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Effects of Applied Knee Modalities During Gait and the Biomechanical Factors Associated with Patellofemoral Pain Syndrome

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EFFECTS OF APPLIED KNEE MODALITIES DURING GAIT AND THE BIOMECHANICAL FACTORS ASSOCIATED WITH PATELLOFEMORAL PAIN SYNDROME

BY

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To the Dean of the School of Human Performance and Leisure Sciences:

I am submitting herewith a thesis written by Lyndsay Segarra entitled "Effects of Applied Knee Modalities During Gait and the Biomechanical Factors Associated with Patellofemoral Pain Syndrome". I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science with a major in Movement Science.

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Dr. Claire Egret, Thesis Committee Chair

We, members of the thesis committee,
have examined this thesis
and recommend its acceptance:

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Accepted:

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Chair, Department of Sport and Exercise Sciences

Accepted:

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Dean, School of Human Performance and Leisure Sciences

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ABSTRACT

Patellofemoral pain syndrome (PFPS) is one of the most common overuse knee disorders among the physically active population (Selfe, Thewlis, Hill, Whitaker, Sutton, & Richards, 2011; Barton, Balachandar, Lack, & Morrissey, 2013; Ng & Wong, 2009; Waryasz & McDermott, 2008; Powers, Doubleday, & Escudero, 2007; Miller, Westrick, Diebal, Marks, & Gerber, 2013; Freedman, Brody, Rosenthal, & Wise, 2014; Nakagawa, Moriya, Maciel, & Serrão, 2012; Wünschel, Leichtle, Obloh, Wülker, & Müller, 2011; Escamilla, Zheng, MacLeod, Edwards, Imamura, Hreljac, Fleisig, Wilk, Moorman III, & Andrews, 2009; Kwon, Yun, & Lee, 2014). There are several biomechanical factors associated with PFPS. Three main factors associated with PFPS are the knee adduction angle, the internal tibial rotation angle, and the anterior shear force. The purpose of this study was to compare the biomechanical alterations related to the application of three different knee modalities: kinesio tape (KT), a neoprene sleeve (NS), a hinge brace (HB), and no modality on healthy knees during weight acceptance of gait to determine which intervention was most effective in the reduction of three main factors that are associated with PFPS. Twenty-five healthy volunteer participants (female = 14; male = 11) with the average age of 30.08, height = 1.74m, and weight = 72.78kg completed 12 gait trials each. The four randomized test conditions consisted of a control (no applied modality), an Ossur neoprene knee sleeve, an Ossur hinge brace, and Kinesio tape (neutral knee taping). Seven infrared VICON motion capture cameras, lower body marker system, and two AMTI force were used to collect the kinematic and kinetic data. A repeated measures MANOVA ($p < 0.05$) analyzed the data to identify if there were significant differences between the different test conditions and the factors tested. Results revealed significant

differences between the different modalities and the factors associated with PFPS. Both the kinesio tape ($p < 0.01$) and the hinge brace ($p < 0.01$) significantly reduced the anterior shear force during weight acceptance of gait compared to the control and the sleeve trials. The hinge brace also significantly increased both the knee adduction angle ($p < 0.01$) and the internal tibial rotation angle ($p < 0.01$) during weight acceptance of gait compared to the other test conditions. Although not significant, the KT revealed moderate results for both the internal tibial rotation and the knee adduction angle comparable to the results found for the control and the neoprene sleeve trials during weight acceptance of gait. The results of this study conflicted with previous research findings in which the hinge brace significantly reduced internal tibial rotation and knee adduction angles during gait and step descent tasks. Further research should be conducted to eliminate conflicting results and ultimately provide the best understanding of how these modalities alter the mechanical factors associated with patellofemoral pain syndrome.

CHAPTER I

INTRODUCTION

Patellofemoral pain syndrome (PFPS) is one of the most common overuse knee disorders among the physically active population (Selfe, Thewlis, Hill, Whitaker, Sutton, & Richards, 2011; Barton, Balachandar, Lack, & Morrissey, 2013; Ng & Wong, 2009; Waryasz & McDermott, 2008; Powers, Doubleday, & Escudero, 2007; Miller, Westrick, Diebal, Marks, & Gerber, 2013; Freedman, Brody, Rosenthal, & Wise, 2014; Nakagawa, Moriya, Maciel, & Serrão, 2012; Wünschel, Leichtle, Obloh, Wülker, & Müller, 2011; Escamilla, Zheng, MacLeod, Edwards, Imamura, Hreljac, Fleisig, Wilk, Moorman III, & Andrews, 2009; Kwon, Yun, & Lee, 2014). There have been many contradictory theories identifying the cause of PFPS. Since PFPS is commonly diagnosed as an overuse injury, there are several risk factors for the development of PFPS (Kwon, Yun, & Lee, 2014). More recently, Freedman, Brody, Rosenthal, and Wise (2014) have identified these risk factors as patellar malalignment accompanied with patellar maltracking, weakness of the lower extremity muscles including abnormal vastus lateralis and vastus medialis reflex timing, tightness of the soft tissues in the lower extremities, anatomical abnormalities of the lower extremity, and altered kinematics of the lower extremity. Several studies have identified an increased knee adduction angle and increased internal tibial rotation as additional risk factors for PFPS (Selfe, Thewlis, Hill, Whitaker, Sutton, & Richards, 2011; Waryasz & McDermott, 2008; Webster, McClelland, Palazzolo, Santamaria, & Feller, 2012; Wünschel, Leichtle, Obloh, Wülker, & Müller, 2011; Foroughi, Smith, Lange, Baker, Fiatarone Singh, & Vanwanseele, 2011).

Many of these precursors to PFPS have been cited by Waryasz and McDermott (2008), and in addition have identified proximal and distal joint risk factors for the development of PFPS. Distally at the foot and ankle, some of the risk factors for the development of PFPS are both pes cavus or pes planus foot type, an increased gastrocnemius and soleus tightness, increased subtalar pronation of the foot, and an increased internal tibial rotation (Waryasz & McDermott, 2008; Kosashvili, Fridman, Backstein, Safir, & Bar Ziv, 2008). Proximally at the hip, some of the contributing factors for PFPS are increased internal femoral rotation, increased hamstring tightness, weak iliopsoas, increased anterior pelvic tilt, increased iliotibial band tightness, and an increased quadriceps tightness (Waryasz & McDermott, 2008). In addition to distal risk factors, Shibuya, Kitterman, LaFontaine, and Jupiter (2014) associated different physical, demographic, and radiographic characteristics with the pes planus foot type deformity, which is associated as a risk factor for PFPS. Risk factors for pes planus foot type are male individuals, increased age, Asian American, African-American, veterans, poor health, increased body mass index (BMI), and arthritis if it is not physiological (Shibuya, Kitterman, LaFontaine, & Jupiter, 2014).

PFPS can affect both the physically active population and the non-physically active population due to the numerous risk factors that can accompany working out or performing activities of daily living. Whether you are rehabilitating an injury from a fall, cleaning your house, or walking to work, individuals perform stair ascent and descent, chair descent and raise (essentially squats), or bending down to pick something up (lunge or one leg squat) regularly and these daily tasks can increase the risk factors for PFPS if not performed correctly. When an individual descends to sit in a chair the patellofemoral joint force and stress increases (Escamilla, et. al., 2009). More specifically, the patellofemoral joint force and stress is greatest during 70°-90° of knee flexion during descent and ascent from a squat or chair descent/ascent (Escamilla, et. al., 2009). Eleven activities of daily living were analyzed for the knee kinematics by Desloovere, Wong, Swings, Callewaert, Vandenneucker, and Leardini (2010). As stated before, some of the risk factors for PFPS are increased knee adduction angle and increased internal tibial rotation. During activities of daily living knee adduction angles were increased during step ascent and a forward lunge, while increased knee internal tibial rotation was found during almost all of the 11 activities of daily living including walking with crossover turn, walking with a sidestep turn, step ascent, step descent, step descent with crossover turn, step descent with sidestep turn, a chair descent, chair ascent, a mild squat, a deep squat, and a lunge (Desloovere, Wong, Swings, Callewaert, Vandenneucker, & Leardini, 2010).

Bracing and taping techniques have been increasingly popular in the clinical practice for reducing the pain and the biomechanical alterations associated with PFPS (Powers, Doubleday, & Escudero, 2007; Selfe, Thewlis, Hill, Whitaker, Sutton, & Richards, 2011; Ng & Wong, 2009; Barton, Balachandar, Lack, & Morrissey, 2013; Khan, Jones, Nokes, & Johnson, 2007; Miller, Westrick, Diebal, Marks, &Gerber, 2013; Arazpour, Notarki, Salimi, Bani, Nabavi, & Hutchins, 2013; Fleming, Renstrom, Beynnon, Engstrom, & Peura, 2000; Freedman, Brody, Rosenthal, &Wise, 2014). Additionally, taping methods are successful at different joints to accommodate other types of dysfunctions such as pain or biomechanical deviation such as impingement (Kaya, Zinnuroglu, & Tugcu, 2011; Huang, Hsieh, Lu, & Su, 2011; Salsich, Brechter, Farwell, & Powers, 2002; Miller, Westrick, Diebal, Marks, &Gerber, 2013). As stated by Miller, Westrick, Diebal, Marks, and Gerber (2013) “kinesio tape activates the cutaneous receptors which may augment and override muscle spindle feedback, when the muscle spindles and cutaneous receptors are activated together, larger responses in kinesthesia and proprioception can be seen at multiple joints compared with skin stretch or muscle spindle activation alone, creating an increase in motor control”. Bracing is idealized for the reduction of range of motion, to increase the quality of control of movements, and the support through circumferential compression activating the cutaneous receptors on the skin bringing heat to the area (Selfe, Thewlis, Hill, Whitaker, Sutton, & Richards, 2011; Khan, Jones, Nokes, & Johnson, 2007).

Statement of the Problem

Research describes several advantages and disadvantages to the three different modalities that was the base of this research (Kinesio tape, neoprene sleeve, and the hinge brace). For example, the kinesio tape (KT) might be expensive, but it is water-resistant, and wears easily under clothes as apposed to the bulkiness of a hinge brace or a neoprene sleeve (Freedman, Brody, Rosenthal, & Wise, 2014). On the other hand, the kinesio tape only lasts about a week after application, an individual has to either have an experienced person apply the tape or research how to apply it themselves, and it covers less circumferential area than a brace does (Barton, Balachandar, Lack, & Morrissey, 2013). Hinge braces and neoprene sleeves provide larger circumferential compression, they are usually a one-time purchase, the hinge brace and the neoprene sleeve alters the kinematics and kinetics of a joint through proper application, and helps protect the joint (Selfe, Thewlis, Hill, Whitaker, Sutton, & Richards, 2011; Khan, Jones, Nokes, &

Johnson, 2007). However, hinge braces and neoprene sleeves can be expensive, tend to move or slide distally down the leg during activities of daily living, misaligning the hinge brace or neoprene sleeve, and hinge braces are large and bulky creating an altered gait pattern by the wearer (Singer & Lamontagne, 2008; Baltaci, Aktas, Camci, Oksuz, Yildiz, & Kalaycioglu, 2011). Therefore, it is imperative to identify which modality provides the best clinical practice for the aid of treatment and rehabilitation to individuals suffering from PFPS.

Purpose of the study

To our knowledge, there is no study comparing the biomechanical alterations of the over the counter kinesio tape, a rehabilitative neoprene sleeve knee brace, and a hinge brace on healthy individuals during gait. Therefore, the purpose of this study was to compare the biomechanical alterations related to the application of three different knee modalities: kinesio tape, a neoprene sleeve, a hinge brace, and no modality on healthy knees during gait to determine which intervention is most effective in the reduction of factors that can cause PFPS.

Research Hypotheses

It was hypothesized that the hinge brace is the most effective on reducing the following compared to the kinesio tape and neoprene sleeve:

(a) Peak knee internal rotation during weight acceptance and

(b) Anterior knee shear force during weight acceptance.

It was also hypothesized that the hinge brace is the least effective on reducing the following compared to the kinesio tape and neoprene sleeve:

(c) Knee adduction angle during weight acceptance of gait.

Operational Definitions

1. Kinematics: a description of movements not pertaining to the forces that are involved (Whiting & Zernicke, 2008).
2. Kinetics: The study of forces and their effects; the assessment of movements pertaining to the forces that are involved (Whiting & Zernicke, 2008).
3. Healthy knees: are described as individuals with no knee pathologies (genu varum/genu valgum) and no knee surgeries (within the past 6 months).
4. Kinesio Tape (KT): authentic elastic tape used in the clinical setting to reduce pain and inflammation and increase range of motion and posture (Huang, Hsieh, Lu, & Su, 2011).
5. Range of motion (ROM): acronym commonly used to describe the amount of movement at a joint.

