

The Effects of Therapeutic Patellar Taping Techniques on Lower Extremity Kinematics
During Running in Individuals with and without Patellofemoral Pain Syndrome

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Abstract

The effectiveness of patellar taping techniques for Patellofemoral Pain Syndrome (PFPS), including McConnell's Medial Glide and Mechanical Correction Technique with Tension in the Base, remains controversial, with no research comparing their effectiveness during running. The purpose of this study was to investigate the effects of the aforementioned therapeutic patellar taping techniques on lower extremity kinematics in runners with and without PFPS. Thirty-two individuals volunteered to participate: 20 healthy participants (10 males, 10 females), and 12 participants diagnosed with PFPS (4 males, 8 females). Three taping interventions (McConnell's Medial Glide taping technique, Mechanical Correction with Tension in the Base taping technique, and no tape) were randomized, and lower extremity kinematics and stride characteristics were obtained. Data were analyzed using descriptive statistics and mixed factorial ANOVAs.

Significant taping effects were found for hip and knee flexion angles at initial contact ($F(2, 60) = 16.796, p = 0.000, \eta_p^2 = 0.359$; $F(2, 60) = 17.274, p = 0.000, \eta_p^2 = 0.365$), and peak hip flexion angles during swing ($F(2, 60) = 6.556, p = 0.003, \eta_p^2 = 0.179$). McConnell's Medial Glide produced more flexion than the Mechanical Correction with Tension in the Base ($p=0.000$; $p=0.000$; $p=0.011$) and no tape condition ($p=0.000$; $p=0.000$; $p=0.031$). Similarly, peak knee flexion angles during stance ($F(2, 60) = 3.509, p = 0.036, \eta_p^2 = 0.105$) and flight time ($F(2, 60) = 5.016, p = 0.010, \eta_p^2 = 0.143$) revealed significant taping effects, with McConnell's Medial Glide resulting in more flexion and shorter flight times than the no tape condition ($p=0.040$; $p=0.012$). Furthermore, a significant taping effect was seen for peak knee flexion angles during swing ($F(2, 60) = 4.964, p = 0.010, \eta_p^2 = 0.142$), with the Mechanical Correction with Tension

in the Base resulting in less flexion than McConnell's Medial Glide ($p=0.042$) and no tape condition ($p=0.041$).

While therapeutic taping techniques were found to influence angular displacements and time differently throughout the running gait cycle, McConnell's Medial Glide was always associated with more hip and knee flexion. Based on the conclusions of this study, it is suggested that tape is better than no tape, with McConnell's Medial Glide being the best option, since it allowed for more hip and knee flexion at initial contact, as well as shorter flight times during swing.

The Effects of Therapeutic Patellar Taping Techniques on Lower Extremity Kinematics During Running in Individuals with and without Patellofemoral Pain Syndrome

Running is an extremely popular form of physical activity (Wirtz, Willson, Kernozek, & Hong, 2012), with approximately 50 million participants in North America (Ferber & Macdonald, 2014). Unfortunately, running has been linked to multiple lower extremity overuse injuries, with 40% of them occurring at the knee (Ferber & Macdonald, 2014). Specifically, patellofemoral pain syndrome (PFPS), characterized by pain over the anterior aspect of the knee (Callaghan & Selfe, 2012; Lan, Lin, Jiang, & Chiang, 2010), accounts for 46-62% of those injuries (Ferber & Macdonald, 2014). As a result, PFPS is one of the most common musculoskeletal conditions (Herrington, Malloy, & Richards, 2005), estimated to affect 25% of the population (Callaghan & Selfe, 2012; Campolo, Babu, Dmochowska, Scariah, & Varughese, 2013), and seems to be especially prevalent in female runners (Wirtz et al., 2012).

A commonly used and inexpensive treatment for PFPS is therapeutic patellar taping (Callaghan & Selfe, 2012). There are a variety of therapeutic taping techniques that are utilized in the clinical setting, typically varying in the type of tape used, the method of application and direction of pull associated with the tape, as well as the number of layers applied to the patella (Callaghan & Selfe, 2012). Two popular techniques that have emerged over the years include McConnell's Medial Glide (Leukotape) and Mechanical Correction with Tension in the Base (Kinesio Tape). However, the effectiveness of these taping techniques remains controversial, and there is currently no literature comparing their effectiveness during running. As a result, this study will investigate the effects of therapeutic patellar taping techniques on lower extremity kinematics in runners with and without PFPS.

Running

Running is characterized as a type of gait with two periods in which neither foot is in contact with the ground (Houglum & Bertoti, 2012). Running occurs at various speeds, and may consist of jogging, slow running, fast running, and sprinting (Houglum & Bertoti, 2012). When investigating the biomechanics of running there are many aspects to consider, such as the running gait cycle and associated kinematics.

The running gait cycle. Running is a cyclical movement in which one stride follows the other in a continuous pattern (Figure 1; Bartlett, 2007). The cycle begins when one foot comes into contact with the running surface, and ends when that same foot comes into contact with that surface again (Nicola & Jewison, 2012; Novacheck, 1998). The running gait cycle can be further divided into two primary phases: stance and swing (Nicola & Jewison, 2012). The stance phase occurs when the foot is in contact with the running surface and accounts for less than 50% of the total running gait cycle (Nicola & Jewison, 2012; Novacheck, 1998). Conversely, the swing phase occurs when the foot is no longer in contact with the running surface and accounts for more than 50% of the total running gait cycle (Nicola & Jewison, 2012; Novacheck, 1998).



Figure 1. Photo sequence of the running stride. Adapted from “What is natural running?,” by Salming, 2013, <http://www.salmingrunning.com/salming-runlab/natural-running.aspx>.

Stance phase. The stance phase of running can be divided into three main events: initial contact, midstance, and toe off (Nicola & Jewison, 2012).

Initial contact. Initial contact occurs when the foot first comes into contact with the running surface; however, the exact part of the foot that initiates contact depends on the runners' footstrike pattern (Nicola & Jewison, 2012). Approximately 80% of long distance runners initiate contact with his/her heel (Novacheck, 1998) and are, thus, deemed heelstrikers (Nicola & Jewison, 2012). Alternatively, runners may initiate contact with his/her midfoot or forefoot and are, therefore, considered midfoot or forefoot strikers (Nicola & Jewison, 2012).

During this time, the goal of the lower extremity is to absorb the impact of the landing and distribute the forces throughout the body (Nicola & Jewison, 2012). According to Nicola and Jewison (2012), this may be accomplished via a pronated, everted, and dorsiflexed ankle, as well as a slightly valgus knee. Conversely, Ferber and Macdonald (2014) have identified that this may be accomplished via a supinated, inverted, and dorsiflexed ankle, as well as a slightly varus knee. The differences occurring at the knee and ankle during this portion of the stance phase are indicative of variations in footstrike patterns amongst runners (Nicola & Jewison, 2012).

Nevertheless, there are additional movements that have been agreed upon. These include the runner having a flexed, varus, and slightly laterally rotated knee that instantly moves into a medially rotated position (Ferber & Macdonald, 2014; Houghlum & Bertoti, 2012), as well as a flexed, adducted, and slightly medially rotated hip (Ferber & Macdonald, 2014; Houghlum & Bertoti, 2012; Nicola & Jewison, 2012; Novacheck, 1998). However, once the forefoot begins to come into contact with the ground and the lower extremity moves under the body, the runner moves into midstance (Nicola & Jewison, 2012; Novacheck, 1998).

Midstance. At midstance, the ankle remains in a dorsiflexed position (Ferber & Macdonald, 2014; Novacheck, 1998). However, during this time, the ankle may either move into a pronated (Ferber & Macdonald, 2014), or supinated position (Nicola & Jewison, 2012).

Additionally, the ankle is everted and the knee moves into a medially rotated position (Ferber & Macdonald, 2014; Houghlum & Bertoti, 2012). Finally, the knee reaches its maximum angle of flexion, while the hip is slightly flexed, adducted, and medially rotated (Ferber & Macdonald, 2014; Novacheck, 1998).

Toe off. In preparation for toe off, the ankle begins to plantarflex and invert causing the foot to move into a supinated position (Ferber & Macdonald, 2014; Houghlum & Bertoti, 2012; Nicola & Jewison, 2012). Concurrently, the knee and hip begin to extend, abduct, and laterally rotate (Ferber & Macdonald, 2014; Houghlum & Bertoti, 2012; Novacheck, 1998). It is through this combination of movements that the body is propelled upwards and forwards at the moment of toe off, thus, initiating the swing phase (Ferber & Macdonald, 2014; Nicola & Jewison, 2012; Novacheck, 1998).

Swing phase. During initial swing, the runner will undergo the first of two flight phases, in which neither foot is in contact with the running surface (Houghlum & Bertoti, 2012; Novacheck, 1998). During this time, the ankle remains plantarflexed, the knee flexes, and the hip extends, abducts, and medially rotates (Houghlum & Bertoti, 2012; Novacheck, 1998). This allows the stance leg to move in an upward and forward direction during midswing, thus, advancing the body forward (Houghlum & Bertoti, 2012). The opposite foot then initiates contact with the running surface and follows the same pattern (Nicola & Jewison, 2012). While this is occurring, the momentum produced at toe off causes the swing limb to accelerate forward (Houghlum & Bertoti, 2012), ultimately resulting in greater hip and knee flexion throughout midswing (Houghlum & Bertoti, 2012; Novacheck, 1998). The ankle also dorsiflexes and the hip continues to abduct and medially rotate (Houghlum & Bertoti, 2012; Novacheck, 1998).

In preparation for initial contact, the runner will enter the terminal swing phase, and undergo the second flight phase (Houglum & Bertoti, 2012; Nicola & Jewison, 2012; Novacheck, 1998). During this time, the swing limb begins to decelerate in preparation for initial contact (Houglum & Bertoti, 2012). The ankle remains dorsiflexed, while the knee extends to reach a near fully extended position, and the hip remains flexed, as well as begins to adduct and laterally rotate (Novacheck, 1998). This marks the end of the running gait cycle, however, since running is a cyclical movement the entire cycle then commences again (Bartlett, 2007).

Kinematics of running. Kinematics is a term used to describe human movement without reference to the forces causing it (Novacheck, 1998; Winter, 2009). There are different kinematic variables including linear and angular displacements, velocities, and accelerations (Winter, 2009). Wide typical ranges of angular displacements at the hip, knee, and ankle have been reported during running (Ferber & Macdonald, 2014; Hamill & Knutzen, 2003; Novacheck, 1998).

Typical lower extremity kinematics during running.

