], and taping applications.[1,7] However, due to limitations, lack of research, and in some cases, improper tape application, no gold standard has been established for the best way to mitigate knee valgum. Researchers for the current study chose to focus on Kinesio® Tape as a mitigation tool due to its various purposes including; muscle facilitation, muscle inhibition, mechanical support, and increased proprioception.[33]

In the present study, a novel application was utilized in theory to reduce the amount of tibial and femoral internal rotation experienced during a dynamic movement with the goal to decrease knee valgum. Our results showed that application of Kinesio® Classic Tape applied in a spiral fashion towards the lateral aspect of the tibial femoral joint as well as from the medial femoral condyle, decreased knee abduction valgum angle 100 ms after initial contact on a DJL. Considering this is a new tape application and has yet to be employed in research, findings from the present investigation are difficult to compare to previous studies. However, comparisons can be made between similar applications with the same purpose.

Limroongreungrat et al. (2019) also observed a decrease in knee valgum 100 ms after initial contact during a DJL when utilizing the Kinesio® ACL application with 75% tension.[1] Although findings are in agreement with our current study, differences are found in the main purpose of the application and what biomechanical error it was attempting to correct. Our taping application was focused specifically on valgum pathomechanics with a secondary goal to help prevent ACL injury. The ACL application utilized by Limroongreungrat et al. (2019) was specific for ACL injury. The researchers applied the tape to the tibial tuberosity then pulled to the medial and lateral condyle of the femur with the goal to limit anterior translation of the tibia.[1] Similarities in mitigation of knee valgum were also found when comparing the Sheikhi et al. (2021) study, which analyzed the effects of 72-hour Kinesio® Tape application on lower extremity kinetics during different landing tasks.[73] For the study, Kinesio® Tex Gold was applied from origin to insertion with 50-75% tension on each participants gastrocnemius, bicep femoris, vastus lateralis, vastus medialis, rectus femoris, gluteus medius, rectus abdominus, and erector spine.[73] Following 72 hours, researchers observed improvements in peak knee abduction angle, sum of knee valgum, and lateral trunk motion during a single drop jump landing ($p < 0.05$).[73] Findings of our present study align with those of Sheikhi et al. (2021) demonstrating a decrease in knee valgum during a landing task. However, multiple tape applications were employed in the Sheikhi et al. (2021) study design making it difficult for researchers to make conclusions about the best tape application to decrease knee valgum. Further research needs to be done to decipher which application or applications had a direct effect on valgum.

In the present study, the facilitative gluteus medius application, applied with the snowflake technique at 10-20% tension, showed no significant results when compared with the control condition. These findings are in contrast with a previous study that reported an immediate decrease in knee valgum in both males (4.0º, 95% CI 3.5-4.5, $P < .001$) and females (4.3º, 95% CI 3.5-5.2, $P < .003$) as well as an increase in gluteal strength when applying a Y-strip from origin to insertion with 15-25% tension.[7] However, researchers applied an incorrect muscle facilitation taping technique by pulling tension from insertion to origin. This technique is incorrect and is purported to inhibit muscle activity, thus the results of the study are hindered. Contrast was also found when comparing Saki et al. (2022) results, which employed a glute medius Y-strip at 15-25% tension.[74] Researchers observed a significant decrease in dynamic knee valgum angle from pre-test to post-test during a DJL ($p < 0.05$).[74] Unlike the Y-strip, lack of research has been completed using the Kinesio® snowflake technique since it is a new application. Consequently, comparisons between previous studies lose pertinence.

Our study aimed to assess Kinesio® Tape's effect on knee valgum for both static and dynamic tasks. To test static lower extremity stability, participants completed Y-balance testing for all three conditions. No observable differences in all three directions, across all three taping techniques were reported for Y-balance testing (A $p= 0.603$, PM $p=0.441$, PL $p=0.459$). The findings from the current study are in contrast with observations from previous studies including Saki et al. (2022) who observed an increase in Y-balance testing scores with application of a Gluteus Medius Y-strip at 15-25% tension.[74] No previous studies have employed Y-balance testing for the spiral or snowflake techniques since they are new applications. In addition, most researchers do not assess both static and dynamic in a single study. Hence, no further comparisons can be made on if our results match that of previous studies.

It is important to note that there were limitations to our study. Firstly, participants included were females between 18 and 40 years old, which limits the generalizability of the findings to only one biological sex and specific age range. No exclusion criteria were established for upper or lower limits of knee valgum, thus resulting in the potential for a large degree of variance. We did not have access to an FMS Y-balance testing unit. Therefore, the test had to be recreated with athletic tape and a tape measure, which may have affected the accuracy of the test due to human error placement. Although markers were placed on each participant prior to the start of testing and were not removed until the end, some markers fell off during DJL test trials and had to be replaced. Replacement of the marker on the participant could have added a slight degree of change of location and measure of the joint angle. Finally, due to marker errors and sensor malfunctions with the 3D motion analysis, DJL data from 10 of the participants was determined unusable therefore limiting our testing population to 20.

In conclusion, we found that while the observed differences are slight, the Kinesio® spiral tape application resulted a significant decrease in knee valgum during a DJL. In contrast, no significant differences were observed in Y-balance testing in all three directions across all three taping techniques. For this reason, we can ascertain that dynamic knee valgum may be mitigated by applying the Kinesio® Tape spiral technique. Thus, by applying the taping technique and mitigating valgum, clinicians can possibly decrease ACL injury risk in female basketball and volleyball athletes.

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APPENDIX. IRB APPROVAL

NDSU NORTH DAKOTA STATE UNIVERSITY

02/18/2021

Dr. Katie Jeanne Lyman
Health, Nutrition & Exercise

IRB Approval of Protocol #IRB0003317, “An Analysis of Kinesio® Tape on Mitigation of Dynamic Knee Valgus”

Co-investigator(s) and research team:

- Katie Jeanne Lyman
- Katelynn Elaine Smedley
- Hannah Nicole Riegel

Approval Date: 02/18/2021
Expiration Date: 02/17/2024
Research site(s): All research will be conducted in Biomechanics Laboratory 3 in the Bentson Bunker Fieldhouse on the NDSU campus at the 1301 Centennial Blvd. Fargo, ND 58102.
Funding Agency:
Review Type: Expedited category # 1,4

The above referenced protocol has been reviewed in accordance with federal regulations (Code of Federal Regulations, Title 45, Part 46, *Protection of Human Subjects*).

Additional approval from the IRB is required:

- Prior to implementation of any changes to the protocol.
- For continuation of the project beyond the approval period. A task will automatically generate for the PI and Co-PI 8 weeks prior to the expiration date. To avoid a lapse in approval, suspension of recruitment, and/or data collection, a report must be received, and the protocol reviewed and approved for continuation prior to the expiration date.

Other institutional approvals:

- Research projects may be subject to further review and approval processes.

A report is required for:

- Any research-related injuries, adverse events, or other unanticipated problems involving risks to participants or others within 72 hours of known occurrence.
- Protocol Deviations
- Any significant new findings that may affect risks to participants.

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

NDSU has an approved FederalWide Assurance with the Department of Health and Human Services: FWA00002439.

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