6. Vertical ground reaction force (vGRF): the reaction force supplied by the ground counteracting the body weight, specifically in the vertical direction (Whiting & Zernicke, 2008).
7. Electromyography (EMG): technique used for analyzing the electrical activity of the skeletal muscles (Whiting & Zernicke, 2008).
8. Patellofemoral pain syndrome (PFPS): a condition of both the muscular dysfunction and malalignment in addition to foot, hip, and knee pathologies (Waryasz & McDermott, 2008).
9. Patellofemoral joint force (PFJF): joint forces are related to the area of contact size within the joint; in addition, the PFJF is also related to the shear force and quadriceps force in the knee (Escamilla, Zheng, Macleod, Brent Edwards, Imamura, Hreljac, Fleisig, Wilk, Moorman III & Andrews, 2009).
10. Vastus medialis oblique (VMO): quadriceps muscle that is associated with PFPS, stating that a weakened or delayed VMO is one of the causes or precursors to the development of PFPS (Waryasz & McDermott, 2008).
11. Knee adduction moment (KAM): is used to assess the medial tibiofemoral contact force, increased KAM is associated with increased loads on the medial knee compartment (Webster, McClelland, Palazzolo, Santamaria, & Feller, 2012).
12. Knee adduction angle (KA): can be described at the movement of the knee towards the midline during gait; knee valgus pathologies have increased knee adduction angles (Selfe, Thewlis, Hill, Whitaker, Sutton & Richards, 2011).
13. Q-angle: with the starting point at the anterior superior iliac crest, a line is drawn down to the center of the patella with a second line drawn from the center of the

patella to the tibial tuberosity (Whiting & Zernicke, 2008). (Normal Q angle range for males is <14° and for females is <17°).

Assumptions

Reliability and validity are preserved through the following assumptions with the addition of controlling factors by the lead investigator of this research:

1. All of the participants were honest providing accurate information pertaining to personal information during their participation.
2. All of the participants gave one hundred percent effort during the entirety of their participation.
3. All of the participations fully understand what was required of them during their participation for this research study.

Delimitations

The lead investigator of this study limited select factors to aid in the internal and external validity and to better control for the variables including:

1. This study was only performed during the gait cycle and not through more dynamic movements found in activities of daily living or among the physically active population.
2. Only the right leg was manipulated with the three different modalities to control for dominance.
3. Participants were over the age of 18 years.
4. Participants were completely voluntary and recruitment will be open to include individuals from Barry University.
5. This study included both males and females.

Limitations

Variables that will influence the data, but will be harder to control are:

1. This study was performed on healthy knees excluding individuals with (a) knee pathologies and (b) knee surgeries within the past six months.
2. The study was conducted in a lab setting.

Significance of the Study

The importance of this study was to understand whether or not the commonly used knee modalities (KT, neoprene sleeve, and functional brace) alter the biomechanical properties of the knee in the ways that they are designed to be beneficial in the reduction of the biomechanical risk factors for the prevention or management of PFPS. To date, there is no research comparing kinesio tape to both a neoprene sleeve and a hinge brace. Quantitative variables that were examined are knee adduction angle, knee shear force, and knee internal rotation angle. All of these variable were examined during weight acceptance phase of gait.

CHAPTER II

LITERATURE REVIEW

The literature review begins with the definition of PFPS and known causes are explored. The signs and symptoms of PFPS are explained followed by some controversial findings. Kinesio taping will then be introduced as the first technique to aide in the reduction of risk factors associated with PFPS, followed by the neoprene knee sleeve, and lastly the hinge knee brace to investigate how these applications of modalities alter the biomechanics of the knee among healthy individuals to aid in the growing community who suffer from PFPS.

Patellofemoral Pain Syndrome

Chronic anterior knee pain is mostly associated with PFPS, which can eventually turn into the degeneration of the knee resulting in osteoarthritis (Barton, Balachandar, Lack, & Morrissey, 2013; Campolo, Babu, Dmochowska, Scariah, & Varughese, 2013). PFPS can be defined as subchondral bone stress due to the articulation of the patellofemoral joint and the associated cartilaginous lesions on the posterior aspect of the patella and/or on the distal aspect of the femur (Waryasz & McDermott, 2008). As the cartilaginous lesions increase, the degeneration of the cartilage increases, resulting in the decreased ability for the cartilage to distribute the patellofemoral joint force (Escamilla, Zheng, Macleod, Brent Edwards, Imamura, Hreljac, Fleisig, Wilk, Moorman III, & Andrews, 2009). Individuals with PFPS present an altered gait pattern with reduced knee flexion during stance, reduced walking velocity, a decreased vasti muscle activity, and decreased peak knee extensor moments (Salsich, Brechter, Farwell, & Powers, 2002).

Patellofemoral pain syndrome accounts for 25-30% of all knee pathologies treated (Escamilla, et. al., 2009; Freedman, Brody, Rosenthal, & Wise, 2014; Nakagawa, Moriya, Maciel, & Serrão, 2012; Kwon, Yun, & Lee, 2014). The cause of patellofemoral pain has received increased attention due to prevalence of the disorder and the many pathologies of the disease. Ng and Wong (2009) describes the cause of PFPS as the abnormal biomechanics of the patellofemoral complex. Powers, Doubleday, and Escudero (2007) explain the cause of PFPS as the altered patellofemoral pressure distribution within the joint and the inflammation of the soft tissues that this causes. In addition, Waryasz and McDermott (2008) also stated the cause of PFPS is the malalignment of the patellofemoral joint and a muscular dysfunction. Some research even stated that the maltracking or malalignment of the patella is caused by a weak or delayed vastus medialis obliqus (VMO) (Barton, Balachandar, Lack, & Morrissey, 2013; Wünschel, Leichtle, Obloh, Wülker, & Müller, 2011; Salsich, Brechter, Farwell, & Powers, 2002). Other research has focused the cause towards the function of the hip and the altered mechanics of the hip among individuals with PFPS compared to those without PFPS (Miller, Westrick, Diebal, Marks, & Gerber, 2013).

The patella is the largest sesamoid bone in the body, with the purpose to protect the tibiofemoral joint (Waryasz &McDermott, 2008). Sesamoid bones are used as pulleys to allow for tendons to glide smoothly over a joint and are usually embedded in those tendons (Waryasz & McDermott, 2008). This pulley system allows for the quadriceps muscles to actively contract extending the leg as the patella glides smoothly through the trochlear groove of the femur creating stress and force upon the patellofemoral joint (Whiting & Zernicke, 2008). According to the study by Waryasz and McDermott (2008), in order for the patella to remain in the trochlear groove, there must be a posterior sagittal pull from the quadriceps force vector. Pathological alterations of patella shape and size as well as of the shape and size of the end of the femur (trochlear groove) and the congruence between the two bones can be the cause of the pain and discomfort for individuals suffering from PFPS (Whiting & Zernicke, 2008). See Figures 1 and 2.

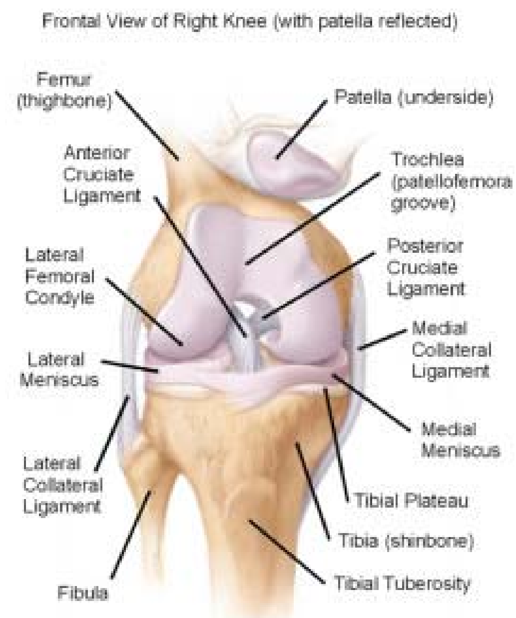

Figure 1: *Anterior aspect of the knee with patellar tendon cut retracted to reveal trochlear groove.*

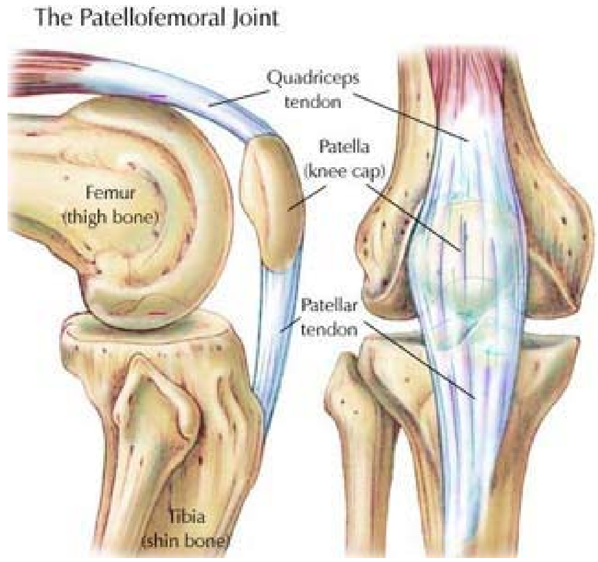

Figure 2: *Sagittal and anterior view of the knee with patella intact.*

Signs and Symptoms of PFPS

The numerous pathologies correlated with PFPS result in numerous signs and symptoms about the knee joint as well as at the proximal hip joint and at the distal ankle joint. Selfe, Thewlis Hill, Whitaker, Sutton, and Richards (2011) focused on the knee alterations during gait among individuals with PFPS, more specifically finding an increased knee internal rotation moment and a greater peak knee adduction (KA) angle. In addition, knee adduction moment (KAM) has been associated with the severity of osteoarthritis of knee (Kean, Hinman, Bowles, Cicuttini, Davies-Tuck, & Bennell, 2012; Foroughi, Smith, Lange, Baker, Fiatarone Singh, & Vanwanseele, 2011; Webster, McClelland, Palazzolo, Santamaria, & Feller, 2012). KAM moment measures the load of the medial knee compartment at one moment, but KAM impulse measures the magnitude of the load during the duration of stance (Kean, Hinman, Bowles, Cicuttini, Davies-Tuck,

& Bennell, 2012). KA angle among individuals with PFPS is susceptible to the development of knee osteoarthritis, resulting in my interest to see if one of the three modalities will assist in the reduction of KA angle.

Pathologies at the ankle such as pes planus and pes cavus foot types have been seen to contribute to PFPS, especially a high arch (pes cavus) foot deformity because this foot type increases the patellofemoral joint pressures (Waryasz & McDermott, 2008; Kosashvili, Fridman, Backstein, Safir, & Ziv, 2008; Arazpour, Notarki, Salimi, Bani, Nabavi, & Hutchins, 2013). Military recruits with patellofemoral pain lasting longer than three months were analyzed by Kosashvili, Fridman, Backstein, Safir, & Ziv, (2008) to investigate the prevalence of pes planus foot type with anterior knee pain. The results concluded that individuals with more moderate to severe pes planus had increased anterior knee pain and that the pes planus foot type was more common among males than females in this population (Kosashvili, Fridman, Backstein, Safir, & Ziv, 2008).

In addition to foot pathologies, Waryasz and McDermott (2008) also investigated knee pathologies; concluding that both genu varum and genu valgum can contribute to PFPS due to the altered patellofemoral and tibiofemoral joint alignment. Other factors included: increased gastrocnemius and soleus tightness decreasing dorsi flexion of the foot, which increases subtalar joint pronation and internal tibial rotation, causing increased femoral rotation, resulting in increased patellofemoral joint stress; ligament laxity increases patellar mobility; hamstring tightness increases knee flexion creating increased patellofemoral joint reaction forces; weak iliopsoas can result in an anterior pelvic tilt destabilizing the pelvis and creating increased internal rotation of the femur increasing the patellofemoral joint stress; iliotibial band tightness can create increased lateral patellofemoral joint stress; patellar crepitus can increase the chondra malacia and decrease the mobility of the patellofemoral joint; patellar maltracking, glide, mobility, and lateral tilt can increase the patellofemoral joint stresses; lastly an increase or decrease of the Q-angle can increase peak patellofemoral pressure because with the altered angle at the hip, the contact pressure changes at the patellofemoral joint (Waryasz & McDermott, 2008). An ipsilateral trunk lean and contralateral pelvic drop accompanied by and increased hip adduction and increased knee abduction during weight bearing activities has been identified to increase the valgus knee angle resulting in an increased PFJF and is more common among females with PFPS according to results from studies performed by Nakagawa, Moriya, Maciel, and Serrão (2012). Many individuals with PFPS portray an altered gait pattern and develop a decreased quadriceps activity because of the knee extensor avoidance (Powers, Doubleday, & Escudero, 2007) and also have and increased peak hip internal rotation and decreased hip muscle strength (Miller, Westrick, Diebal, Marks, & Gerber, 2013).

Anterior knee pain is the most common symptom of PFPS. This anterior knee pain can be aggravated by activities of daily living such as stair climbing (ascending and descending), squatting (other activities during loaded flexion) (Campolo, Babu, Dmochowska, Scariah, & Varughese, 2013; Nakagawa, Moriya, Maciel, & Serrão, 2012), after prolonged sitting with knees flexed, and perceived instability (Powers, Doubleday, & Escudero, 2007). During stepping maneuvers there is a noticeable difference between males and females in ipsilateral trunk lean, pelvic drop, hip adduction, and knee abduction among a general population (Nakagawa, Moriya, Maciel, & Serrão, 2012). Females in general, had increased ipsilateral trunk lean, pelvic drop, hip adduction, and knee abduction compared the males during the both the ascend and descend of the stepping (Nakagawa, Moriya, Maciel, & Serrão, 2012). Differences were found between females with PFPS and females without PFPS during the stepping maneuvers where the females with PFPS had increased ipsilateral trunk lean, increased pelvic drop, and a decrease in gluteus maximus activity (Nakagawa, Moriya, Maciel, & Serrão, 2012). Both groups of females showed increased hip adduction and increased knee abduction during all degrees of ascend and descend (Nakagawa, Moriya, Maciel, & Serrão, 2012).