Hip. At initial contact, the hip is in approximately 23-50° of flexion, 12° of adduction to 2.5° of abduction (Ferber & Macdonald, 2014; Hamill & Knutzen, 2003; Novacheck, 1998), and 2.5-15° of medial rotation (Ferber & Macdonald, 2014; Novacheck, 1998). Once in midstance, the hip reaches approximately 25-40° of flexion, 1-15° of adduction, as well as 2.5-14° of medial rotation (Ferber & Macdonald, 2014; Novacheck, 1998). At the moment of toe off, the hip ranges from 10° of flexion (Ferber & Macdonald, 2014) to 5° of extension (Hamill & Knutzen, 2003; Novacheck, 1998). Furthermore, the hip ranges from approximately 1° of medial rotation (Novacheck, 1998) to 8° of lateral rotation, as well as 5° of adduction to 2.5° of abduction (Ferber & Macdonald, 2014). At initial swing, the hip reaches approximately 6° of extension,

however, it quickly flexes throughout midswing until it reaches a maximum of approximately 55° (Novacheck, 1998). At terminal swing the hip extends to reach approximately 47° of flexion (Novacheck, 1998).

Knee. At initial contact the knee has been reported to range from approximately 1° of extension to 40° of flexion (Ferber & Macdonald, 2014; Hamill & Knutzen, 2003; Novacheck, 1998). During this time, the knee is also in 1-5° of abduction and 2-10° of lateral rotation (Ferber & Macdonald, 2014). At midstance, the knee reaches approximately 38-60° of flexion (Ferber & Macdonald, 2014; Hamill & Knutzen, 2003; Novacheck, 1998), 5-12° of medial rotation, and ranges from 5° of adduction to 5° of abduction (Ferber & Macdonald, 2014). At toe off, the knee is in approximately 10-20° of flexion (Ferber & Macdonald, 2014; Novacheck, 1998), as well as 2.5-7° of abduction, and 1-10° of lateral rotation (Ferber & Macdonald, 2014). Once in the swing phase, the knee will begin to flex throughout initial swing until it reaches a maximum of approximately 90° at midswing (Novacheck, 1998). At terminal swing, the knee will extend to reach approximately 25° of flexion (Novacheck, 1998).

Ankle. At initial contact, the ankle is in approximately 10-17° of dorsiflexion (Ferber & Macdonald, 2014; Hamill & Knutzen, 2003; Novacheck, 1998) and 5° of eversion to 5° of inversion (Ferber & Macdonald, 2014). Once midstance is reached, the ankle further dorsiflexes to reach approximately 15-30° of dorsiflexion (Ferber & Macdonald, 2014; Hamill & Knutzen, 2003; Novacheck, 1998). In addition, the ankle will be in roughly 2-10° of eversion (Ferber & Macdonald, 2014). Once toe off is reached, the ankle plantarflexes to reach approximately 5-20° of plantarflexion (Ferber & Macdonald, 2014; Hamill & Knutzen, 2003; Novacheck, 1998). The ankle will also range from roughly 1° of eversion to 10° inversion (Ferber & Macdonald, 2014).

Anatomy

Patellofemoral joint. The patella is a small sesamoid bone located within the quadriceps tendon (Figure 2; Tortora & Nielsen, 2009). Typically, it glides both inferiorly and superiorly between the medial and lateral femoral condyles during flexion and extension of the knee; however, movement also occurs medially and laterally (Tortora & Nielsen, 2009).

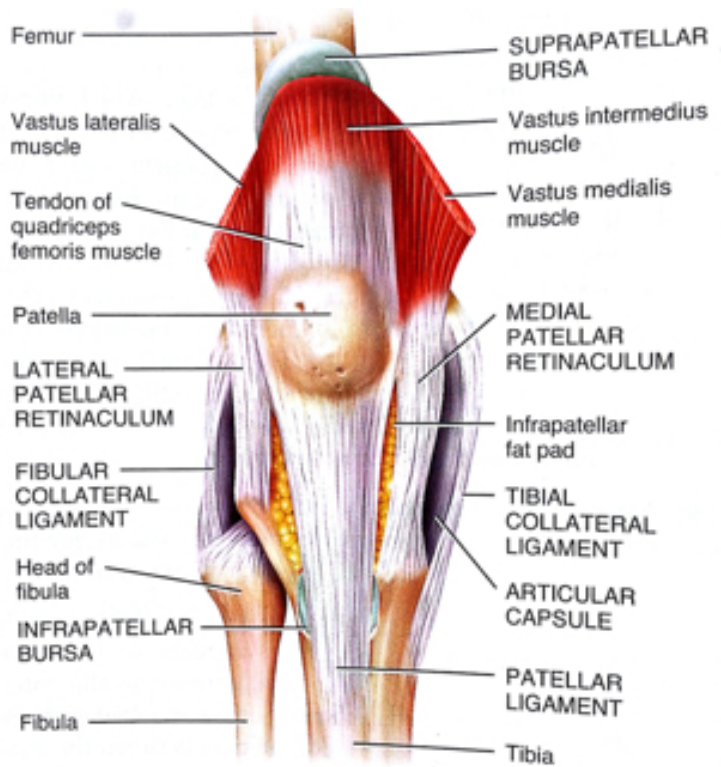


Figure 2. Anterior view of the patellofemoral joint. Adapted from “Principles of human anatomy (11th Ed.),” by G. J. Tortora & M. T. Nielsen, 2009, p. 278.

A primary function of the patella is to increase the pull of the quadriceps tendon and to sustain its position during movement (Tortora & Nielsen, 2009), thus increasing the quadriceps lever arm and mechanical advantage (McConnell, 1986; Tortora & Nielsen, 2009). However, in order for the patella to function effectively, it must track correctly within the trochlear notch (patellar surface) of the femur (McConnell, 1986). This region is commonly referred to as the patellofemoral joint (PFJ; Figure 3) and is defined as the area “between the posterior surface of

the patella and the patellar surface of the femur” (Tortora & Nielson, 2009, p. 238). However, it is also defined as the “intermediate component of the tibiofemoral (knee) joint” (medial and lateral joints comprised of the medial and lateral femoral and tibial condyles as well as the menisci; Tortora & Nielson, 2009, p. 238).

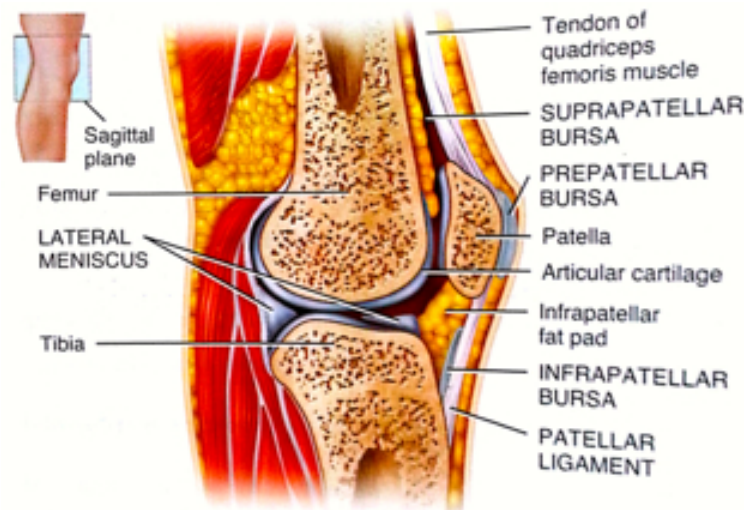


Figure 3. Sagittal view of the patellofemoral joint. Adapted from “Principles of human anatomy (11th Ed.),” by G. J. Tortora & M. T. Nielsen, 2009, p. 278.

Primary movers.

Hip. Several muscles are responsible for the movements at the hip (Figure 4; Figure 5), resulting in movements that occur in all three planes (sagittal, frontal, transverse; Houglum & Bertoti, 2012). The primary flexors include the iliopsoas, rectus femoris, sartorius, pectineus, and tensor fascia latae muscles (Houglum & Bertoti, 2012). On the other hand, the hip extensors include the gluteus maximus, biceps femoris, semimembranosus, semitendinosus, and the posterior fibres of the adductor magnus muscles (Houglum & Bertoti, 2012). Furthermore, the primary hip adductors include the adductor longus, adductor brevis, adductor magnus, gracilis, and pectineus muscles (Houglum & Bertoti, 2012). Alternatively, the primary hip abductors include the gluteus medius and minimus, as well as the tensor fascia latae muscles (Houglum &

Bertoti, 2012). The lateral rotators consist of the posterior fibres of gluteus medius, gluteus maximus, and sartorius muscles, while the medial rotators include the anterior fibres of gluteus medius, as well as the gluteus minimus and tensor fascia latae muscles (Houglum & Bertoti, 2012). However, it is important to note that there are no primary medial rotators, and as such, the muscles listed are the secondary movers (Houglum & Bertoti, 2012).

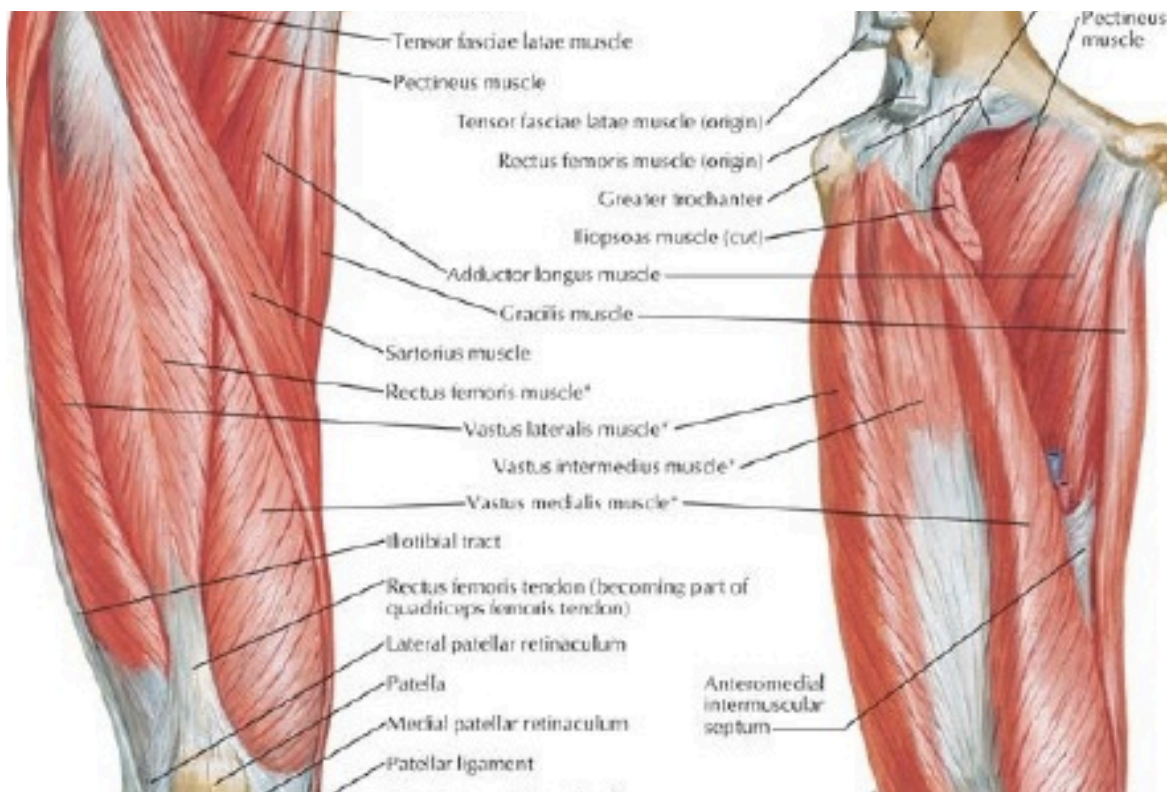


Figure 4. Primary movers at the hip and knee (anterior view). Adapted from “Atlas of human anatomy (5th Ed.),” by F. H. Netter, 2010, p. 390.

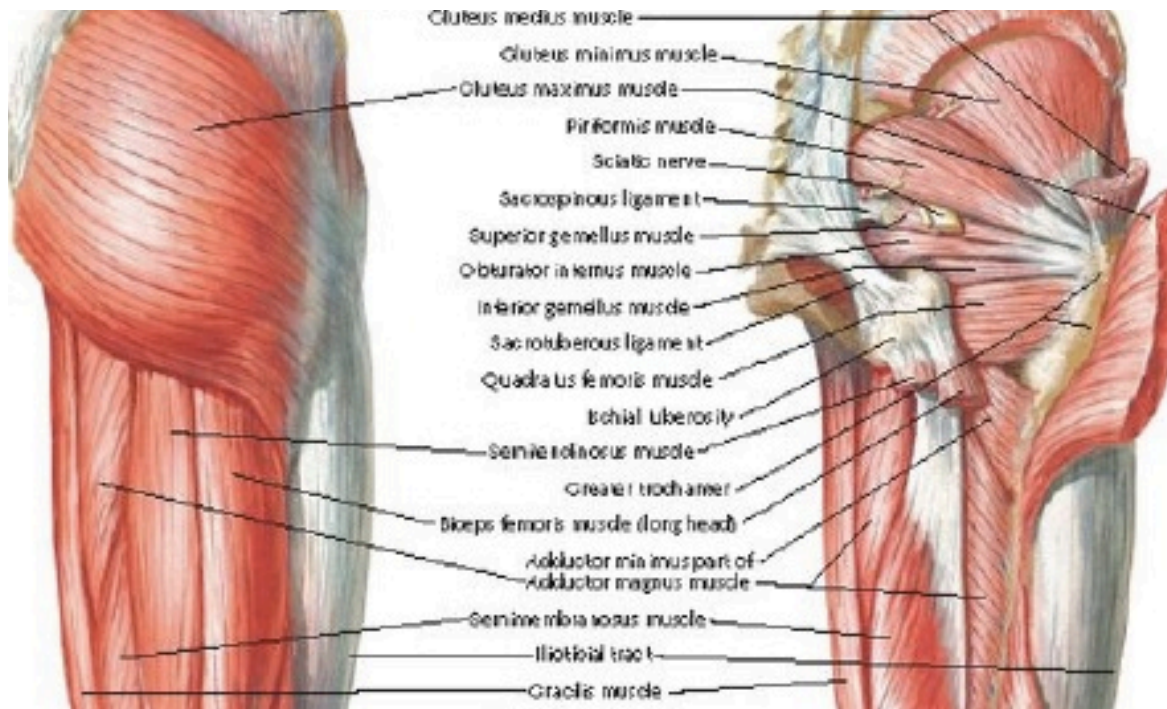


Figure 5. Primary movers at the hip and knee (posterior view). Adapted from “Atlas of human anatomy (5th Ed.),” by F. H. Netter, 2010, p. 392.

Knee. There are many muscles responsible for the movements at the knee (Figures 4-6). The primary knee extensors include the quadriceps femoris muscle group, which consist of the rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius muscles (Houglum & Bertoti, 2012). However, the vastus medialis muscle can be divided into two sections, the superior head known as the vastus medialis longus, and the inferior head known as the vastus medialis obliquus (Carlson & Smith, 2012). Since the vastus medialis longus muscle fibres are longitudinally oriented along the shaft of the femur, it is the section responsible for knee extension. Conversely, the vastus medialis obliquus muscle fibres are slanted horizontally, thus, playing a role in medial patellar stabilization (Carlson & Smith, 2012; Houglum & Bertoti, 2012).

The primary knee flexors include the hamstrings, which consist of the biceps femoris, semitendinosus, and semimembranosus muscles; however, the gastrocnemius, plantaris,

popliteus, gracilis, and sartorius muscles also assist with knee flexion (Houglum & Bertoti, 2012). Furthermore, the medial rotators include the semitendinosus, semimembranosus, popliteus, gracilis, and sartorius muscles, while the lateral rotator consists of the biceps femoris muscle (Houglum & Bertoti, 2012).

Ankle. The primary muscles responsible for ankle plantarflexion include the gastrocnemius and soleus muscles; however, the plantaris, tibialis posterior, flexor digitorum longus, and flexor hallucis longus muscles also play a role (Figure 6; Houglum & Bertoti, 2012).

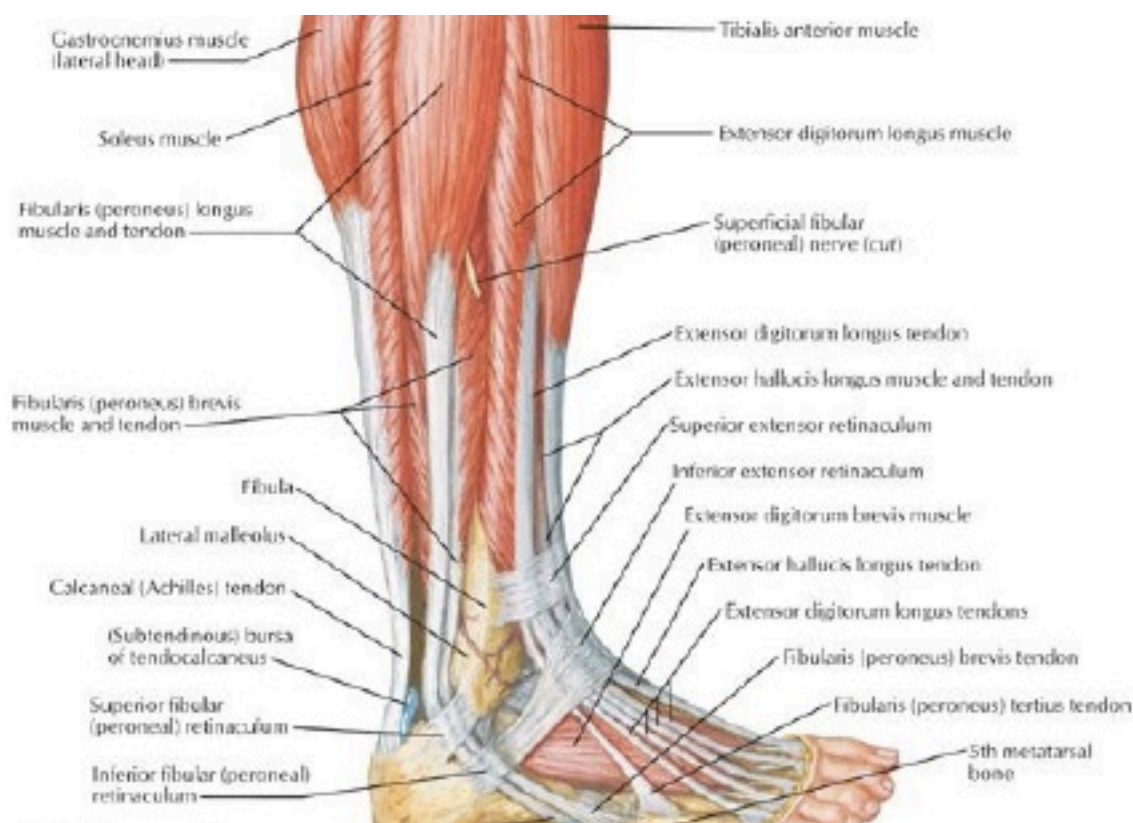


Figure 6. Primary movers at the ankle (lateral view). Adapted from “Atlas of human anatomy (5th Ed.),” by F. H. Netter, 2010, p. 407.

The anterior muscle group, consisting of the tibialis anterior, extensor hallucis longus, extensor digitorum longus, and peroneus tertius muscles, are responsible for ankle dorsiflexion (Figure 7; Houglum & Bertoti, 2012). Furthermore, the primary muscles involved in ankle eversion include

the peroneus longus and brevis, extensor digitorum longus, and peroneus tertius muscles (Figure 6; Houglum & Bertoti, 2012). Additionally, the tibialis posterior muscle is the sole primary mover responsible for inversion (Houglum & Bertoti, 2012).



Figure 7. Primary movers at the ankle (anterior view). Adapted from “Atlas of human anatomy (5th Ed.),” by F. H. Netter, 2010, p. 406.

Patellofemoral Pain Syndrome

There is no universal definition for PFPS; however, it has been previously described as pain over the anterior aspect of the knee (Callaghan & Selfe, 2012; Lan et al., 2010). Although the etiology of PFPS remains unclear, it has been associated with abnormal biomechanical factors that alter the shearing and compressive forces of the PFJ (Aytar et al., 2011; Callaghan & Selfe, 2012; Herrington et al., 2005; Mostamand, Bader, & Hudson, 2010; Osorio et al., 2013). This may include stiffness in the iliotibial band, an imbalance or weakness in the quadriceps

muscles (more specifically, the vastus medialis), the presence of a large quadriceps angle (Q-angle), overall hip weakness (especially the hip lateral rotators and abductors), as well as poor positioning of the patella (Barton, Levinger, Menz, & Webster, 2009; Bolgla & Boling, 2011; Osorio et al., 2013). Furthermore, “poor hip rotation control, excessive foot pronation, femoral anteversion, tibial torsion, bone configuration, or tight muscles” (p. 412) have been reported to alter patellofemoral kinematics (Derasari, Brindle, Alter, & Sheehan, 2010). Additionally, some individuals with PFPS also present with higher body mass indexes, which results in greater forces being placed on the PFJ (Callaghan & Selfe, 2012).