Research provides contradictory results to certain pathologies of PFPS. Many studies conclude a weak or delayed VMO is one of the main signs of PFPS (Barton, Balachandar, Lack, & Morrissey, 2013; Ng & Wong, 2009; Waryasz & McDermott, 2008), but some of this research has directly stated results have not found significance between a weak or delayed VMO among individuals with PFPS compared to those without (Miller, Westrick, Diebal, Marks, & Gerber, 2013; Powers, Doubleday, & Escudero, 2007). In addition, strengthening the VMO has been found to improve the patellar tracking, but it also increases the internal tibial rotation with increased knee flexion (Wünschel, Leichtle, Obloh, Wülker, & Müller, 2011). This increased internal tibial rotation during knee flexion and during stance can be a risk factor for the development of PFPS (Waryasz & McDermott, 2008; Arazpour, Notarki, Salimi, Bani, Nabavi, & Hutchins, 2013). On the other hand, Kwon, Yun, and Lee (2014) compared individuals with PFPS to those without PFPS investigating the shortening of the hamstring muscles and the quadriceps angle (Q-angle). Results identified a significant difference between shortening of the hamstring muscles among the PFPS group compared to the control group and if the participant had a static Q-angle greater than 15°

the more likely the participant is to have PFPS (Kwon, Yun, & Lee, 2014). One study focused on the signs and symptoms of PFPS did not even mention Q-angle as a pathological sign contributing to the effects of PFPS (Barton, Balachandar, Lack, & Morrissey, 2013). Overall, the main goals when treating PFPS are to reduce the pain and increase functional ability. This can be achieved through proper bilateral lower limb muscular strengthening with the aid of bracing and taping techniques, as well as non-steroidal anti-inflammatory drugs (Powers, Doubleday & Escudero, 2007).

Successful conservative treatments have been applied to rehabilitation practices for PFPS when they are practiced correctly. For example, many clinicians and trainers have their patients perform activities such as the lunge and the squat to strengthen the quadriceps muscles to aid in the correct tracking of the patella (Escamilla, et. al., 2009); (Swinton, Lloyd, Keogh, Agouris, & Stewart, 2012). When these movements are performed incorrectly and there is forward translation of the knee past the toes, the patellofemoral joint force (PFJF) and stress increases (Escamilla, et. al., 2009);(Swinton, Lloyd, Keogh, Agouris, & Stewart, 2012). During the descent of the squat, the PFJF progressively increases and is at it's peak during 60°-90° of knee flexion during both the descent and ascent of the squat (Escamilla, et. al., 2009). Strengthening the vastus lateralis resulted in a decrease in the PFJF and lateral loading of the quadriceps, reducing the internal tibial rotation at angles greater than 70° (Wünschel, Leichtle, Obloh, Wülker, & Müller, 2011). When the squat is performed compressive and shear forces are increased with increased knee flexion angles (Swinton, Lloyd, Keogh, Agouris, & Stewart, 2012).

Knowing the causes, signs, and symptoms of PFPS is critical to the care, management, and treatment of this overuse injury. Some of the current practices for the management of PFPS are different bracing and taping techniques that will now be investigated.

Kinesio Tape and PFPS

Bracing and taping techniques are used for the reduction of pain and aid in correcting the malalignment or maltracking of the patellofemoral joint among those who suffer from PFPS. Miller, Westrick, Diebal, Marks, and Gerber (2013) state the reason in why KT should be effective is because the KT's contribution among kinesthesia cutaneous receptors creating an increase in motor control due to the coupling of both muscle spindle fibers and the cutaneous receptors, resulting in an increased response in kinesthesia and proprioception. The kinesio tape is designed to mimic the properties and elastic qualities of the skin (Freedman, Brody, Rosenthal, & Wise, 2014), providing the correct stimulus to activate muscles and facilitate skin tension and circulation through the interstitial tissues. Selfe, Thewlis, Hill, Whitaker, Sutton, and Richards (2011) have stated that corrective taping for PFPS is now considered to be a standard rehabilitative practice by clinicians for individuals suffering from PFPS. Effects of elastic taping have revealed a decrease in pain and inflammation, increase in ROM and posture, as well as the tape has deemed comfortable to its' wearers (Huang, Hsieh, Lu, & Su, 2011; Salsich, Brechter, Farwell, & Powers, 2002). The reason for these effects are that the kinesio tape increases proprioception, stability, support and protection of the joint, as well as alters the alignment and biomechanical kinematics and kinetics normalizing the function of joints, increasing fluid circulation, fascia relaxation with ligament and tendon support (Huang, Hsieh, Lu, & Su, 2011). For example, the application of KT has been associated with the increase in quadriceps muscle activity as well as an increased in the quadriceps torque (Salsich, Brechter, Farwell, & Powers, 2002).

Campolo, Babu, Dmochowska, Scariah, and Varughese (2013) examined the effects KT would have on knee pain among those with PFPS compared to without KT during squatting and stair climbing tasks. The results of this study were consistent with other findings (Barton, Balachandar, Lack, & Morrissey, 2013; Ng & Wong, 2009; Freedman, Brody, Rosenthal, & Wise, 2014; Huang, Hsieh, Lu, & Su, 2011) in revealing that the application of KT technique significantly relieved pain among participants with PFPS. Freedman, Brody, Rosenthal, and Wise (2014) used the application of patellar tracking applied kinesio tape to improve the functionality and to reduce the pain of individuals with PFPS during three different functional tasks. The applied patellar tracking kinesio tape significantly improved the distance of the single leg triple hop test, but did not have any significant alterations to the other functional tests performed in this study (Freedman, Brody, Rosenthal, & Wise, 2014). During gait and stair climbing trials, Salsich, Brechter, Farwell, and Powers (2002) results indicated that when patellar taping was applied, there was a significant reduction in pain, the walking speed increased, knee flexion increased, and knee extensor moment increased during the stair climb activities.

In addition, Ng and Wong (2009) also examined the quadriceps muscle activity before and after fatigue from stretch reflex testing among individuals with PFPS. Results revealed there was no significant difference in the onset of timing between the vastus lateralis and the vastus medialis oblique (VMO) during the different test conditions of KT, placebo tape, and no tape (Ng & Wong, 2009). There was a significant difference in the amplitude of the VMO among testing conditions as there was less VMO activity in the KT condition compared to the no tape condition (Ng & Wong, 2009). Contradictory results were found by Barton, Balachandar, Lack, and Morrissey (2013); concluding that the results revealed an earlier muscle activation timing of the VMO when the kinesio tape was applied, but a decrease in the VMO amplitude. Investigations of 20 articles reviewing PFPS and different taping techniques with the addition of biomechanical alterations upon the knee concluded that there was no significant reduction in patellofemoral joint force, nor did the data find a significant increase in knee flexion and knee flexion moments (Barton, Balachandar, Lack, & Morrissey, 2013).

Different taping techniques applying the KT at the proximal hip joint focusing on gluteus medius activation instead of the knee, among those with PFPS, was examined by Miller, Westrick, Diebal, Marks, and Gerber (2013). The results concluded a significant increase in range of motion (ROM) of the knee among participants with the KT during the double legged squat task compared to the placebo tape and the no tape testing conditions, but no significant difference during the Y balance test between groups (Miller, Westrick, Diebal, Marks, & Gerber, 2013). The Y balance test consists of balancing on the test limb while the contralateral limb is reaching out in three different directions, anteriorly, posteriomedial, and posteriolateral (Miller, Westrick, Diebal, Marks, & Gerber, 2013). The effects of the kinesio tape on the triceps surae during a maximum vertical jump examining the vertical ground reaction force (vGRF) and electromyography (EMG) were investigated. The results indicated that when the kinesio tape was applied there was a significant difference in the vGRF compared to the control group (Huang, Hsieh, Lu, & Su, 2011). There was also a noticeable increase of EMG activity of the medial gastrocnemious when the kinesio tape was applied (Huang, Hsieh, Lu, & Su, 2011). The Kinesio tape has also been a successful modality when applied to the shoulder for individuals with shoulder impingement as compared to physical therapy alone (Kaya, Zinnuroglu, & Tugcu, 2011). In this study, there was a significant decrease of pain and a significant increase in the functionality of the arm and shoulder among the KT group, in the two weeks that were tested, compared to the group that only received physical therapy (Kaya, Zinnuroglu, & Tugcu, 2011).

There are some controversial findings regarding the application of KT for the pain and biomechanical alterations of the knee among individuals with PFPS. The application of KT was shown to decrease the ROM of the knee during step descent tasks among individuals with PFPS, there was no significant difference in velocity or in the reduction of peak KA angle (Selfe, Thewlis, Hill, Whitaker, Sutton, & Richards, 2011). There was no difference in jump height when kinesio tape was applied to the triceps surae, but vertical jump height, vGRF, and EMG decreased in the placebo tape group compared to the control (no tape) and the KT group (Huang, Hsieh, Lu, & Su, 2011). Lastly, there was no significant reduction in pain among individuals with PFPS with the applied KT at the hip (Miller, Westrick, Diebal, Marks, & Gerber, 2013).

Neoprene Sleeve and PFPS

Individuals with PFPS tend to alter their lower limb mechanics during gait and other activities of daily living (Powers, Doubleday, & Escudero, 2007; Selfe, Thewlis, Hill, Whitaker, Sutton, & Richards, 2011). Bracing is applied to the knee in attempt to correct the altered mechanics for normal kinematic and kinetic movement patterns

(Singer & Lamontagne, 2008). The neoprene knee sleeve has been identified to aid in the coordination and proprioception of the limb (Baltaci, Aktas, Camci, Oksuz, Yildiz, & Kalaycioglu, 2011). These findings are also supported by Selfe, Thewlis, Hill, Whitaker, Sutton, and Richards (2011), stating that the warmth and compression of the neoprene sleeve enhances proprioception, which in turn increases the stability of the knee. The neoprene sleeve has also been reported to reduce knee pain and improve overall function (Arazpour, Notarki, Salimi, Bani, Nabavi, & Hutchins, 2013). In addition, the neoprene sleeve can aid in correcting the patellar tracking, which should decrease pain and allow more comfortable mobility among individuals with PFPS (Powers, Doubleday, & Escudero, 2007).

Many studies concluded that the neoprene sleeve can inhibit the ROM of the knee during gait, descending stairs, and other activities of daily living such as a squat, balancing, and jumping compared to the absence of the sleeve among both healthy participants and those diagnosed with PFPS, but can also improve the quality of control, decrease pain, and increase proprioception and overall function of the knee (Baltaci, Aktas, Camci, Oksuz, Yildiz, & Kalaycioglu, 2011; Singer & Lamontagne, 2008; Selfe, Thewlis, Hill, Whitaker, Sutton, & Richards, 2011). One study evaluated the mechanics of the knee among individuals with PFPS and how patellar bracing affects these mechanics during step descent tasks. Results found that the quality of control was enhanced with the application of the sleeve and the patellofemoral joint contact area was increased reducing the joint pressure during step descent tasks compared to no sleeve among participants with PFPS (Selfe, Thewlis, Hill, Whitaker, Sutton, & Richards, 2011). Another study compared the kinematics and kinetics of the sleeve brace during gait among healthy individuals. The peak knee flexion was decreased with the application of the neoprene sleeve during gait compared to no sleeve among healthy participants (Singer & Lamontagne, 2008). To compare, research has also been conducted using the neoprene sleeve on individuals with PFPS during gait during a six-week period (Arazpour, Notarki, Salimi, Bani, Nabavi, & Hutchins, 2013). Pain was reduced by 59.6%, the walking speed, cadence, and step length increased, knee flexion angles increased during initial contact, loading response, and swing phases of gait with the application of the neoprene sleeve (Arazpour, Notarki, Salimi, Bani, Nabavi, & Hutchins, 2013). There was no significant difference in peak knee adduction angle or velocity during the step descent tasks, though there was a reduction in knee varus angle with the applied neoprene sleeve compared to no sleeve among individuals with PFPS (Selfe, Thewlis, Hill, Whitaker, Sutton, & Richards, 2011).

Conversely, when the neoprene sleeve was applied to participants with PFPS there was a significant increase in knee flexion during the loading response of gait (Powers, Doubleday, & Escudero, 2007). In addition, one study (Baltaci, Aktas, Camci, Oksuz, Yildiz, & Kalaycioglu, 2011) examined how the neoprene knee sleeve would affect balance, proprioception, coordination, and muscular power performances among healthy individuals. Baltaci, Aktas, Camci, Oksuz, Yildiz, and Kalaycioglu (2011) revealed that the neoprene sleeves were not as effective in aiding in proprioception, balance, coordination, and muscular power as compared to other bracing techniques among healthy individuals during activities of daily living such as balancing tasks, squatting tasks and jumping tasks. The effects of pain, knee extensor torque production, and gait characteristics after a sleeve brace was applied to individuals suffering from

PFPS during gait were examined by Powers, Doubleday and Escudero (2007). There was no significant difference in pain, velocity, cadence, and stride length among neoprene sleeve trials compared to no sleeve trials among individuals with PFPS (Powers, Doubleday, and Escudero, 2007).