The primary theory, however, is that most patellofemoral pain is derived from some type of patellar misalignment (McConnell, 1986), most commonly associated with a lateralization of the patella within the PFJ (Smith, McNamara, & Donell, 2013). As a result, individuals with PFPS present with pain during activities that produce considerably higher amounts of shearing and compressive forces on the PFJ (Aminaka & Gribble, 2005; Campolo et al., 2013; Lan et al., 2010; Mostamand et al., 2010; Osorio et al., 2013). Aggravating activities typically include squatting, ascending/descending stairs, prolonged sitting, kneeling, and/or running; all of which are associated with knee flexion (Aminaka & Gribble, 2005; Campolo et al., 2013; Lan et al., 2010; Mostamand et al., 2010; Osorio et al., 2013). As such, PFPS can limit function and mobility, ultimately impairing quality of life (Campolo et al., 2013; Herrington et al., 2005). However, there are many interventions for PFPS such as active exercise, electrotherapeutic modalities, foot orthosis, bracing, and therapeutic taping (Bolgla & Boling, 2011).

Lower extremity kinematics associated with patellofemoral pain syndrome during running. Several studies have investigated lower extremity kinematics associated with PFPS during running (Dierks et al., 2008; Noehren, Pohl, Sanchez, Cunningham, & Lattermann, 2012;

Souza & Powers, 2009; Willson & Davis, 2008). All studies investigated peak hip medial rotation and peak hip adduction angles, with values ranging from 3-11.8° and 8.7-20° respectfully. Souza and Powers (2009) and Noehren et al. (2012) found that females with PFPS had greater peak hip medial rotation (PFPS: 11.8°, control: 4.2°; PFPS: 9.8°, control: 5.2°). This is consistent within the literature suggesting that individuals with PFPS have weak hip lateral rotators (Barton et al., 2009). Conversely, Willson and Davis (2008) found that females with PFPS had less peak hip medial rotation (PFPS: 3°, control: 6°), while Dierks et al. (2008) reported no differences among males and females with PFPS at the beginning or at the end of a prolonged run (PFPS: 5.1, 4.6, control: 6.0°, 5.8°). The inconsistent findings between studies may be attributed to different marker placements, participants' gender (Noehren et al., 2012), differences in peak angle definitions during the gait cycle (Barton et al., 2009), or variations in running patterns (James & Brubaker, 1972).

Furthermore, Willson and Davis (2008) and Noehren et al. (2012) found that females with PFPS had greater peak hip adduction (PFPS: 13.5°, control: 10.5°; PFPS: 20°, control: 17.8°). Once again, this is consistent within the literature suggesting that individuals with PFPS have associated hip abductor weakness (Barton et al., 2009). Conversely, Dierks et al. (2008) found that individuals with PFPS had less peak hip adduction (PFPS: 8.7°, 8.8°; control: 11.8°, 12.0°); while Souza and Powers (2009) reported no differences among their female participants (PFPS: 15.5°, control: 15.1°).

In addition, three studies investigated the distal kinematics associated with PFPS during running (Dierks et al., 2008; Noehren et al., 2012; Willson and Davis, 2008). No differences were seen in peak knee adduction (PFPS: 1.6°, 1.2°; control: 1.3°, 1.1°; Dierks et al., 2008); however, females with PFPS demonstrated greater peak shank medial rotation (PFPS: -10.0°,

control: -6.5° ; Noehren et al., 2012) and peak knee lateral rotation (PFPS: 4.2° , control: 1.8° ; Willson & Davis, 2008). Noehren et al. (2012) suggested that the increase in shank medial rotation might be a result of abnormal hip mechanics. On the other hand, Barton et al. (2009) suggested that the increased knee lateral rotation caused individuals with PFPS to present with a greater Q-angle and changed the articulation area of the PFJ. These conflicting results indicate further research is necessary to provide clarification.

Therapeutic Taping

Taping is widely used either by itself or in conjunction with active exercise for the prevention and rehabilitation of athletic injuries (Aytar et al., 2011; Williams, Whatman, Hume, & Sheerin, 2012). According to Aytar et al. (2011) “the essential function of most taping techniques is to provide support during movement” (p.135). When applied to the knee, “the therapeutic effects of knee taping include minimizing pain, increasing muscle strength, improving the gait pattern, and enhancing the functional outcome of patients with sports injuries, osteoarthritis and PFPS” (Aytar et al., 2011, p. 135). Studies have shown that the effectiveness of tape in the treatment of PFPS is controversial, however, despite this, taping remains widely used in present day clinical practice (Aminaka & Girbble, 2005; Callaghan & Selfe, 2012; Campolo et al., 2013; Fu et al., 2008; Lan et al., 2010; Osorio et al., 2013). Two commonly used taping techniques to treat PFPS include McConnell’s Medial Glide and Mechanical Correction with Tension in the Base (K. Kase, Wallis, & Kase, 2013; McConnell, 1986).

McConnell’s medial glide. McConnell’s Medial Glide technique was originally described in 1986 (McConnell, 1986). This technique uses Leukotape, which is a specialized, highly adhesive rigid tape that can be worn for up to 18 hours (Campolo et al., 2013; Pfeiffer et al., 2004). Due to its rigidity, Leukotape acts as a structurally supportive tape (Campolo et al.,

2013), thus, making it ideal for McConnell's Medial Glide. McConnell's technique has been proposed to facilitate the activation of the vastus medialis so that the PFJ can remain stabilized against the lateral pull of the vastus lateralis muscle (Herrington et al., 2005). It has also been proposed to "reposition the patella within the femoral trochlear groove, change the patella contact pressure, and joint reaction force", ultimately decreasing the "load, joint stresses and pain" (Herrington et al., 2005, p. 605). However, the mechanism by which these are achieved is unclear (Herrington et al., 2005).

The goal of McConnell's technique is to correct abnormal tracking of the patella (McConnell, 1986). This technique can involve multiple components (tilt, rotation, and/or glide) depending on each individual's need (McConnell, 1986). Since individuals normally present with tight lateral thigh structures, they will typically require a medial tilt, medial rotation, and/or medial glide (McConnell, 1986). If the individual presents with a lateral tilt of the patella, the medial tilt will be utilized (McConnell, 1986). This involves taping from the midline of the patella to the medial border (McConnell, 1986). If the individual presents with an excessive lateral or medial rotation of the inferior pole, then the correct rotation will be used (McConnell, 1986). To correct for the lateral rotation, the patella is taped superiorly and medially from the inferior pole, whereas, the medial rotation involves taping the patella inferiorly and medially from the superior pole (McConnell, 1986). However, the most common component used in the taping application process is the medial glide (McConnell, 1986). This technique corrects for the lateralization of the patella by displacing it medially (McConnell, 1986). More specifically, this technique involves applying Leukotape from the lateral aspect to medial aspect of the patella while simultaneously gliding the patella medially (Figure 8; Herrington et al., 2005; McConnell, 1986).



Figure 8. McConnell's Medial Glide (a).

The effects of McConnell taping techniques in individuals with PFPS has been extensively researched, however, many do not specify which technique was used, or use a combination of the aforementioned techniques. Nevertheless, numerous studies have confirmed that McConnell taping is effective in decreasing pain during a variety of activities (Aminaka & Gribble, 2008; Bockrath, Wooden, Worrell, Ingersoll, & Farr, 1993; Christou, 2004; Herrington & Payton, 1997; McConnell, 1986; Mostamand et al., 2010; Ng & Cheng, 2002; Paoloni et al., 2012; Powers et al., 1997; Salsich, Brechter, Farwell, & Powers, 2002; Whittingham, Palmer, & Macmillan, 2004). Unfortunately, the underlying mechanism by which this is achieved remains unclear (Aminaka & Gribble, 2005; Callaghan & Selfe, 2012; Crossley, Cowan, Bennell, & McConnell, 2000). In an attempt to determine the underlying mechanism, various studies have investigated the effects of McConnell taping on patellar alignment (Bockrath et al., 1993; Derasari et al., 2010; Gigante, Pasquinelli, Paladini, Ulisse, & Greco, 2001), as well as quadriceps muscle electromyographic (EMG) activity and the onset of vastus medialis and vastus lateralis activity (Christou, 2004; Cowan, Bennell, & Hodges, 2002; Gilleard, McConnell, &

Parsons, 1998; Herrington & Payton, 1997; McConnell, 1986; Ng & Cheng, 2002). The evidence supporting its use remains contradictory.

There has been limited research investigating the effects of McConnell taping on lower extremity kinematics in individuals with PFPS. Powers et al. (1997) examined the effect of McConnell's Medial Glide on knee flexion during free (self-selected speed) and fast walking, as well as ascending and descending ramps and stairs. They found that McConnell's Medial Glide significantly increased knee flexion during all conditions. Similarly, Salsich et al. (2002) investigated the effects of McConnell taping on knee flexion while ascending and descending stairs. They too concluded that McConnell taping significantly increased knee flexion during stair ambulation. This increase in knee flexion may allow those with PFPS to more readily load the PFJ, resulting in increased force absorption, overall quadriceps activity, as well as greater PFJ reaction force (Powers et al., 1997).

While this research provides some evidence supporting the use of McConnell taping for individuals with PFPS, it is limited to walking and stair ambulation. Additionally, the research is limited to only knee flexion. As a result, future research is needed to determine if McConnell taping, and more specifically McConnell's Medial Glide technique, is effective in altering lower extremity kinematics during other functional activities such as running.

Mechanical correction with tension in the base. Kase developed the Kinesio Taping Method in 1973 (K. Kase et al., 2013). Kinesio Tape comes in a variety of colours (to allow for an increase or decrease in skin temperature, as well as to enhance or neutralize ones perception of its effectiveness) and is a water resistant, elastic, cotton tape with a heat-activated adhesive (K. Kase et al., 2013) formulated to stretch up to 120-140% of its length (Fu et al., 2008; C. Lee, D. Lee, Jeong, & Lee, 2012; Osorio et al., 2013; Williams et al., 2012). The tape was designed to

mimic human skin with the amount of stretch and thickness imitating the epidermis, and the adhesive pattern simulating a fingerprint pattern (K. Kase et al., 2013). These features limit the body's perception of the tape, allowing individuals to no longer feel the sensory stimulation after about 10 minutes; allow for partial to full range of motion; as well as greater adhesion when worn over three to five days (K. Kase et al., 2013). Furthermore, the tapes elasticity and convolutions within the tape have been purported to lift the skin allowing for more space between the dermis and underlying muscles for improved circulation of fluids (Aytar et al., 2011; C. Lee et al., 2012; K. Kase et al., 2013; Osorio et al., 2013; Williams et al., 2012). As a result of these features, Kinesio Tape has been postulated to decrease pain and inflammation, improve circulation and proprioception, as well as provide support (Aytar et al., 2011; Campolo et al., 2013; Fu et al., 2008; K. Kase et al., 2013; C. Lee et al., 2012; Osorio et al., 2013; Williams et al., 2012).