Hinge Brace and PFPS

The position of the knee, between the two longest levers (femur and tibia) of the body creates the tendency for increasing injury, resulting in the increased use for orthotic knee braces as management for these injuries (Khan, Jones, Nokes, & Johnson, 2007). More involved knee braces such as the functional prophylactic knee brace, or more commonly known as the hinge brace, are supposed to aid in maintaining the proper alignment of the knee preventing injuries (Singer & Lamontagne, 2008; Baltaci, Aktas, Camci, Oksuz, Yildiz, & Kalaycioglu, 2011; Dai, Butler, Garrett, & Queen, 2012; Fleming, Renstrom, Beynnon, Engstrom, & Peura, 2000). Many believe that the hinge brace is directly used for protecting the anterior cruciate ligament grafts during rehabilitation to restore the joints' kinematics and kinetics (Fleming, Renstrom, Beynnon, Engstrom, & Peura, 2000).

Some controversy has arisen with the application of knee bracing, one being the distal migration of the brace during activity (Singer & Lamontagne, 2008). In addition to the downward sliding of the brace, some research has reported an increase in knee injuries with the application of hinge braces, and undesired altered contralateral limb mechanics (Baltaci, Aktas, Camci, Oksuz, Yildiz, & Kalaycioglu, 2011; Dai, Butler, Garrett, & Queen, 2012). The most important factor when applying a prophylactic type brace is that the braces hinges must align with the natural axes of the knee to allow for proper mechanical functioning (Singer & Lamontagne, 2008). Improper placement of these types of braces can result in increased shear forces on the soft tissues of the knee resulting in the decreased ability for the brace to prevent anterior translation of the tibia on the femur creating increased strain to the anterior cruciate ligament and other structures of the knee (Singer & Lamontagne, 2008; Fleming, Renstrom, Beynnon, Engstrom,& Peura, 2000).

The functional prophylactic knee brace (hinge brace) is used to prevent, protect, stabilize, decreasing the joint laxity and improving the quality of control about the knee (Khan, Jones, Nokes, & Johnson, 2007; Fleming, Renstrom, Beynnon, Engstrom, & Peura, 2000). The application of the hinge brace has been seen to reduce anterior shear force, pain, and instability, while increasing the ROM (Dai, Butler, Garrett, & Queen, 2012). Anterior cruciate ligament graft strains were analyzed during both braced and non-braced, weight bearing and non-weight bearing conditions during different applied loading trials. The results of these trials revealed that the braced conditions significantly reduced the shear strain on the knee during both weight bearing and non-weight bearing conditions (Fleming, Renstrom, Beynnon, Engstrom, & Peura, 2000). Unfortunately the knee brace did not reduce any varus or valgus strain applied to the knee during the weight bearing or non-weight bearing conditions (Fleming, Renstrom, Beynnon, Engstrom, & Peura, 2000).

A comparison of lower limb mechanics among healthy individuals with the application of hinged braces was examined. Singer and Lamontagne (2008) found that the addition of the hinged brace resulted in a reduced peak ankle plantar flexion moment as well as significantly decreased the peak knee flexion angles during gait among healthy individuals. In addition, there was a significant increase in the knee adduction angle during gait trials with the applied hinge brace for healthy individuals (Singer & Lamontagne, 2008). The hinge brace was applied to anterior cruciate ligament repaired adolescents to evaluate the limb asymmetries and bracing effects during cutting tasks (Dai, Butler, Garrett, & Queen, 2012). The results of these trials identified a decrease in ground reaction force (GRF), extensor moments, knee flexion, and knee flexion moment on the surgical limb (braced leg) compared to the contralateral limb, as well as increased the overall initial knee flexion velocity for both the surgical and contralateral limbs (Dai, Butler, Garrett, & Queen, 2012). Another study investigating performance of balance, coordination, proprioception, and muscular power found that the hinged knee brace was more effective for balance, proprioception, and muscular power as compared to no brace and sleeve trials among healthy individuals during different loading tasks such as balancing, squatting, and jumping (Baltaci, Aktas, Camci, Oksuz, Yildiz, & Kalaycioglu, 2011).

Contradictory results were found by Khan, Jones, Nokes, and Johnson (2007), when examining the knee flexion angles for the hinge braces in unlocked and locked conditions during gait analysis and revealed that knee flexion angles significantly increased when a hinged knee brace was applied to healthy individuals during gait analysis. When hinged knee braces were locked into specific low flexion angles, there was a significant increase in knee flexion angles during gait among healthy individuals (Khan, Jones, Nokes, & Johnson, 2007). Khan Jones, Nokes, and Johnson (2007) noted that there was minimal to no distal migration of the hinge braces used during the gait trials. A noticeable and significant decrease in peak knee internal rotation was observed during hinged brace gait trials compared to non-braced trials among healthy individuals (Singer & Lamontagne, 2008).

This study investigated the alteration of knee kinematics and kinetics during gait with the application of the three knee modalities (KT, neoprene sleeve, and hinge brace) and no modality to identify which of these modalities should be implemented to aid in the relief of individuals with PFPS. The dependent variables focused on in this study were the knee adduction angle, knee shear force, and knee internal rotation angle during weight acceptance of gait.

CHAPTER III

METHOD SECTION

Participants

Twenty-five volunteer participants that are 18 years or older performed in this study. Participants were limited to only healthy knees, excluding the following participants who indicate they have: (a) knee pathologies such as genu varum or genu valgum or (b) knee surgeries within the past six months. The participants all signed an informed consent and have been informed of their right to stop their participation in this study at any time. Benefits and risks of this study were made clear to the participants before signing the informed consent. There are no known risks associated with the participation in this study.

Instrumentation

The three knee modalities that were used are the Kinesio Tape (KT), Ossur neoprene knee sleeve, and a Ossur hinge knee brace (see Figures 3, 4, and 5). Seven infrared VICON motion analysis cameras (operating at 240 frames/sec) were used to capture the movement (3D motion analysis system VICON, Oxford Metrics Ltd, Oxford, England). A lower body marker system comprised of sixteen 1cm spherical reflective markers were used to apply the coordinate system to capture the 3D movements in space (see Figure 6). Two AMTI (Advanced Medical Technology, Inc., Watertown, MA, USA) force plates were used to record forces. VICON Nexus software 1.8.3 and Polygon 3.5.1 software was used to analyze data collected.

Figure 3. *Kinesio Tape applied to give full knee support.*

Figure 4. *Ossur neoprene knee sleeve.*

Figure 5. *Ossur hinge knee brace.*

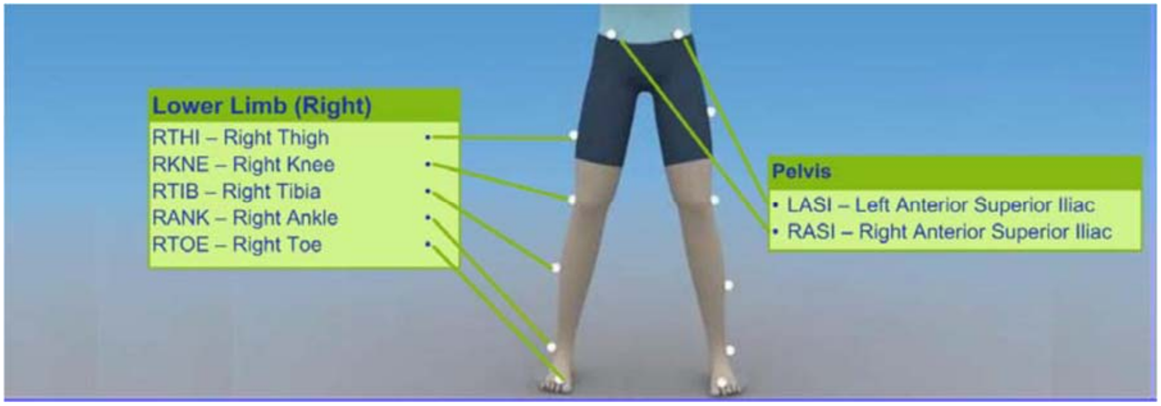

Figure 6. *Lower Body Marker System Frontal View (not pictured the LPSI: left posterior superior iliac, RPSI: right posterior superior iliac, LCAL: left calcaneus, RCAL: right calcaneus).*

Subject Preparation

Participants were asked to wear tight fitting shorts during gait trials to eliminate marker errors. The participant's measurements were taken, by the lead investigator and recorded in millimeters according to the VICON Nexus manual (Table 1). Sixteen lower body markers were applied to the participant according to the VICON Nexus manual (see Figure 6) and marked for reference to reapply markers if the different trial conditions for the applied modalities require the removal of markers. Participants were introduced to the controlled walking space to familiarize themselves to the area in which the gait trials will be captured. Once the participants have walked over the movement space and have naturally hit the force plates during gait in the movement space, the starting position for the participant was marked so that they will begin each trial from the same starting location.

Table 1: *Body Measurements*

	Measurements
General	Body Mass (kg)
Lower Body	Ankle Width (mm)
	Knee Width (mm)
	Leg Length (mm)

Procedures

Cameras were calibrated according to the VICON manual. Next, a static capture of the participant was taken to create a local coordinate system. The application of modalities (test conditions) was randomized and the order unknown to the participant that performed the gait analysis trials under the following testing conditions: (1) no modality, (2) kinesio tape, (3) neoprene sleeve, and (4) hinge brace on right knees only. The lead investigator applied all three modalities to everyone who participated in the study.

The kinesio tape was applied to the knee in three strips to create a full knee support while the knee was in a 90˚ bent position. The first strip was placed on the lateral tibial condyle with no tension to anchor the strip. The strip was then pulled to 100% tension and applied medially across the patellar tendon, then anchored with no tension to the medial tibial condyle. The second strip was anchored with no tension to the distal 1/3 portion of the VL, followed by a 50% tension the length of the VL, wrapping under the patella, across the patellar tendon and anchored with no tension just distal to the medial tibial condyle. The same procedure was followed for the third strip starting at the distal 1/3 portion of the VMO and anchoring just distal to the lateral tibial condyle. The lead investigator applied the two braces so that the patella sits squarely in the circular opening of each brace and that the hinges are aligned with the axes and joint line of the knee.

Participants were asked to walk normally, at a self-selected pace, in the designated movement space over the two force plates for a distance of 8 strides. Three trials of each testing conditions were recorded and analyzed. Each participant performed a total of 12 gait trials. All gait trials were performed with the participant walking in the same direction. For example, the participant had the KT applied to the right knee followed by the reflective markers. The participant walked in the marked recording space (approximately 12ft by 3ft) for 8 strides over the two force plates for three separate gait trials. This procedure was followed until all of the testing conditions have been met at random (no modality, KT, neoprene sleeve, and hinge brace).

Data Analysis

The kinematic dependent variables that were analyzed during the gait trials of all testing conditions include:

(a) The knee adduction angle during weight acceptance of gait.
(b) The knee internal rotation angle during weight acceptance of gait.

The kinetic dependent variable that was analyzed during the gait trials of all testing conditions was:

(a) The knee anterior shear forces during weight acceptance of gait.

The independent variable that was analyzed during the gait trials is the type of modality (testing condition) and includes the following four levels:

(a) The application of the neutral knee Kinesio Tape.
(b) The applied Ossur neoprene knee sleeve.
(c) The applied Ossur hinge knee brace.
(d) No modality.

In addition, negative numbers found among the anterior shear trials mean that the knee is actually in a posterior shear direction and if positive, then anterior shear is present.

Negative numbers found in the internal tibial rotation trials mean the knee is actually in a external tibial rotation direction and positive numbers are in an internal tibial rotation direction. The closer the numbers for all of the gait trials are to zero, the closer the knee is to a neutral position.

Statistical Analysis

Polygon 3.5.1 software was used to analyze kinematic and kinetic data collected by the VICON infrared cameras and the force plates. A repeated measures MANOVA statistical test was performed to examine the significance (set at $p \leq 0.05$). Follow up series of dependent *t*-tests were used to compare all of the dependent variables during the gait trials to identify differences between independent variables. All statistical tests were analyzed by Statistical Package for Social Sciences (SPSS) version 22.0 (SPSS Inc., Chicago, IL, USA).

CHAPTER IV

RESULTS SECTION

The purpose of this study was to compare the biomechanical alterations related to the application of three different knee modalities on healthy knees during gait to determine which intervention is most effective in the reduction of factors that are associated with PFPS. It was hypothesized that the hinge brace was the most effective on reducing the following compared to the kinesio tape and neoprene sleeve:

(a) Peak knee internal rotation moment during weight acceptance of gait,

(b) Anterior knee shear force during weight acceptance of gait,

And was the least effective on reducing the following compared to the kinesio tape and neoprene sleeve:

(c) Knee adduction angle during weight acceptance of gait.

Twenty-five volunteer participants who met the inclusion criteria were analyzed in this study. Of the twenty-five participants (n = 25), 14 were female and 11 male. The participants in this study had an average age of 30.08 years (± 1.87 years), an average height of 1.74m (± 0.05m), and an average mass of 72.78kg (±1.71kg). *See Table 2.*

Table 2: *Participant Descriptives*

	Female (14)		Male (11)	
	Mean	Standard Deviation	Mean	Standard Deviation
Age (years)	28.79	7.68	30.64	7.54
Height (meters)	1.69	0.05	1.83	0.05
Mass (kg)	66.40	6.23	87.07	11.70

*25 Volunteer participants comprised of 14 females and 11 males.