The Mechanical Correction Technique with Tension in the Base is used to provide a "positional stimulus through the skin" (K. Kase et al., 2013, p. 29). Unlike McConnell's Medial Glide, this method utilizes the elastic properties of the tape to provide functional support, but not fixate the tissue (K. Kase et al., 2013). This technique can be used in all populations due to its moderate stimulus and corrective effectiveness (K. Kase et al., 2013). This technique involves anchoring a Y-strip with a long base to the lateral aspect of the knee, applying 50-70% stretch and pressure until the lateral border of the patella is reached, in which case the tails are applied along the superior and inferior borders of the patella with 15-25% stretch (Figure 9; K. Kase et al., 2013).



Figure 9. Mechanical Correction with Tension in the Base (a).

Like McConnell's Medial Glide technique, there is limited and conflicting evidence supporting the use of Kinesio Tape. Various systematic reviews have been conducted to summarize the effectiveness of Kinesio Tape for a multitude of injuries, yet they have all concluded that there is minimal evidence supporting its use over other therapeutic treatments (Parreira, Costa, Hespanhol Junior, Lopes, & Costa, 2013; Morris, Jones, H. Ryan, & Ryan, 2013, Williams et al., 2012). The available literature investigating the effects of Kinesio Tape in individuals with PFPS is very limited and a variety of Kinesio Taping Methods have been used; none of which used the Mechanical Correction with Tension in the Base technique.

Freedman, Brody, Rosenthal, and Wise (2014) investigated the immediate effects of a Kinesio Taping method to improve pain during squatting, ascending and descending stairs, and a single-leg triple jump test, as well as single-leg triple jump distance. Kinesio Tape was found to significantly decrease pain during all but one activity (squatting), and to significantly increase the single-leg triple jump distance.

C. Lee et al. (2012) investigated the effects of a Kinesio Taping method on pain during stair climbing, however, they also examined its effectiveness on vastus medialis and vastus lateralis EMG activity during a maximal voluntary isometric contraction. They found that the Kinesio Tape significantly decreased pain as well as vastus medialis and vastus lateralis EMG activity. Furthermore, they concluded that Kinesio Tape was able to significantly increase maximal voluntary isometric contraction strength.

Conversely, Aytar et al. (2011) investigated the acute effects (45 minutes) of a Kinesio Taping method on pain, isokinetic strength (measured at 60° and 180°/second), joint position sense, as well as static and dynamic balance when compared to placebo. The results showed that the Kinesio Tape and placebo tape significantly improved strength and balance, however, only the Kinesio Tape significantly improved all strength and balance components. Furthermore, Akbas, Atay, and Yuksel (2011) examined if the addition of Kinesio Tape to a stretching and strengthening exercise program would have any effect on pain, flexibility, patellar location, and functional performance (Kujala Scale). With the exception of a more rapid improvement in hamstring muscle flexibility (measured in degrees of tension), Kinesio Tape did not have a significant effect.

These conflicting results suggest that there is a need for further research. In particular, research using different Kinesio Taping techniques, such as mechanical corrections, are needed to determine the effectiveness of Kinesio Tape in individuals with PFPS, as further outlined by Akbas et al. (2011). The literature comparing different therapeutic taping techniques in individuals with PFPS is scarce.

Campolo et al. (2013) compared the effectiveness of McConnell's Medial Glide, a Kinesio Taping method, and no tape on pain during a squat lift and stair-climbing task. Both

therapeutic taping techniques were effective in decreasing pain during stair climbing, however, only the Kinesio Taping method was able to significantly decrease pain. Similarly, Osorio et al. (2013) compared the effectiveness of McConnell's Medial Glide and a Kinesio Taping method on pain, and quadriceps strength and endurance during strength testing. Both therapeutic taping techniques resulted in significantly decreased pain, and increased strength and endurance. No significant differences existed between the two therapeutic taping techniques. Due to the limited and inconsistent evidence comparing therapeutic patellar taping techniques, it is evident that future research is needed. Therefore, additional research investigating the effects of therapeutic patellar taping techniques during the performance of different functional tasks in individuals with PFPS is warranted.

Research Problem

Research examining the running gait cycle has provided relatively consistent findings (Ferber & Macdonald, 2014; Houglum & Bertoti, 2012; Nicola & Jewison, 2012; Novacheck, 1998), however, variable kinematic ranges have been identified (Ferber & Macdonald, 2014; Hamill & Knutzen, 2003; Novacheck, 1998). Kinematic abnormalities have been found between individuals with and without PFPS (Dierks et al., 2008; Noehren et al., 2012; Souza & Powers, 2009; Willson & Davis, 2008). Furthermore, the number of studies examining the effects of therapeutic taping on lower extremity kinematics is limited and controversial due to the differing techniques and activities being used (Powers et al., 1997; Salsich et al., 2002). Additionally, there is limited to no research comparing different therapeutic taping techniques (Campolo et al., 2013; Osorio et al., 2013), and none have investigated the effects during running. Given that running has clearly been linked to PFPS (Aminaka & Gribble, 2005; Ferber & Macdonald, 2014; Osorio et al., 2013; Wirtz et al., 2012), and that therapeutic taping has become a commonly used

treatment for PFPS (Aminaka & Girbible, 2005; Callaghan & Selfe, 2012; Campolo et al., 2013; Fu et al., 2008; K. Kase et al., 2013; Lan et al., 2010; McConnell, 1986; Osorio et al., 2013), there is a need to identify its effectiveness during running.

Purpose

The purpose of this study is to investigate the effects of therapeutic patellar taping techniques (McConnell's Medial Glide and Mechanical Correction with Tension in the Base) on lower extremity kinematics during the different phases of the running gait cycle in runners with and without PFPS. The following questions will be used to guide this study:

1. What is the interaction effect between therapeutic taping and group/condition when measuring hip and knee flexion angles during the initial contact phase of running?
2. What is the interaction effect between therapeutic taping and group/condition when measuring peak hip and knee adduction angles during the stance phase of running?
3. What is the interaction effect between therapeutic taping and group/condition when measuring the change in angle for hip and knee adduction, and hip medial rotation during the stance phase of running?
4. What is the interaction effect between therapeutic taping and group/condition when measuring peak knee flexion angle during the stance phase of running?
5. What is the interaction effect between therapeutic taping and group/condition when measuring peak hip and knee flexion angles during the swing phase of running?
6. What is the interaction effect between therapeutic taping and group/condition when measuring contact time and flight time during the running gait cycle?

Method

Participants

A total of 32 individuals volunteered for this study: 20 healthy participants (males = 10, females = 10; defined by the exclusion criteria), and 12 participants diagnosed with PFPS by a healthcare professional (males = 4, females = 8). Participant characteristics are presented in Table 1. All participants had previous running experience of at least 30 minutes per day, for a minimum of three days a week (Ferber, Kendall, & Farr, 2011), and were between the age of 19 and 47 years. However, due to PFJ osteoarthritic changes being more prevalent in individuals over the age of 40 (Barton et al., 2009; Cowan, Hodges, Bennell, & Crossley, 2002), participants over this age were asked about their arthritic history, and were excluded if any arthritic changes were present.

Table 1

Participant Characteristics

	Healthy						Patellofemoral Pain Syndrome					
	Females			Males			Females			Males		
	Age (yr)	Ht. (cm)	Wt. (kg)	Age (yr)	Ht. (cm)	Wt. (kg)	Age (yr)	Ht. (cm)	Wt. (kg)	Age (yr)	Ht. (cm)	Wt. (kg)
	20	170.0	60.0	23	186.0	75.0	33	172.7	71.4	25	186.0	91.1
	22	169.3	57.3	22	173.4	67.9	22	167.0	53.2	23	178.4	74.8
	24	172.4	59.9	24	188.0	80.0	44	170.5	67.0	47	167.6	78.3
	20	174.8	75.3	37	184.5	83.7	23	177.2	65.2	25	190.6	77.1
	23	174.2	63.1	20	174.2	64.6	26	172.5	59.8			
	22	179.3	71.9	22	178.4	73.0	24	167.7	61.4			
	24	162.4	54.2	39	179.0	75.6	25	166.5	77.7			
	22	172.5	61.6	19	180.0	79.8	24	162.6	61.3			
	30	173.0	64.5	33	194.0	89.2						
	26	175.6	67.1	22	179.4	76.3						
M	23.3	172.4	63.5	26.1	181.7	76.5	27.6	169.6	64.6	30.0	180.7	80.3
SD	3.0	4.5	6.5	7.3	6.4	7.2	7.4	4.6	7.5	11.4	10.1	7.3

Participants were excluded from the study if they: 1) had current knee pain or a history of knee pain within the past 6 months (healthy group only); 2) had an injury affecting his/her lower extremity or had any surgical procedure to the lower extremity within the past 6 months; 3) had a known and uncontrolled cardiovascular pathology or neuropathy; 4) had osteoarthritis in his/her lower extremity; 5) had a known allergy to adhesives such as Band Aids or tape; and/or 6) were pregnant. Pregnant females undergo many anatomical and physiological changes that can ultimately alter their balance, the amount of force placed on the joints, as well as the amount of laxity seen within the joints of the lower extremity (Anderson, Parr, & Hall, 2009; Artal & O'Toole, 2003). As such, they were excluded from the study.

Procedures

Recruitment. After receiving approval from Lakehead University's Research Ethics Board, participants were recruited via purposive and convenience sampling. Various medical establishments (physiotherapy clinics, doctor's offices, and chiropractic clinics), athletic facilities (Lakehead University Hangar, Canada Games Complex, Confederation College Bubble, and Movati Athletic), retail stores (The Running Room, Stride Orthopaedics & Footwear, and Fresh Air Experience), and running groups (Masters running group, Thunder Bay triathlon group, as well as other running groups within these organizations) were approached, and recruitment flyers (Appendix A) were posted upon an owners/managers approval. In addition, recruitment flyers were posted on the social media sites of the student researcher and Lakehead University's School of Kinesiology.