The scientific hypothesis was tested using a repeated measures MANOVA with the independent variable at four levels (no modality, kinesio tape, neoprene sleeve, and hinge brace) and three dependent variables being knee adduction angle, internal tibial rotation, and knee anterior shear force. The alpha was set at 0.05 for this research. Statistical analysis revealed there is an overall significant difference within subjects between modality and each variable $F(1, 24) = 8.41$, $p < 0.01$, $p = 0.00$. There was an overall significant difference between anterior shear force and modality $F(1, 24) = 17.18$, $p < 0.01$, $p = 0.00$ and between internal tibial rotation angle and modality $F(1, 24) = 5.65$, $p < 0.05$, $p = 0.02$. Although, there was no overall significant difference between knee adduction angles and modalities $F(1, 24) = 3.161$, $p > 0.05$, $p = 0.08$, follow-up t-tests identify there was a significant increase in knee adduction angle during the hinged brace trials as compared to the other test conditions (Table 6). Negative numbers found among the anterior shear trials mean that the knee is actually in a posterior shear direction and in the positive direction are anterior shear. In addition, negative numbers found among the anterior shear trials mean that the knee is actually in a posterior shear direction and if positive, then anterior shear is present. Negative numbers found in the internal tibial rotation trials mean the knee is actually in a external tibial rotation direction and positive numbers are in an internal tibial rotation direction. The closer the numbers for all of the gait trials are to zero, the closer the knee is to a neutral position. *See Table 3, 4, 5 and 6.*

Table 3: *Descriptive Statistics for Mean Measurements*

Measure	Modality	N	Mean	Std. Deviation
Knee Adduction	Control	25	1.09	7.39
	Neoprene Sleeve	25	1.88	6.57
	Hinge Brace	25	5.19	2.51
	Kinesio Tape	25	3.04	3.61
Anterior Shear	Control	25	3.43	7.01
	Neoprene Sleeve	25	3.75	4.16
	Hinge Brace	25	-2.83	3.74
	Kinesio Tape	25	-3.17	5.17
Internal Tibial Rotation	Control	25	-6.76	9.31
	Neoprene Sleeve	25	-5.28	7.04
	Hinge Brace	25	2.38	4.36
	Kinesio Tape	25	-4.80	7.34

*Knee Adduction and Internal Tibial Rotation measured in degrees. Anterior Shear force measured in newtons. Negative numbers found among the anterior shear row indicate the knee is in a posterior shear position. Negative numbers found among the internal tibial rotation row indicate the knee is in an external tibial rotation position.

Anterior Shear Force

Follow up t-tests were used to identify were the significance was found. There was a significant decrease in anterior shear force between the hinge brace modality and the control (no modality) $p < 0.01$, ($p = 0.001$); as well as between the brace modality and the sleeve modality during weight acceptance of gait $p < 0.01$, ($p = 0.00$). There was no significant difference between the brace and the kinesio tape for shear force during weight acceptance $p > 0.05$, ($p = 0.74$). There was a significant decrease in anterior shear force between the kinesio tape and the control $p < 0.01$, ($p = 0.001$), as well as between the kinesio tape and the sleeve during weight acceptance $p < 0.01$, ($p = 0.00$). There was no significant difference between the control and the sleeve testing conditions for anterior shear force during weight acceptance $p > 0.05$, ($p = 0.65$). *See Table 4.*

Table 4: *Pairwise Comparisons of Anterior Shear Force*

Modality	Modality	Mean Difference	Standard Error	Significance
Control	Sleeve	-0.32	0.71	0.65
	Brace	6.27	1.71	**0.001
	KT	6.60	1.81	**0.001
Sleeve	Control	0.32	0.71	0.65
	Brace	6.59	1.22	**0.00
	KT	6.60	1.31	**0.00
Brace	Control	-6.27	1.71	**0.001
	Sleeve	-6.59	1.22	**0.00
	KT	0.33	0.99	0.74
KT	Control	-6.60	1.81	**0.001
	Sleeve	-6.93	1.31	**0.00
	Brace	-0.33	0.99	0.74

*Anterior Shear force measured in newtons. **Indicates significance.

Internal Tibial Rotation

There was a significant increase in internal tibial rotation between the hinge brace modality and the three other test conditions (control, sleeve, and kinesio tape) during weight acceptance of gait, all at the $p < 0.01$ significance level, $p = 0.00$ for all conditions. This resulted in an increased internal tibial rotation angle during hinge braced conditions compared to the other test conditions. There were no significant differences between the control (no modality) and the sleeve or kinesio tape during weight acceptance. There were no significant differences between the sleeve and the kinesio tape testing conditions during weight acceptance. *See Table 5.*

Table 5: *Pairwise Comparisons of Internal Tibial Rotation*

Modality	Modality	Mean Difference	Standard Error	Significance
Control	Sleeve	-1.48	1.02	0.16
	Brace	-9.14	1.91	**0.00
	KT	-1.95	1.58	0.22
Sleeve	Control	1.48	1.02	0.16
	Brace	-7.66	1.56	**0.00
	KT	-0.47	1.53	0.75
Brace	Control	9.14	1.91	**0.00
	Sleeve	7.66	1.56	**0.00
	KT	7.18	1.58	**0.00
KT	Control	1.95	1.58	0.22
	Sleeve	0.47	1.53	0.75
	Brace	-7.18	1.58	**0.00

*Internal Tibial Rotation measured in degrees. **Indicates significance.

Knee Adduction Angle

There was a significant increase in knee adduction angle between the hinge brace test condition and the three other testing conditions (control, sleeve, and kinesio tape) during weight acceptance of gait, all at the $p < 0.01$ significance level. The hinge brace modality had significantly higher knee adduction angle compared to the control $p = 0.004$. The hinge brace had a significantly higher knee adduction angle compared to the neoprene sleeve condition $p = 0.008$. The hinge brace had a significantly higher knee adduction angle compared to the kinesio tape condition $p = 0.003$. This resulted in the hinge brace having a significantly increased mean knee adduction angle from the other test conditions during weight acceptance of gait. There were no significant differences between the control (no modality) condition and the neoprene sleeve or the control and the kinesio tape modality during weight acceptance of gait. There was no significant difference between the neoprene sleeve and the kinesio tape during weight acceptance of gait. *See Table 6.*

Table 6: *Pairwise Comparisons of Knee Adduction Angle*

Modality	Modality	Mean Difference	Standard Error	Significance
Control	Sleeve	-0.75	0.56	0.17
	Brace	-4.11	1.29	**0.004
	KT	-1.95	1.39	0.17
Sleeve	Control	0.79	0.56	0.17
	Brace	-3.31	1.13	**0.008
	KT	-1.15	1.27	0.37
Brace	Control	4.11	1.29	**0.004
	Sleeve	3.31	1.13	**0.008
	KT	2.15	0.65	**0.003
KT	Control	1.95	1.39	0.17
	Sleeve	1.15	1.27	0.37
	Brace	-2.15	0.65	**0.003

*Knee Adduction measured in degrees. **Indicates significance.

CHAPTER V

DISCUSSION

Purpose of the Study

The purpose of this study was to identify which modality (neoprene sleeve, hinge brace, or kinesio tape) can effectively reduce the common factors associated with patellofemoral pain syndrome (knee adduction, anterior shear force, internal tibial rotation) during gait. The focus of the study was on knee biomechanics. It was hypothesized that the hinge brace would have the most impact on reducing the anterior shear force and the internal tibial rotation during weight acceptance of gait compared to the kinesio tape and the neoprene sleeve. In addition, it was hypothesized that the hinge brace would also have the least amount of impact on reducing the knee adduction angle during weight acceptance of gait compared to the kinesio tape and the neoprene sleeve.

Findings

The results of this study revealed that there was a significant difference within subjects dependent variables (anterior shear force, internal tibial rotation, and knee adduction angle) and the different modalities (control, neoprene sleeve, prophylactic functional brace, and kinesio tape) during gait $F (1, 24) = 8.41$, $p < 0.01$, $p = 0.00$. Furthermore, overall significant differences were found between the anterior shear force and modality $F (1, 24) = 17.18$, $p < 0.01$, $p = 0.00$ and between the internal tibial rotation and modality $F (1, 24) = 5.65$, $p < 0.05$, $p = 0.02$. There was no overall significant difference between the knee adduction angle and the different modalities $F (1, 24) = 3.161$, $p > 0.05$, $p = 0.08$, although follow-up t-tests revealed there are some significant differences between modalities. The results of this research negated the research hypothesis that the hinge brace would decrease the anterior shear force, as well as decrease the internal tibial rotation the most compared to the other modalities, but had the supported that the hinge brace would have the least amount of impact on reducing the knee adduction angle. In fact, the kinesio tape decreased the anterior shear force the most m = -3.17N, although the hinge brace was a close second for the reduction of anterior shear force m = -2.83N. The control, or no modality, had the least amount of knee adduction angle m = 1.09° and internal tibial rotation m = -6.76° compared to the other modalities. The hinge brace had the greatest knee adduction angle m = 5.19° compared to the other modalities. Overall, the kinesio tape had moderate knee adduction angle m = 3.04°, the least amount of anterior shear force m = -3.17N, and a moderate internal tibial rotation angle m = -4.80° compared to the other modalities. *Refer to Table 3.*

Anterior Shear Force

The anterior shear force was significantly reduced during both the hinge brace (m = -2.83N) and the kinesio tape (m = -3.17N) trials as compared to the control (m = 3.43N) and the neoprene sleeve (m = 3.75N). There was a significant decrease in anterior shear force between the hinge brace and the control (p = 0.001) and between the hinge brace and the neoprene sleeve (p = 0.00). The kinesio tape significantly reduced the anterior shear force compared to the control (p = 0.001) and the neoprene sleeve (p = 0.00) during weight acceptance of gait. It appears that the kinesio tape and the hinge brace reduced the anterior shear force by realigning the femurs' tendency to anteriorly slide forward on the tibia during weight acceptance of gait compared to the neoprene sleeve and the control test conditions. There was no significant differences between the hinge brace and the kinesio tape $p = 0.74$, for anterior shear force as both modalities were effective in reducing the anterior shear force. The application of the kinesio tape and the hinge brace may support the knee in similar ways, preventing the femur from moving anteriorly upon the tibia reducing the anterior shear force during the weight acceptance of gait. Comparable to Fleming et al. (2000), the hinge brace significantly reduced the anterior shear force during both nonweightbearing and weightbearing conditions ($p = 0.04$). Findings by Barton et al. (2013) identify that the studies (20) they reviewed on patellar taping and patellofemoral pain syndrome had no overall significant difference in anterior shear force and kinesio tape during unilateral squat tasks resulting in no evidence that the tape reduces anterior shear force. These findings contradict the results of this study, but very few of the articles reviewed by Barton et al. (2013) addressed anterior shear force. The decrease in anterior shear force reduces the patellofemoral joint force, which can aid in the reduction of pain and discomfort for individuals with patellofemoral pain syndrome.

Internal Tibial Rotation

There was a significant increase in internal tibial rotation angle during the hinge brace condition compared to the other test conditions during weight acceptance of gait at the $p < 0.01$ level, ($p = 0.00$). Results identified that the hinge brace significantly increased the internal tibial rotation angle ($m = 2.38°$) as compared to the three other test conditions (control: $m = -6.76$, neoprene sleeve: $m = -5.28°$, and kinesio tape: $m = -4.80°$). There was no significant difference in the internal tibial rotation between the control and neoprene sleeve or kinesio tape conditions during weight acceptance of gait. There was also no significant difference in internal tibial rotation angle between the neoprene sleeve and the kinesio tape trials during weight acceptance of gait. These results are contradictory to other findings where the hinge brace was found to decrease internal tibial rotation angle during step descent tasks (Selfe et al., 2011). The contradictory results found by Selfe et al. (2011) of reduced internal tibial rotation may be due to the step descent tasks performed, while this study focused on gait and these are two different movement patterns that will yield different results. In addition, Singer and Lamontagne (2008) found that both the neoprene sleeve and the hinge brace significantly reduced the peak internal tibial rotation angle during gait. Singer and Lamontagne (2008) focused on peak internal tibial rotation which does not identify at which part of the gait cycle these results are found, whereas this study focused on internal tibial rotation during weight acceptance of gait. The reduction of internal tibial rotation angle can also decrease the amount of patellofemoral joint force, which can aid in the reduction of pain associated with patellofemoral pain syndrome.

Knee Adduction

Although there is no overall significance within subjects for the knee adduction angle during weight acceptance of gait, there was a significant increase in knee adduction angle between the hinge brace ($p < 0.01$) and the three other test conditions (control, neoprene sleeve, and kinesio tape) during weight acceptance of gait. The hinge brace had a significantly increased knee adduction angle (m = 5.19°) compared to the other test conditions (control: m = 1.09°, sleeve: m = 1.88°, kinesio tape: m = 3.04°). Many individuals will alter their natural gait pattern with the application of the hinge brace when there is no instruction given or the individual has not had sufficient time to adjust to the brace. This can result in decreased knee flexion, increased hip abduction, resulting in an increased knee adduction, which may have occurred during this study. The control or no modality test condition had the lowest mean knee adduction angle (m = 1.09°) compared to the other test conditions. Singer and Lamontagne (2008) found similar results in which peak knee adduction angles were greatest during the hinge brace trials; moderate during the neoprene sleeve trials, and lowest during the non-braced gait trials. The results may be similar to the ones of this study if the participants were not given specific instructions on how to walk in the braces or enough time spent in the brace to adjust to the application of the different modalities. The results of this study contradict findings from Selfe et al. (2011) in which knee adduction angles were reduced during both braced and taped conditions while performing step descent tasks. Selfe et al. (2011) focused on knee adduction angles during a step descent task not gait, which is why their results may conflict with the results of this study. During a step descent task an individual usually strikes with the forefoot followed by support of the midfoot (weight acceptance) and the last part of the foot to touch ground is the rearfoot. This technique is opposite of gait in which individuals tend to strike with the rearfoot, followed by support of the midfoot (weight acceptance) and propelled forward by pushing off of the forefoot. Selfe et al. (2011) did not identify which phase of the step descent task was analyzed which also may be the reason for the conflicting results in knee adduction angle for hinge braced conditions. A reduced knee adduction angle can reduce patellofemoral joint force, which will ultimately aid in the reduction of pain associated with patellofemoral pain syndrome.

Study Limitations

While the study presented new insight to the effects of different modalities during gait and the factors associated with patellofemoral pain syndrome, the results are limited due to the following:

(a) The participants' natural gait pattern may have been altered due to the requirement to hit the force plate during the gait trials.

(b) The volunteer participants were all considered "healthy" with no knee pain or ailments. The participants were not individuals with PFPS.

(c) The study analyzed gait and not a more dynamic movement such as jogging, running, squats, change of direction, and jumping exercises.

(d) The brands used in this study were Ossur (for the hinge brace and the neoprene sleeve) and Kinesio Tape (for the tape); other brands might produce different results.

(e) The study was limited to the hinge brace, the neoprene sleeve, and the kinesio tape. There are several more types of braces and tape available on the market that can be studied such as arthritis braces, ACL braces, buttress support braces, knee wraps, and knee straps.

Recommendations for Future Study

Future research should include dynamic movements that are common among activities of daily living. The participants performed 12 gait trials each for a distance of 8 strides. The distance may not be a long enough space for each person to adjust to the different modalities. In addition, there are many studies that apply their focus to pain and whether or not it is reduced after applying the different modalities for individuals with patellofemoral pain syndrome instead of identifying how the different modalities alter the kinematics and kinetics during movement. More factors that are associated with patellofemoral pain syndrome can be investigated, such as peak knee flexion angle, knee extension moment, knee compressive force, hip abduction, and pathologies such as pes planus or pes cavus foot type and the size and shape of both the individuals' patella and trochlear groove. With the numerous factors associated with patellofemoral pain syndrome, any alteration in the kinetic chain (both distally and proximally) to the knee can have an effect on one of the many factors associated with PFPS.

The contradictory nature of the findings compels the need for future research to determine a more concise understanding of how these modalities alter the kinematics and kinetics that are associated with patellofemoral pain syndrome. This will better equip clinicians, therapist, and athletic trainers to aid in the reduction of these factors more precisely. In addition, the market is flooded with a variety of brands ad options of braces and tape. The variance in fit and design between options could have a compounded effect, ultimately changing the mechanics in numerous ways. It would be interesting to see if these modalities alter the mechanics by gender. Due to the reviewed research combining gender and not separating gender to see if gender effects how the modalities operate, it was not tested in this study. Lastly, the results of these gait trials were all immediate effects of the application of the different modalities. Research should continue to analyze the effects of these applied modalities over time by focusing on how time can affect the results of applied modalities both during gait and more dynamic movements.

Conclusion

Within the limitations of this study, the results can suggest that there are significant differences between the different modalities (control, neoprene sleeve, hinge brace, and kinesio tape) and the factors associated with patellofemoral pain syndrome (knee adduction angle, anterior shear force, and internal tibial rotation angle). Overall the kinesio tape has the capability to:

(a) Significantly reduce the anterior shear force during weight acceptance of gait compared to the control ($p < 0.01$) and the neoprene sleeve ($p < 0.01$).

(b) Significantly reduce the internal tibial rotation angle during weight acceptance of gait compared to the hinge brace ($p < 0.01$).

(c) Significantly reduce the knee adduction angle during weight acceptance of gait compared to the hinge brace ($p < 0.01$).

Although the kinesio tape did not significantly differ in internal tibial rotation and knee adduction from the control and the neoprene trials, it was not severely increased like the hinge brace.

The results contradict the research hypothesis that the hinge brace would reduce the anterior shear force and the internal tibial rotation angle the most during weight acceptance of gait compared to the other test conditions (control, neoprene sleeve, and kinesio tape), because the kinesio tape outperformed the hinge brace on all levels. The hinge brace did significantly reduce the anterior shear force during weight acceptance of gait compared to the control ($p < 0.01$) and the neoprene sleeve ($p < 0.01$), but did not reduce the anterior shear force compared to the kinesio tape condition ($p > 0.05$). The hinge brace significantly increased the internal tibial rotation during weight acceptance of gait compared to all test conditions ($p < 0.01$). The hinge brace also significantly increased the knee adduction angle during weight acceptance of gait compared to all test conditions ($p < 0.01$).

The results of this study have enhanced our understanding of how the different applied knee modalities can alter the mechanical properties of the knee. It is ideal that an individual would first be analyzed to identify which current mechanical knee factor is most severe during gait, such as an increased anterior shear force causing them to suffer from PFPS. This information would benefit clinicians' to properly prescribe the applied modality that would make the best alteration for that person, which in this scenario would be the application of the kinesio tape. Overall, the results of this study can recommend the best practical application for individuals with patellofemoral pain syndrome to use kinesio tape to decrease associated factors identified in this research (anterior shear force, internal tibial rotation angle, and knee adduction angle) to restore the normal mechanical properties of the knee.

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APPENDIX A

BARRY UNIVERSITY
SCHOOL OF HUMAN PERFORMANCE AND LEISURE SCIENCES (HPLS)
THE DEPARTMENT OF SPORT AND EXERCISE SCIENCES

CONSENT TO PARTICIPATE IN RESEARCH

The research topic: Effects of Applied Knee Modalities During Gait and the Biomechanical Factors Associated with Patellofemoral Pain Syndrome.

You are invited to participate in a research project. The research is being conducted by Lyndsay Segarra, a graduate student in the Human Performance and Leisure Sciences department at Barry University, and is seeking information that will be useful in the field of Biomechanics and Physical Therapy.

Why is this study being conducted?

The aims of the research are identify which knee modality will be most effective in correcting the altered kinematics and kinetics of the knee that are accompanied with patellofemoral pain syndrome. In accordance with these aims, the following procedures will be used: 3D motion analysis system VICON, force plates, Kinesio Tape, neoprene knee sleeve, and prophylactic functional brace will be used during gait trials. We anticipate the number of participants to be 25.

What will happen if you partake in this study?

If you decide to participate in this research, you will be asked to do the following: be present for a screening and overview of what is to be expected as well as to participate completing in one session of twelve gait trials that will take 45 to 90 minutes to complete.

Your consent to be a research participant is strictly voluntary and should you decline to participate or should you choose to drop out at any time during the study, there will be no adverse effects associated.

There are no known risks in participating in this study. There are no known benefits.

As a research participant, information you provide will be held in confidence to the extent permitted by law. Any published results of the research will refer to group averages only and no names will be used in the study. Data will be kept in a locked file in the researcher's office. All 3D motion analysis data will be numerically coded without the use of names. Your signed consent form will be kept separate from the data. All data and consent forms will be destroyed after 5 years.

If you have any questions or concerns regarding the study or your participation in the study, you may contact me, Lyndsay Segarra, at (786)218-3142 or at Lyndsay.segarra@mymail.barry.edu, my advisor, Dr. Claire Egret, at (305)899-3064, or the Institutional Review Board point of contact, Barbara Cook, at (305)899-3020. If you are satisfied with the information provided and are willing to participate in this research, please signify your consent by signing this consent form.

Voluntary Consent

I acknowledge that I have been informed of the nature and purposes of this experiment by Lyndsay Segarra and that I have read and understand the information presented above, and that I have received a copy of this form for my records. I give my voluntary consent to participate in this experiment.

______________________ __________ __________________________

Signature of Participant Date Researcher Date

APPENDIX B

PARTICIPANT QUESTIONNAIRE

1. Is the participant 18 years old and capable of signing informed consent?
   YES [ ]   NO [ ]

2. Is the participant able to comply with the protocol?
   YES [ ]   NO [ ]

3. Do you have any knee pathologies genu varum (bow legged) or genu valgum (knocked kneed)?
   YES [ ]   NO [ ]

4. Have you had any knee surgeries?
   YES [ ]   NO [ ]

5. Do you currently have any knee pain?
   YES [ ]   NO [ ]

6. If yes (to knee pain), on a scale from 1 to 10 with 10 being excruciating pain, how bad is your knee pain currently?
   1   2   3   4   5   6   7   8   9   10

7. If yes (to knee pain), will your knee pain inhibit you to complete 12 gait trials?
   YES [ ]   NO [ ]

8. If yes (to knee pain), do you currently wear a knee brace or tape on your knee?
   YES [ ]   NO [ ]

9. Have you ever been diagnosed with osteoarthritis?
   YES [ ]   NO [ ]

APPENDIX C

MANUSCRIPT

Effects of Applied Knee Modalities During Gait and the Biomechanical Factors Associated with Patellofemoral Pain Syndrome.

Abstract

Patellofemoral pain syndrome (PFPS) is one of the most common overuse knee disorders among the physically active population (Selfe, Thewlis, Hill, Whitaker, Sutton, & Richards, 2011; Barton, Balachandar, Lack, & Morrissey, 2013; Ng & Wong, 2009; Waryasz & McDermott, 2008; Powers, Doubleday, & Escudero, 2007; Miller, Westrick, Diebal, Marks, & Gerber, 2013; Freedman, Brody, Rosenthal, & Wise, 2014; Nakagawa, Moriya, Maciel, & Serrão, 2012; Wünschel, Leichtle, Obloh, Wülker, & Müller, 2011; Escamilla, Zheng, MacLeod, Edwards, Imamura, Hreljac, Fleisig, Wilk, Moorman III, & Andrews, 2009; Kwon, Yun, & Lee, 2014).There are several biomechanical factors associated with PFPS. Three main factors associated with PFPS are the knee adduction angle, the internal tibial rotation angle, and the anterior shear force (Selfe, Thewlis, Hill, Whitaker, Sutton, & Richards, 2011; Waryasz & McDermott, 2008; Webster, McClelland, Palazzolo, Santamaria, & Feller, 2012; Wünschel, Leichtle, Obloh, Wülker, & Müller, 2011; Foroughi, Smith, Lange, Baker, Fiatarone Singh, & Vanwanseele, 2011). The purpose of this study was to compare the biomechanical alterations related to the application of three different knee modalities: kinesio tape (KT), a neoprene sleeve, a hinge brace, and no modality on healthy knees during weight acceptance of gait to determine which intervention is most effective in the reduction of three main factors that are associated with PFPS. Twenty-five healthy volunteer participants (female = 14; male = 11) with the average age of 30.08, height = 1.74m, and weight = 72.78kg completed 12 gait trials each. The four randomized test conditions consisted of a control (no applied modality), an Ossur neoprene knee sleeve, an Ossur hinge brace, and Kinesio tape (neutral knee taping). Seven infrared VICON motion capture cameras, lower body marker system, and two AMTI force were used to collect the kinematic and kinetic data. A repeated measures MANOVA ($p < 0.05$) analyzed the data to identify if there were significant differences between the different test conditions and the factors tested. Results revealed there are significant differences between the different modalities and the factors associated with PFPS. Both the kinesio tape ($p < 0.01$) and the hinge brace ($p < 0.01$) significantly reduced the anterior shear force during weight acceptance of gait compared to the control and the sleeve trials. The hinge brace also significantly increased both the knee adduction angle ($p < 0.01$) and the internal tibial rotation angle ($p < 0.01$) during weight acceptance of gait compared to the other test conditions. Although not significant, the KT revealed moderate results for both the internal tibial rotation and the knee adduction angle comparable to the results found for the control and the neoprene sleeve trials during weight acceptance of gait. The results of this study conflicted with previous research findings in which the hinge brace significantly reduced internal tibial rotation

and knee adduction angles during gait and step descent tasks. Further research should be conducted to eliminate conflicting results and ultimately provide the best understanding of how these modalities alter the mechanical factors associated with patellofemoral pain syndrome.