Potential participants were then asked to contact the student researcher if interested in participating, or were contacted by the student researcher herself via e-mail and social media. Potential participants were then emailed a copy of the recruitment letter (Appendix B) and

consent form (Appendix C), in order to ensure that he/she met the inclusion and exclusion criteria for the study. Eligible participants were then scheduled for a testing time that was mutually convenient, and were asked to wear short, tight fitting athletic shorts, a t-shirt, and his/her regular running shoes and short socks for testing.

Set up. Prior to data collection, the computer-aided video motion analysis system (Peak Motus 9.2) was set up in the Exercise Physiology Lab (SB-1025) within the School of Kinesiology at Lakehead University. In order to fulfill the minimum camera requirements for 3D analysis, as well as meet the suggested frame rate for video analysis of running (Payton & Bartlett, 2008), two Basler high-speed cameras (sampling at 100 frames per second) were utilized. The two cameras were placed on tripods and positioned perpendicular and diagonal to the Tackmaster treadmill, which was oriented to have the participant's affected or selected leg closest to the cameras (Figure 10).

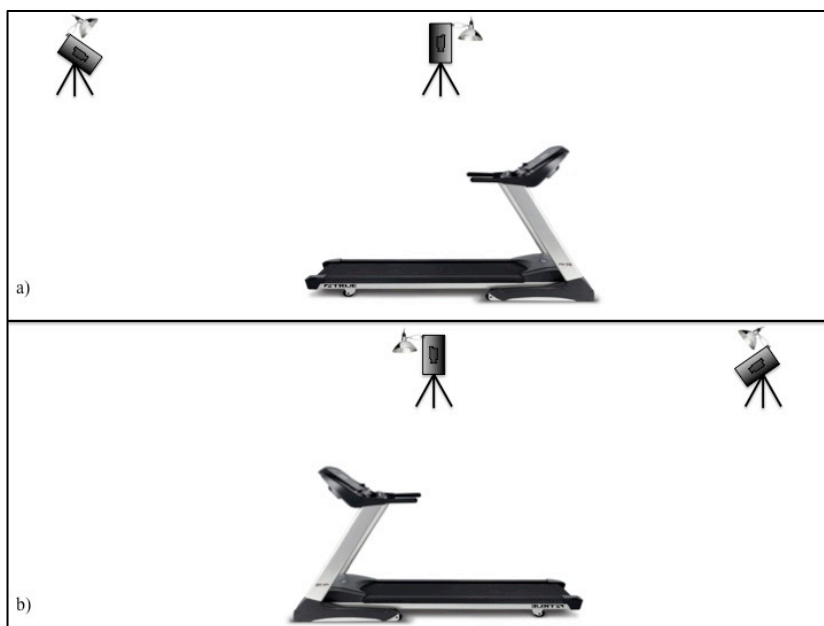


Figure 10. Treadmill and camera set up for the control group and participants with PFPS in their left knee (a) and participants with PFPS in their right knee (b).

The cameras were then manually focused and the shutter speed was set to 1/1000 of a second,

ensuring a clear image of the lower extremity (Payton & Bartlett, 2008). Due to the high shutter speed, floodlights were positioned next to each camera (Payton & Bartlett, 2008). The cameras were then synchronized using Peak Motus to ensure simultaneous capturing of images (Payton & Bartlett, 2008).

Next, a calibration tree was used to calibrate the space where the treadmill was to be located for the testing. The tree consisted of 8 rods with a total of 32 fixed points, each with a known x, y, and z coordinate. This is an important step so that the calculation of positional information can be done with respect to a known frame of reference (Payton & Bartlett, 2008). The Direct Linear Transformation (DLT) method (Appendix D), one of the most widely used techniques in 3D kinematic analyses, was then used to determine the linear relationship between the 2D image coordinates and the 3D real world coordinates (Payton & Bartlett, 2008; Pourcelot, Audigié, Degueurce, Geiger, & Denoix, 2000). Once the space was calibrated, the calibration tree was removed and the treadmill was positioned appropriately for data collection.

Testing. Testing took approximately 45 minutes to complete. Upon arrival, the purpose and methodology of the study were explained to the participant, written consent was obtained, and a Physical Activity Readiness Questionnaire for Everyone (Par-Q+; Appendix E) was completed to ensure eligibility. The participant's age, height (cm) and weight (kg) were then recorded. Next, the participant assisted with the randomization process used to determine the order of the three taping interventions (McConnell's Medial Glide, Mechanical Correction with Tension in the Base, and no tape). This involved having the participant draw one of three labeled pieces of paper (each starting with a different taping intervention) from an envelope.

In order to maintain consistency, the taping interventions were applied to the left knee of those in the healthy group, and to the affected knee of those with PFPS. In the case of bilateral

PFPS, the left leg was selected for standardization. The materials required for the taping interventions included pre-tape adhesive spray, Hypafix (a hypoallergenic adhesive tape), Leukotape, and Kinesio Tape. Prior to any tape application, pre-tape adhesive was sprayed over the anterior aspect of the knee. McConnell's Medial Glide followed the technique outlined by McConnell (1986) and Herrington et al. (2005; Figure 11). A thin layer of Hypafix was initially laid over the patella. Leukotape was then anchored to the lateral border of the patella beginning at the lateral femoral condyle. The patella was then glided medially, while applying the Leukotape over top of the patella. Finally, the tape was tensioned over the medial border of the patella, and anchored to the posterior aspect of the medial femoral condyle. Upon completion of the technique a noticeable skin crease was present. As suggested by Aminaka and Gribble (2008), the skin crease was utilized to standardize the amount of medialization to the patella.



Figure 11. McConnell's Medial Glide (b).

Conversely, the Mechanical Correction with Tension in the Base followed the technique outlined by K. Kase et al. (2013; Figure 12). A Y-strip with two-inch base was measured from the lateral femoral condyle to the medial border of the patella prior to being cut. The

participant's knee was then placed in approximately 20-30° of flexion and the tape was anchored without stretch just superior to the lateral border of the patella. With one hand over the anchor, 50-75% stretch was applied to the base, while simultaneously applying a downward and inward pressure until the lateral border of the patella was reached. The base of the Y-strip was then held in place while getting the participant to further flex his/her knee. The tails were then applied along the superior and inferior borders of the patella using 15-25% stretch, with the very end of the tails being applied without any stretch. Finally, the tape was rubbed to initiate adhesion.



Figure 12. Mechanical Correction with Tension in the Base (b).

In order to minimize any bias towards colour preference, the colour was the same for each type and brand of tape. In addition, the consistency of the application method of taping was controlled by having one qualified individual (the primary researcher) complete the taping interventions. This individual was a Kinesio Taping Practitioner (certified through the completion of Kinesio Taping Canada's KT1 and KT2 courses) who had previous experience working with athletic and physical therapists, as well as working as a student trainer at Lakehead University.

Reflective markers and tape for tracking 3D movement followed a modified Helen Hayes marker set (Figure 13; Richards, 2008). The first and second markers were placed on the outside of the running shoe on the base of the fifth metatarsal and middle of the calcaneus. The third, fourth, and fifth markers were positioned on the lateral malleolus, lateral femoral epicondyle, and the greater trochanter, respectively. The sixth and seventh markers were referred to as ‘wands’ (markers adhered to Styrofoam cones on a plastic backing), and were placed over the lateral aspect of the femur and tibia. A tape measure was used to determine the centre of each segment, relative to the proximal and distal markers, prior to their application. Furthermore, zinc oxide tape was used to ensure their adhesion throughout the running protocol.

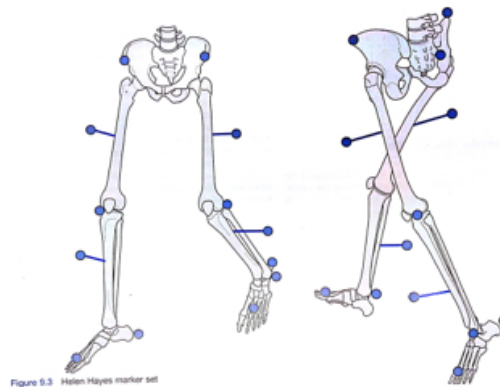


Figure 13. Original Helen Hayes marker set. Adapted from “Biomechanics in clinic and research,” by J. Richards, 2008, Philadelphia, PA: Elsevier Limited, p. 118.

Following marker placement, participants were asked to run on the treadmill at 3.22 m/s (zero percent grade). This specific speed was selected since it was the mean speed within the range specified by previous biomechanical PFPS running studies (Ferber et al., 2011; Heiderscheit, Hamill, & Van Emmerik, 2002; Noehren et al., 2012; Souza & Powers, 2009; Willson & Davis, 2008; Wirtz et al., 2012). As suggested by Schmitz, Pohl, Woods, and Noehren

(2014), participants were asked to engage in a 5 minute warm up on the treadmill at a self-selected pace below 3.22 m/s. The first taping intervention (previously determined through the randomization process) was then applied to the participant's affected/selected leg, prior to running at the selected speed of 3.22 m/s for 37 seconds. The initial 30 seconds of the run was not recorded, as it was used to allow the participants to accommodate to the speed and reach a steady state of running prior to recording the remaining 7 seconds (Ferber et al., 2011). A five-minute recovery period was then provided, during which the next taping intervention was applied. The same procedure (37 seconds at 3.22 m/s with 5 minute recovery period) was followed for the remaining taping interventions. Once all trials were completed, the participants engaged in a five-minute cool down on the treadmill at the same self-selected pace as the warm up. Upon completion, the reflective markers were removed, indicating the end of the testing session.

Data processing. Following data collection, the data was processed using Peak Motus. The recorded video was cropped to include three strides, which included 4 touchdowns and 3 toe offs, with at least 5 frames at the beginning and end of the trial as padding. The points of interest, identified by the reflective markers, were then digitized using automatic digitizing with manual digitizing when needed for all three strides. In addition, the events (initial contact and toe off) were identified for each stride. The data was then processed at 100 Hz and smoothed using a Butterworth digital filter at a cutoff frequency that would reduce the small random errors that may have occurred during digitizing while maintaining the shape of the data curve. The cutoff frequency was determined using the optimal method with prescribed limit (calculated using the Jackson Knee Method; Jackson, 1979), and ranged between 5 and 10 Hz.