Introduction

Patellofemoral pain syndrome (PFPS) is one of the most common overuse knee disorders among the physically active population (Selfe, Thewlis, Hill, Whitaker, Sutton, & Richards, 2011; Barton, Balachandar, Lack, & Morrissey, 2013; Ng & Wong, 2009) (Waryasz & McDermott, 2008; Powers, Doubleday, & Escudero, 2007; Miller, Westrick, Diebal, Marks, & Gerber, 2013; Freedman, Brody, Rosenthal, & Wise, 2014; Nakagawa, Moriya, Maciel, & Serrão, 2012; Wünschel, Leichtle, Obloh, Wülker, & Müller, 2011; Escamilla, Zheng, MacLeod, Edwards, Imamura, Hreljac, Fleisig, Wilk, Moorman III, & Andrews, 2009; Kwon, Yun, & Lee, 2014). There have been many contradictory theories identifying the cause of PFPS. Since PFPS is commonly diagnosed as an overuse injury, there are several risk factors for the development of PFPS (Kwon, Yun, & Lee, 2014). More recently, Freedman, Brody, Rosenthal, and Wise (2014) have identified these risk factors as patellar malalignment accompanied with patellar maltracking, weakness of the lower extremity muscles including abnormal vastus lateralis and vastus medialis reflex timing, tightness of the soft tissues in the lower extremities, anatomical abnormalities of the lower extremity, and altered kinematics of the lower extremity. Several studies have identified an increased knee adduction angle and increased internal tibial rotation as additional risk factors for PFPS (Selfe, Thewlis, Hill, Whitaker, Sutton, & Richards, 2011; Waryasz & McDermott, 2008; Webster, McClelland, Palazzolo, Santamaria, & Feller, 2012; Wünschel, Leichtle, Obloh, Wülker, & Müller, 2011; Foroughi, Smith, Lange, Baker, Fiatarone Singh, & Vanwanseele, 2011). In addition, any type of squat or lunge activity increases the knee anterior shear force, ultimately increasing the patellofemoral joint force (PFJF), which is another leading factor, associated with PFPS (Swinton, Lloyd, Keogh, Agouris, & Stewart, 2012). If PFPS remains untreated it can eventually turn into the degeneration of the knee resulting in osteoarthritis (Barton, Balachandar, Lack, & Morrissey, 2013; Campolo, Babu, Dmochowska, Scariah, & Varughese, 2013).

Successful conservative treatments have been applied to rehabilitation practices for PFPS when they are practiced correctly. For example, many clinicians and trainers have their patients perform activities such as the lunge and the squat to strengthen the quadriceps muscles to aid in the correct tracking of the patella (Escamilla, et. al., 2009); (Swinton, Lloyd, Keogh, Agouris, & Stewart, 2012). During the descent of the squat, the PFJF progressively increases and is at it's peak during 60°-90° of knee flexion during both the descent and ascent of the squat (Escamilla, et. al., 2009). Strengthening the vastus lateralis resulted in a decrease in the PFJF and lateral loading of the quadriceps, reducing the internal tibial rotation at angles greater than 70° (Wünschel, Leichtle, Obloh, Wülker, & Müller, 2011). When the squat is performed compressive and shear forces are increased with increased knee flexion angles (Swinton, Lloyd, Keogh, Agouris, & Stewart, 2012).

Bracing and taping techniques are used for the reduction of pain and aid in correcting the malalignment or maltracking of the patellofemoral joint among those who suffer from PFPS. Miller, Westrick, Diebal, Marks, and Gerber (2013) state the reason in why KT should be effective is because the KT's contribution among kinesthesia cutaneous receptors creating an increase in motor control due to the coupling of both muscle spindle fibers and the cutaneous receptors, resulting in an increased response in kinesthesia and proprioception. The kinesio tape is designed to mimic the properties and elastic qualities of the skin (Freedman, Brody, Rosenthal, & Wise, 2014), providing the correct stimulus to activate muscles and facilitate skin tension and circulation through the interstitial tissues. Effects of elastic taping have revealed a decrease in pain and inflammation, increase in ROM and posture, as well as the tape has deemed comfortable to its' wearers (Huang, Hsieh, Lu, & Su, 2011; Salsich, Brechter, Farwell, & Powers, 2002). The neoprene knee sleeve has been identified to aid in the coordination and proprioception of the limb (Baltaci, Aktas, Camci, Oksuz, Yildiz, & Kalaycioglu, 2011). These findings are also supported by Selfe, Thewlis, Hill, Whitaker, Sutton, and Richards (2011), stating that the warmth and compression of the neoprene sleeve enhances proprioception, which in turn increases the stability of the knee. The neoprene sleeve has also been reported to reduce knee pain and improve overall function (Arazpour, Notarki, Salimi, Bani, Nabavi, & Hutchins, 2013). In addition, the neoprene sleeve can aid in correcting the patellar tracking, which should decrease pain and allow more comfortable mobility among individuals with PFPS (Powers, Doubleday, & Escudero, 2007). The functional prophylactic knee brace (hinge brace) is used to prevent, protect, stabilize, decreasing the joint laxity and improving the quality of control about the knee (Khan, Jones, Nokes, & Johnson, 2007; Fleming, Renstrom, Beynnon, Engstrom, & Peura, 2000). The application of the hinge brace has been seen to reduce anterior shear force, pain, and instability, while increasing the ROM (Dai, Butler, Garrett, & Queen, 2012).

Most of the research is controversial because of how contradictory the results are of the application of bracing and taping techniques for the reduction of factors associated with PFPS. The purpose of this study was to compare the biomechanical alterations related to the application of three different knee modalities: KT, a neoprene sleeve, a hinge brace, and no modality on healthy knees during gait to determine which intervention was most effective in the reduction of factors that can cause PFPS. The factors that were examined in this study are knee adduction angle, internal tibial rotation angle, and knee anterior shear force during weight acceptance of gait among a healthy population. It was hypothesized that the hinge brace will provide the most support by reducing the internal tibial rotation and the anterior shear force as compared to the control, the kinesio tape and the neoprene sleeve, but will have the least effect in reducing the knee adduction angle compared to the other modalities.

Methods

Participants

Twenty-five volunteer participants were analyzed in this study. Both male and female participants above the age of 18 with no history of knee pathologies or knee surgeries were included in this study.

Instrumentation

The three knee modalities that were used are the Kinesio Tape (KT), Ossur neoprene knee sleeve, and a Ossur prophylactic functional knee brace (see Figures 3, 4, and 5). Seven infrared VICON motion analysis cameras (operating at 240 frames/sec) were used to capture the movement (3D motion analysis system VICON, Oxford Metrics Ltd, Oxford, England). A lower body marker system comprised of sixteen 1cm spherical reflective markers were used to apply the coordinate system to capture the 3D movements in space (see Figure 6). Two AMTI (Advanced Medical Technology, Inc., Watertown, MA, USA) force plates will be used to record forces. VICON Nexus software 1.8.3 and Polygon 3.5.1 software was used to analyze data collected.

Procedures

Cameras were calibrated according to the VICON manual. Next, a static capture of the participant was taken to create a local coordinate system. The application of modalities (test conditions) were randomized and the order unknown to the participant that performed the gait analysis trials under the following testing conditions: (1) no modality, (2) kinesio tape, (3) neoprene sleeve, and (4) hinge brace on right knees only. The lead investigator applied all three modalities to everyone participating in the study.

The kinesio tape was applied to the knee in three strips to create a full knee support while the knee was in a 90˚ bent position. The first strip is to be placed on the lateral tibial condyle with no tension to anchor the strip. The strip is then pulled to 100% tension and applied medially across the patellar tendon, then anchored with no tension to the medial tibial condyle. The second strip is anchored with no tension to the distal 1/3 portion of the VL, followed by a 50% tension the length of the VL, wrapping under the patella, across the patellar tendon and anchored with no tension just distal to the medial tibial condyle. The same procedure was followed for the third strip starting at the distal 1/3 portion of the VMO and anchoring just distal to the lateral tibial condyle. The lead investigator applied the two braces so that the patella sits squarely in the circular opening of each brace and that the hinges are aligned with the axes and joint line of the knee.

Participants were asked to walk normally, at a self selected pace, in the designated movement space over the two force plates for a distance of 8 strides. Three trials of each testing condition were recorded and analyzed. Each participant performed a total of 12 trials. All gait trials were performed with the participant walking in the same direction. For example, the participant had the KT applied to the right knee followed by the reflective markers. The participant then walked in the marked recording space (approximately 12ft by 3 ft) for 8 strides over the two force plates for three separate trials. This procedure was followed until all of the testing conditions have been met at random (no modality, KT, neoprene sleeve, and functional brace).

Data Analysis

The kinematic dependent variables that were analyzed during the gait trials of all testing conditions include the peak knee adduction angle during weight acceptance and the peak knee internal rotation during weight acceptance. The kinetic dependent variable that was analyzed during the gait trials of all testing conditions include the knee anterior shear forces during weight acceptance. The independent variable that was analyzed during the gait trials was the type of modality (testing condition) and includes the following four levels the application of the neutral knee Kinesio Tape, the applied Ossur neoprene knee sleeve, the applied Ossur prophylactic functional knee brace, and no modality. In addition, negative numbers found among the anterior shear trials mean that the knee is actually in a posterior shear direction and if positive, then anterior shear is present. Negative numbers found in the internal tibial rotation trials mean the knee is actually in a external tibial rotation direction and positive numbers are in an internal tibial rotation direction. The closer the numbers for all of the gait trials are to zero, the closer the knee is to a neutral position.

Statistical Analysis

Polygon 3.5.1 software was used to analyze kinematic and kinetic data collected by the VICON infrared cameras and the force plates. A repeated measures MANOVA statistical test was performed to examine the significance (set at $p \leq 0.05$). Follow up series of dependent *t*-tests were used to compare all of the dependent variables during the gait trials to identify differences between independent variables. All statistical tests were analyzed by Statistical Package for Social Sciences (SPSS) version 22.0 (SPSS Inc., Chicago, IL, USA).

Results

Twenty-five volunteer participants who met the inclusion criteria were analyzed in this study. Of the twenty-five participants (n = 25), 14 were female and 11 male. The participants in this study had an average age of 30.08 years (± 1.87 years), an average height of 1.74m (± 0.05m), and an average mass of 72.78kg (±1.71kg). *See Table 1.*

Table 1: *Participant Descriptives*

	Female (14)		Male (11)	
	Mean	Standard Deviation	Mean	Standard Deviation
Age (years)	28.79	7.68	30.64	7.54
Height (meters)	1.69	0.05	1.83	0.05
Mass (kg)	66.40	6.23	87.07	11.70

*25 Volunteer participants comprised of 14 females and 11 males.

The scientific hypothesis was tested using a repeated measures MANOVA with the independent variable at four levels (no modality, kinesio tape, neoprene sleeve, and hinge brace) and three dependent variables being knee adduction angle, internal tibial rotation, and knee anterior shear force. The alpha was set at 0.05 for this research. Statistical analysis revealed there is an overall significant difference within subjects between modality and each variable $F(1, 24) = 8.41$, $p < 0.01$, $p = 0.00$. There is a significant difference between anterior shear force and modality $F(1, 24) = 17.18$, $p < 0.01$, $p = 0.00$ and between internal tibial rotation angle and modality $F(1, 24) = 5.65$, $p < 0.05$, $p = 0.02$. Although, there is no overall significant difference between knee adduction angles and modalities $F(1, 24) = 3.161$, $p > 0.05$, $p = 0.08$, follow-up t-tests identify there was a significant increase between knee adduction angle and the hinge brace as compared to the other test conditions (Table 6). *See Table 2, 3, 4 and 5.*

Table 3: *Descriptive Statistics for Mean Measurements*

Measure	Modality	N	Mean	Std. Deviation
Knee Adduction	Control	25	1.09	7.39
	Neoprene Sleeve	25	1.88	6.57
	Hinge Brace	25	5.19	2.51
	Kinesio Tape	25	3.04	3.61
Anterior Shear	Control	25	3.43	7.01
	Neoprene Sleeve	25	3.75	4.16
	Hinge Brace	25	-2.83	3.74
	Kinesio Tape	25	-3.17	5.17
Internal Tibial Rotation	Control	25	-6.76	9.31
	Neoprene Sleeve	25	-5.28	7.04
	Hinge Brace	25	2.38	4.36
	Kinesio Tape	25	-4.80	7.34

*Knee Adduction and Internal Tibial Rotation measured in degrees. Anterior Shear force measured in newtons. Negative numbers found among the anterior shear row indicate the knee is in a posterior shear position. Negative numbers found among the internal tibial rotation row indicate the knee is in an external tibial rotation position.

There was a significant decrease in anterior shear force between the hinge brace modality and the control (no modality) $p < 0.01$, ($p = 0.001$); as well as between the hinge brace modality and the sleeve modality during weight acceptance $p < 0.01$, ($p = 0.00$). There was a significant decrease in anterior shear force between the kinesio tape and the control $p < 0.01$, ($p = 0.001$), as well as between the kinesio tape and the sleeve during weight acceptance $p < 0.01$, ($p = 0.00$). *See Table 3.* There was a significant increase in internal tibial rotation angle between the hinge brace modality and the three other test conditions (control, sleeve, and kinesio tape) during weight acceptance, all at the $p < 0.01$ significance level, ($p = 0.00$) for all conditions. *See Tale 4.* There was a significant increase in knee adduction angle between the hinge brace test condition and the three other testing conditions (control, sleeve, and kinesio tape) during weight acceptance, all at the $p < 0.01$ significance level. *See Table 5.*

Table 3: *Pairwise Comparisons of Anterior Shear Force*

Modality	Modality	Mean Difference	Standard Error	Significance
Control	Sleeve	-0.32	0.71	0.65
	Brace	6.27	1.71	**0.001
	KT	6.60	1.81	**0.001
Sleeve	Control	0.32	0.71	0.65
	Brace	6.59	1.22	**0.00
	KT	6.60	1.31	**0.00
Brace	Control	-6.27	1.71	**0.001
	Sleeve	-6.59	1.22	**0.00
	KT	0.33	0.99	0.74
KT	Control	-6.60	1.81	**0.001
	Sleeve	-6.93	1.31	**0.00
	Brace	-0.33	0.99	0.74

*Anterior shear force measured in newtons. **Indicates significance.