Reliability Assessment

The data of two participants, one healthy male (left leg) and one female diagnosed with PFPS in her right leg, was used to establish the intra-rater reliability of the study. Intra-rater reliability, the ability of a single rater to reproduce an outcome under the same conditions (Gwet, 2014), was determined by having the primary researcher digitize the same running sequence twice (Payton & Bartlett, 2008). It was then quantified using the interclass correlation coefficient (ICC; Gwet, 2014). The ICC values for all measurements ranged from 0.84 to 0.99 (Table 2), indicating good to excellent intra-rater reliability

Table 2

Intra-rater Reliability

	Male (Healthy)		Female (PFPS)	
	ICC	RMSE	ICC	RMSE
Hip Flexion	0.99	0.02	0.99	0.03
Hip Adduction	0.84	0.04	0.98	0.02
Hip Rotation	0.99	0.01	0.99	0.01
Knee Flexion	0.99	0.02	0.99	0.01
Knee Adduction	0.98	0.02	0.98	0.02

Data Analysis

A statistical analysis was completed using SPSS for Mac (Version 23). Descriptive statistics (means and standard deviations) were calculated for each phase of the running gait cycle to organize and tabulate the information. The independent variables were taping technique (McConnell's Medial Glide, Mechanical Correction with Tension in the Base, no tape), and group/condition (healthy, PFPS). Mixed factorial analyses of variance (ANOVA's) were performed to examine the interaction effects between the independent variables to address each of the research questions. Levene's Test was used to ensure equal variances between groups. The

statistical significance was set at $p < 0.05$.

Dependent variables. This study measured angular displacement and time under different conditions. For angular displacement this included: hip flexion angle at initial contact, knee flexion angle at initial contact, peak hip adduction angle during stance, change in hip adduction angle during stance, peak knee adduction angle during stance, change in knee adduction angle during stance, change in hip medial rotation angle during stance, peak knee flexion angle during stance, peak hip flexion angle during swing, and peak knee flexion angle during swing.

Hip flexion angle at initial contact. The hip flexion angle at initial contact was defined as the angle between the knee (lateral femoral epicondyle), hip (greater trochanter), and the XZ reference plane at the moment of initial contact. Smaller values were indicative of more hip flexion.

Knee flexion angle at initial contact. The knee flexion angle at initial contact was defined as the joint angle between the hip (greater trochanter), knee (lateral femoral epicondyle), and ankle (lateral malleolus) at the moment of initial contact. Smaller values signified more knee flexion.

Peak hip adduction angle during stance. The peak hip adduction angle during stance was defined as the maximum angle between the hip (greater trochanter), knee (lateral femoral epicondyle), and the YZ reference plane during stance. Larger values indicated more hip adduction.

Change in hip adduction angle during stance. The change in hip adduction angle during stance was defined as the change in hip adduction from the moment of initial contact to the peak (maximum) angle seen during stance. This angle was calculated by subtracting the hip adduction angle seen at initial contact from the peak hip adduction angle seen during stance.

Peak knee adduction angle during stance. The peak knee adduction angle during stance was defined as the maximum angle between the ankle (lateral malleolus), knee (lateral femoral epicondyle), and the YZ reference plane seen during stance. Larger values were indicative of more knee adduction.

Change in knee adduction angle during stance. The change in knee adduction angle during stance was defined as the change in knee adduction from the moment of initial contact to the peak (maximum) angle seen during stance. This angle was calculated by subtracting the knee adduction angle seen at initial contact from the peak knee adduction angle seen during stance.

Change in hip medial rotation angle during stance. In the case of hip medial rotation, a moving plane was created between the hip (greater trochanter), thigh (femoral wand), and the knee (lateral femoral epicondyle). As a result, the hip medial rotation angle was defined as the angle between the moving plane (thigh) and XZ reference plane. The change in hip medial rotation angle was defined as the change in hip medial rotation from the moment of initial contact to the peak (maximum) angle seen during stance. This angle was calculated by subtracting the hip medial rotation angle seen at initial contact from the peak hip medial rotation angle seen during stance.

Peak knee flexion angle during stance. The peak knee flexion angle during stance was defined as the maximum joint angle between the hip (greater trochanter), knee (lateral femoral epicondyle), and ankle (lateral malleolus) seen during stance. Smaller values signified more knee flexion.

Peak hip flexion angle during swing. The peak hip flexion angle during swing was defined as the maximum angle between the knee (lateral femoral epicondyle), hip (greater trochanter), and the XZ reference plane seen during swing. Smaller values were indicative of

more hip flexion.

Peak knee flexion angle during swing. The peak knee flexion angle during swing was defined as the maximum joint angle between the hip (greater trochanter), knee (lateral femoral epicondyle), and ankle (lateral malleolus) seen during swing. Smaller values signified more knee flexion.

The time variables consisted of contact time and flight time and both variables were averaged over the three strides and measured in seconds.

Contact time. Contact time was defined as the amount of time spent in contact with the ground from the moment of initial contact until toe off.

Flight time. Flight time was defined as the amount of time spent in the air from the moment of toe off until initial contact.

Results

The analysis focused on investigating the effects of therapeutic patellar taping techniques (McConnell's Medial Glide and Mechanical Correction with Tension in the Base) on lower extremity kinematics during the different phases of the running gait cycle in runners with and without PFPS.

Hip and Knee Flexion Angles at Initial Contact

Descriptive statistics. The mean hip flexion angles and standard deviations at initial contact during running are presented for each taping technique and group/condition in Table 3. Similarly, the mean knee flexion angles and standard deviations at initial contact during running are depicted for each taping technique and group/condition in Table 4.

Table 3

Mean Hip Flexion Angles (\pm SD) at Initial Contact During Running

	Mechanical Correction Technique ($^{\circ}$)	McConnell's Medial Glide ($^{\circ}$)	No Tape ($^{\circ}$)
Healthy	69.20 (\pm 2.61)	68.30 (\pm 2.30)	69.33 (\pm 2.08)
PFPS	66.97 (\pm 3.87)	66.31 (\pm 4.17)	67.12 (\pm 4.01)
Total	68.36 (\pm 3.27)	67.55 (\pm 3.22)	68.50 (\pm 3.09)

Values are presented as mean (\pm SD).

Table 4

Mean Knee Flexion Angles (\pm SD) at Initial Contact During Running

	Mechanical Correction Technique ($^{\circ}$)	McConnell's Medial Glide ($^{\circ}$)	No Tape ($^{\circ}$)
Healthy	166.11 (\pm 3.20)	164.23 (\pm 2.98)	166.33 (\pm 2.69)
PFPS	167.18 (\pm 3.50)	165.87 (\pm 3.99)	167.21 (\pm 3.28)
Total	166.51 (\pm 3.30)	164.85 (\pm 3.43)	166.66 (\pm 2.90)

Values are presented as mean (\pm SD).

Interaction effects. The mixed factorial ANOVA revealed that there was no significant interaction effect between taping technique and group/condition for hip flexion angles at initial contact, $F(2, 60) = 0.312, p = 0.733, \eta_p^2 = 0.010$. There was no significant difference between groups for mean hip flexion angles at initial contact for McConnell's Medial Glide, Mechanical Correction Technique with Tension in the Base, and no tape (Figure 14).

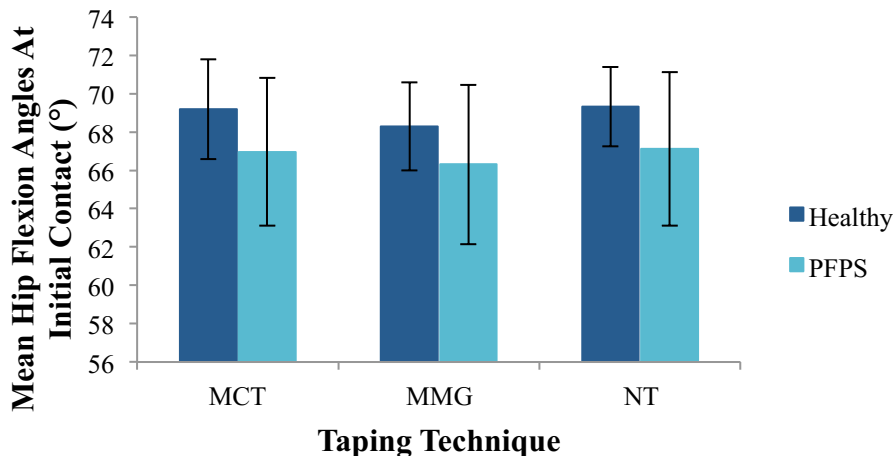


Figure 14. Mean hip flexion angles at initial contact during running ($^{\circ}$) in runners with and without patellofemoral pain syndrome (healthy, PFPS) for each taping technique (Mechanical Correction Technique with Tension in the Base, MCT; McConnell's Medial Glide, MMG; no tape, NT). Error bars denote the standard deviations around the mean.

There was also no significant interaction effect between taping technique and group/condition for knee flexion angles at initial contact, $F(2, 60) = 0.741$, $p = 0.481$, $\eta_p^2 = 0.024$. There was no significant difference between groups for mean knee flexion angles at initial contact for McConnell's Medial Glide, Mechanical Correction Technique with Tension in the Base, and no tape (Figure 15).

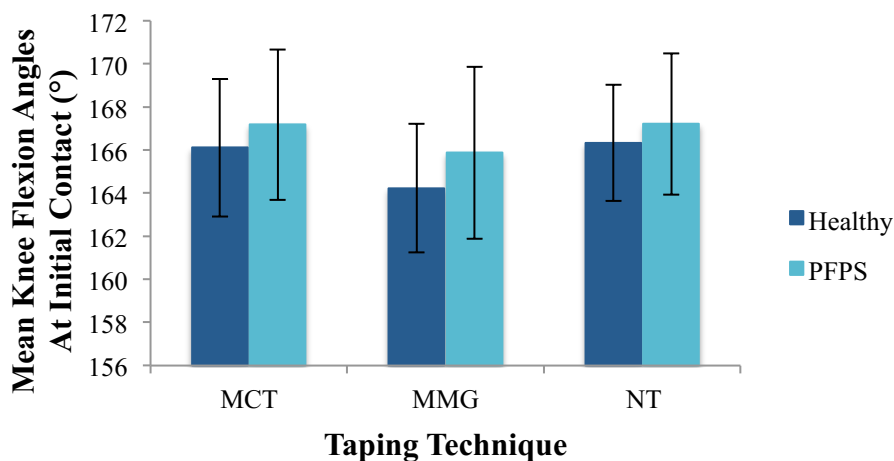


Figure 15. Mean knee flexion angles at initial contact during running ($^{\circ}$) in runners with and without patellofemoral pain syndrome (healthy, PFPS) for each taping technique (Mechanical Correction Technique with Tension in the Base, MCT; McConnell's Medial Glide, MMG; no tape, NT). Error bars denote the standard deviations around the mean.