Table 4: *Pairwise Comparisons of Internal Tibial Rotation*

Modality	Modality	Mean Difference	Standard Error	Significance
Control	Sleeve	-1.48	1.02	0.16
	Brace	-9.14	1.91	**0.00
	KT	-1.95	1.58	0.22
Sleeve	Control	1.48	1.02	0.16
	Brace	-7.66	1.56	**0.00
	KT	-0.47	1.53	0.75
Brace	Control	9.14	1.91	**0.00
	Sleeve	7.66	1.56	**0.00
	KT	7.18	1.58	**0.00
KT	Control	1.95	1.58	0.22
	Sleeve	0.47	1.53	0.75
	Brace	-7.18	1.58	**0.00

*Internal tibial rotation measured in degrees. **Indicates significance.

Table 5: *Pairwise Comparisons of Knee Adduction Angle*

Modality	Modality	Mean Difference	Standard Error	Significance
Control	Sleeve	-0.75	0.56	0.17
	Brace	-4.11	1.29	**0.004
	KT	-1.95	1.39	0.17
Sleeve	Control	0.79	0.56	0.17
	Brace	-3.31	1.13	**0.008
	KT	-1.15	1.27	0.37
Brace	Control	4.11	1.29	**0.004
	Sleeve	3.31	1.13	**0.008
	KT	2.15	0.65	**0.003
KT	Control	1.95	1.39	0.17
	Sleeve	1.15	1.27	0.37
	Brace	-2.15	0.65	**0.003

*Knee adduction measured in degrees. **Indicates significance.

Discussion

The purpose of this study was to identify which modality (neoprene sleeve, hinge brace, or kinesio tape) can effectively reduce the common factors associated with patellofemoral pain syndrome (knee adduction, anterior shear force, internal tibial rotation) during gait. The focus of the study was on knee biomechanics. It was hypothesized that the hinge brace, out of the three test modalities, would have the most impact on reducing the anterior shear force and the internal tibial rotation during weight acceptance of gait, but have the least impact on reducing the knee adduction angle compared to the other modalities.

The results of this study revealed that there was a significant difference within subjects dependent variables (anterior shear force, internal tibial rotation, and knee adduction angle) and the different modalities (control, neoprene sleeve, prophylactic functional brace, and kinesio tape) during gait $F(1, 24) = 8.41$, $p < 0.01$, $p = 0.00$. Furthermore, overall significant differences were found between the anterior shear force and modality $F(1, 24) = 17.18$, $p < 0.01$, $p = 0.00$ and between the internal tibial rotation and modality $F(1, 24) = 5.65$, $p < 0.05$, $p = 0.02$. There was no overall significant difference between the knee adduction angle and the different modalities $F(1, 24) = 3.161$, $p > 0.05$, $p = 0.08$, although follow-up t-tests revealed there are some significant differences between modalities. The results of this research negated the research hypothesis that the hinge brace would decrease the anterior shear force, as well as decrease the internal tibial rotation the most compared to the other modalities. In fact, the kinesio tape decreased the anterior shear force the most (m = -3.17N), although the hinge brace was a close second for the reduction of anterior shear force (m = -2.83N). The control, or no modality, had the least amount of knee adduction angle (m = 1.09°) and internal tibial rotation (m = -6.76°) compared to the other modalities. The hinge brace had the greatest knee adduction angle (m = 5.19°) compared to the other modalities. Overall, the kinesio tape had moderate knee adduction angle (m = 3.04°), the least amount of anterior shear force (m = -3.17N), and a moderate internal tibial rotation angle (m = -4.80°) compared to the other modalities.

The anterior shear force was significantly reduced during both the hinge brace (m = -2.83N) and the kinesio tape (m = -3.17N) trials as compared to the control (m = 3.43N) and the neoprene sleeve (m = 3.75N). There was a significant decrease in anterior shear force between the hinge brace and the control ($p = 0.001$) and between the hinge brace and the neoprene sleeve ($p = 0.00$). It appears that the kinesio tape and the hinge brace reduced the anterior shear force by realigning the femurs' tendency to anteriorly slide forward on the tibia during weight acceptance of gait compared to the neoprene sleeve and the control test conditions. There was no significant differences between the hinge brace and the kinesio tape ($p = 0.74$), for anterior shear force as both modalities were effective in reducing the anterior shear force. The application of the kinesio tape and the hinge brace may support the knee in similar ways preventing the femur to move anteriorly upon the tibia reducing the anterior shear force during the weight acceptance of gait. The kinesio tape significantly reduced the anterior shear force compared to the control ($p = 0.001$) and the neoprene sleeve ($p = 0.00$). Comparable to Fleming et al. (2000), the hinge brace significantly reduced the anterior shear force during both nonweightbearing and weightbearing conditions ($p = 0.04$). Findings by Barton et al. (2013), identify that the studies (20) they reviewed on patellar taping and patellofemoral pain syndrome had no overall significant difference in a anterior shear force and kinesio tape during unilateral squat tasks resulting in no evidence that the tape reduces anterior shear force. These findings contradict the results of this study, but very few of the articles reviewed by Barton et al. (2013) addressed anterior shear force. The decrease in anterior shear force reduces the patellofemoral joint force, which can aid in the reduction of pain and discomfort for individuals with patellofemoral pain syndrome.

There was a significant increase in internal tibial rotation angle during the hinge brace condition compared to the other test conditions during weight acceptance of gait at the $p < 0.01$ level, ($p = 0.00$). Results identified that the hinge brace significantly increased the internal tibial rotation angle (m = 2.38°) as compared to the three other test conditions (control: m = -6.76, neoprene sleeve: m = -5.28°, and kinesio tape: m = -4.80°). There was no significant difference in the internal tibial rotation between the control and neoprene sleeve or kinesio tape conditions during weight acceptance of gait. There was also no significant difference in internal tibial rotation angle between the neoprene sleeve and the kinesio tape trials during weight acceptance of gait. These results are contradictory to other findings where the hinge brace was found to decrease internal tibial rotation angle during step descent tasks (Selfe et al., 2011). The contradictory results found by Selfe et al. (2011) of reduced internal tibial rotation may be due to the step descent tasks performed, while this study focused on gait and these are two different movement patterns that will yield different results. In addition, Singer and Lamontagne (2008) found that both the neoprene sleeve and the hinge brace significantly reduced the peak internal tibial rotation angle during gait. Singer and Lamontagne (2008) focused on peak internal tibial rotation which does not identify at which part of the gait cycle these results are found, whereas this study focused on internal tibial rotation during weight acceptance of gait. The reduction of internal tibial rotation angle can also decrease the amount of patellofemoral joint force, which can aid in the reduction of pain associated with patellofemoral pain syndrome.

Although there is no overall significance within subjects for the knee adduction angle during weight acceptance of gait, there was a significant increase in knee adduction angle between the hinge brace ($p < 0.01$) and the three other test conditions (control, neoprene sleeve, and kinesio tape) during weight acceptance of gait. The hinge brace had a significantly increased knee adduction angle ($m = 5.19°$) compared to the other test conditions (control: $m = 1.09°$, sleeve: $m = 1.88°$, kinesio tape: $m = 3.04°$). Many individuals will alter their natural gait pattern with the application of the hinge brace when there is no instruction given or the individual has not had sufficient time to adjust to the brace. This can result in decreased knee flexion, increased hip abduction, resulting in an increased knee adduction, which may have occurred during this study. The control or no modality test condition had the lowest mean knee adduction angle compared to the other test conditions. Singer and Lamontagne (2008) found similar results in which peak knee adduction angles were greatest during the hinge brace trials; moderate during the neoprene sleeve trials, and lowest during the non-braced gait trials. The results may be similar to the ones of this study if the participants were not given specific directions on how to walk in the braces or enough time spent in the brace to adjust to the application of the different modalities. The results of this study contradict findings from Selfe et al. (2011) in which knee adduction angles were reduced during both hinge brace and taped conditions while performing step descent tasks. Selfe et al. (2011) focused on knee adduction angles during a step descent task not gait, which is why their results may conflict with the results of this study. During a step descent task an individual usually strikes with the forefoot followed by support of the midfoot (weight acceptance) and the last part of the foot to touch ground is the rearfoot. This technique is opposite of gait in which individuals tend to strike with the rearfoot, followed by support of the midfoot (weight acceptance) and propelled forward by pushing off of the forefoot. Selfe et al. (2011) did not identify which phase of the step descent task was analyzed which also may be the reason for the conflicting results in knee adduction angle for hinge braced conditions. A reduced knee adduction angle can reduce patellofemoral joint force, which will ultimately aid in the reduction of pain associated with patellofemoral pain syndrome.

While this study presented new insight to the effects of different modalities during gait and the factors associated with patellofemoral pain syndrome, the results are limited due to the following: The participants' natural gait pattern may have been altered due to the requirement to hit the force plate during the gait trials. The volunteer participants were all considered "healthy" with no knee pain or ailments. The participants were not individuals with PFPS. The study analyzed gait and not a more dynamic movement, such as jogging, running, change of direction, squatting, or jumping exercises. The brands used in this study were Ossur (for the braces) and Kinesio Tape (for the tape), other brands might produce different results. The study was limited to the hinge brace, the neoprene sleeve, and the kinesio tape. There are several more types of braces and tape available on the market that can be studied such are arthritic braces, ACL braces, buttress braces, knee wraps, and knee straps.

Future research should include dynamic movements that are common among activities of daily living. The participants performed 12 gait trials each for a distance of 8 strides. The distance may not be a long enough space for each person to adjust to the different modalities. In addition, there are many studies that apply their focus to pain and whether or not it is reduced after applying the different modalities for individuals with patellofemoral pain syndrome instead of identifying how the different modalities alter the kinematics and kinetics during movement. More factors that associated with patellofemoral pain syndrome can be investigated, such as peak knee flexion angle, knee extension moment, knee compressive force, hip abduction, and pathologies such as pes planus or pes cavus foot type and the size and shape of both the individuals' patella and trochlear groove. With the numerous factors associated with patellofemoral pain syndrome, any alteration in the kinetic chain (both distally and proximally) to the knee can have an effect on one of the many factors associated with PFPS.

The contradictory nature of the findings compels the need for future research to determine a more concise understanding of how these modalities alter the kinematics and kinetics that are associated with patellofemoral pain syndrome. This will better equip clinicians, therapist, and athletic trainers to aid in the reduction of these factors more precisely. In addition, the market is flooded with a variety of brands ad options of braces and tape. The variance in fit and design between options could have a compounded effect, ultimately changing the mechanics in numerous ways. It would be interesting to see if these modalities alter the mechanics by gender. Due to the reviewed research combining gender and not separating gender to see if gender effects how the modalities operate, it was not tested in this study. Lastly, the results of these gait trials were all immediate effects of the application of the different modalities. Research should continue to analyze the effects of these applied modalities over time by focusing on how time can affect the results of applied modalities both during gait and more dynamic movements.

Conclusion

Within the limitations of this study, the results can suggest that there are significant differences between the different modalities (control, neoprene sleeve, hinge brace, and kinesio tape) and the factors associated with patellofemoral pain syndrome (knee adduction angle, anterior shear force, and internal tibial rotation angle). Overall the kinesio tape has the capability to: Significantly reduce the anterior shear force during weight acceptance of gait compared to the control ($p < 0.01$) and the neoprene sleeve ($p < 0.01$). Significantly reduced the internal tibial rotation angle during weight acceptance of gait compared to the hinge brace ($p < 0.01$). Significantly reduced the knee adduction angle during weight acceptance of gait compared to the hinge brace ($p < 0.01$).

Although the kinesio tape did not significantly differ in internal tibial rotation and knee adduction from the control and the neoprene trials, it was not severely increased like the hinge brace.

The results contradict the research hypothesis that the hinge would reduce the anterior shear force and the internal tibial rotation angle the most during weight acceptance of gait compared to the other test conditions (control, neoprene sleeve, and kinesio tape), because the kinesio tape outperformed the hinge brace on all levels. The hinge brace did significantly reduce the anterior shear force during weight acceptance of gait compared to the control ($p < 0.01$) and the neoprene sleeve ($p < 0.01$), but did not reduce the anterior shear force compared to the kinesio tape condition ($p > 0.05$). The hinge brace significantly increased the internal tibial rotation during weight acceptance of gait compared to all test conditions ($p < 0.01$). The hinge brace also significantly increased the knee adduction angle during weight acceptance of gait compared to all test conditions ($p < 0.01$).

The results of this study have enhanced our understanding of how the different applied knee modalities can alter the mechanical properties of the knee. It is ideal that an individual would first be analyzed to identify which current mechanical knee factor is most severe during gait, such as an increased anterior shear force causing them to suffer from PFPS. This information would benefit clinicians' to properly prescribe the applied modality that would make the best alteration for that person, which in this scenario would be the application of the kinesio tape. Overall, the results of this study can recommend the best practical application for individuals with patellofemoral pain syndrome to use kinesio tape to decrease associated factors identified in this research (anterior shear force, internal tibial rotation angle, and knee adduction angle) to restore the normal mechanical properties of the knee.

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