Main effects. The mixed factorial ANOVA for hip flexion angle at initial contact revealed a significant main effect for taping technique, $F(2, 60) = 16.796, p = 0.000, \eta_p^2 = 0.359$. The post hoc analysis revealed that the mean hip flexion angle at initial contact for McConnell's Medial Glide ($67.55^\circ \pm 3.22$) was significantly smaller than the mean hip flexion angle at initial contact for the Mechanical Correction Technique with Tension in the Base ($68.36^\circ \pm 3.27, p = 0.000$), and no tape condition ($68.50^\circ \pm 3.09, p = 0.000$). There was no significant difference, however, between the mean hip flexion angle at initial contact for the Mechanical Correction Technique with Tension in the Base and no tape condition ($p = 1.000$). No significant main effect was found for group/condition, $F(1, 30) = 3.788, p = 0.061, \eta_p^2 = 0.112$.

For knee flexion angle at initial contact a significant main effect for taping technique was found, $F(2, 60) = 17.274, p = 0.000, \eta_p^2 = 0.365$. The post hoc analysis revealed that the mean knee flexion angle at initial contact for McConnell's Medial Glide ($164.85^\circ \pm 3.43$) was significantly smaller than for the Mechanical Correction Technique with Tension in the Base ($166.51^\circ \pm 3.30, p = 0.000$), and no tape condition ($166.66^\circ \pm 2.90, p = 0.000$). There was no significant difference, however, between the Mechanical Correction Technique with Tension in the Base and no tape condition ($p = 1.000$). No significant main effect was found for group/condition, $F(1, 30) = 1.166, p = 0.289, \eta_p^2 = 0.037$.

Peak Hip and Knee Adduction Angles During the Stance Phase of Running

Descriptive statistics. The mean peak hip adduction angles and standard deviations during the stance phase of running are shown for each taping technique and group/condition in Table 5. Likewise, the mean peak knee adduction angles and standard deviations during the stance phase of running are presented for each taping technique and group/condition in Table 6.

Table 5

Mean Peak Hip Adduction Angles (\pm SD) During the Stance Phase of Running

	Mechanical Correction Technique ($^{\circ}$)	McConnell's Medial Glide ($^{\circ}$)	No Tape ($^{\circ}$)
Healthy	10.60 (\pm 2.61)	10.90 (\pm 2.61)	10.94 (\pm 2.73)
PFPS	12.40 (\pm 5.94)	12.61 (\pm 6.09)	12.52 (\pm 5.74)
Total	11.28 (\pm 4.18)	11.54 (\pm 4.25)	11.53 (\pm 4.10)

Values are presented as mean (\pm SD).

Table 6

Mean Peak Knee Adduction Angles (\pm SD) During the Stance Phase of Running

	Mechanical Correction Technique ($^{\circ}$)	McConnell's Medial Glide ($^{\circ}$)	No Tape ($^{\circ}$)
Healthy	8.34 (\pm 2.13)	7.76 (\pm 2.17)	8.39 (\pm 1.98)
PFPS	8.27 (\pm 3.75)	8.42 (\pm 4.15)	8.80 (\pm 3.76)
Total	8.31 (\pm 3.27)	8.01 (\pm 3.02)	8.55 (\pm 2.73)

Values are presented as mean (\pm SD).

Interaction effects. There was no significant interaction effect between taping techniques and group/condition for peak hip adduction angles during stance phase, $F(2, 60) = 0.198$, $p = 0.821$, $\eta_p^2 = 0.007$. There was no significant difference between group/condition and taping techniques for mean peak hip adduction angles during stance (Figure 16).

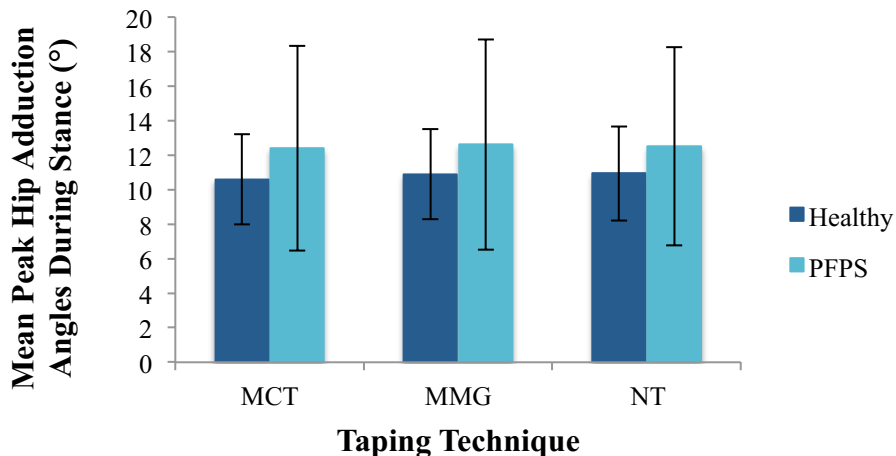


Figure 16. Mean peak hip adduction angles during the stance phase of running (°) in runners with and without patellofemoral pain syndrome (healthy, PFPS) for each taping technique (Mechanical Correction Technique with Tension in the Base, MCT; McConnell's Medial Glide, MMG; no tape, NT). Error bars denote the standard deviations around the mean.

There was also no significant interaction effect between taping techniques and group/condition for the mean peak knee adduction angles during the stance phase of running, $F(2, 60) = 1.343, p = 0.269, \eta_p^2 = 0.043$. There was no significant difference between the mean peak knee adduction angles during stance for group/condition or taping technique (Figure 17).

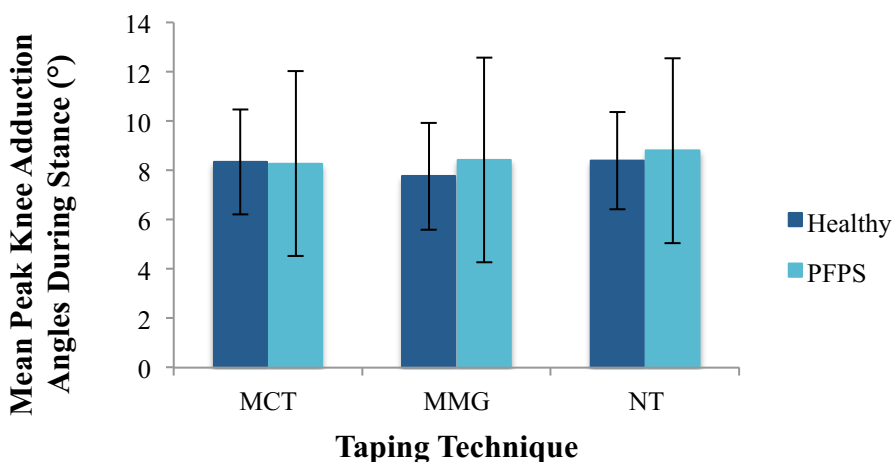


Figure 17. Mean peak knee adduction angles during the stance phase of running (°) in runners with and without patellofemoral pain syndrome (healthy, PFPS) for each taping technique (Mechanical Correction Technique with Tension in the Base, MCT; McConnell's Medial Glide, MMG; no tape, NT). Error bars denote the standard deviations around the mean.

Main effects. The mixed factorial ANOVA for peak hip adduction angle during the stance phase of running did not reveal a significant main effect for taping technique, $F(2, 60) = 1.249$, $p = 0.294$, $\eta_p^2 = 0.040$, or group/condition, $F(1, 30) = 1.276$, $p = 0.268$, $\eta_p^2 = 0.041$. Likewise, for peak knee adduction angle during the stance phase of running, no significant main effect was found for taping technique, $F(2, 60) = 2.509$, $p = 0.090$, $\eta_p^2 = 0.077$, or group/condition, $F(1, 30) = 0.105$, $p = 0.748$, $\eta_p^2 = 0.003$.

Change in Hip Adduction, Knee Adduction, and Hip Medial Rotation Angles During the Stance Phase of Running

Descriptive statistics. The mean change in hip adduction angles and standard deviations during the stance phase of running are presented for each taping technique and group/condition in Table 7. Similarly, the mean change in knee adduction angles and standard deviations during the stance phase of running are seen for each taping technique and group/condition in Table 8. Additionally, the mean change in hip medial rotation angles and standard deviations during the stance phase of running are shown for each taping technique and group/condition in Table 9.

Table 7

Mean Change in Hip Adduction Angles (\pm SD) During the Stance Phase of Running

	Mechanical Correction Technique ($^{\circ}$)	McConnell's Medial Glide ($^{\circ}$)	No Tape ($^{\circ}$)
Healthy	1.77 (\pm 1.57)	1.73 (\pm 1.57)	2.01 (\pm 1.54)
PFPS	1.84 (\pm 0.94)	1.79 (\pm 0.86)	1.95 (\pm 1.58)
Total	1.80 (\pm 1.35)	1.75 (\pm 1.33)	1.99 (\pm 1.53)

Values are presented as mean (\pm SD).

Table 8

Mean Change in Knee Adduction Angles (\pm SD) During the Stance Phase of Running

	Mechanical Correction Technique ($^{\circ}$)	McConnell's Medial Glide ($^{\circ}$)	No Tape ($^{\circ}$)
Healthy	0.96 (\pm 0.71)	1.19 (\pm 0.96)	1.05 (\pm 0.91)
PFPS	0.85 (\pm 0.96)	1.06 (\pm 0.80)	1.01 (\pm 0.65)
Total	0.92 (\pm 0.80)	1.14 (\pm 0.89)	1.04 (\pm 0.81)

Values are presented as mean (\pm SD).

Table 9

Mean Change in Hip Medial Rotation Angles (\pm SD) During the Stance Phase of Running

	Mechanical Correction Technique ($^{\circ}$)	McConnell's Medial Glide ($^{\circ}$)	No Tape ($^{\circ}$)
Healthy	-3.50 (\pm 3.65)	-3.56 (\pm 3.71)	-3.78 (\pm 3.63)
PFPS	-4.33 (\pm 3.41)	-4.21 (\pm 3.81)	-4.14 (\pm 3.57)
Total	-3.81 (\pm 3.53)	-3.80 (\pm 3.70)	-3.92 (\pm 3.55)

Values are presented as mean (\pm SD).

Interaction effects. There was no significant interaction effect between taping technique and group/condition for change in hip adduction angles during stance, $F(2, 60) = 0.117$, $p = 0.890$, $\eta_p^2 = 0.004$. There was no significant difference between group/condition and taping technique for mean change in hip adduction angles during stance (Figure 18).

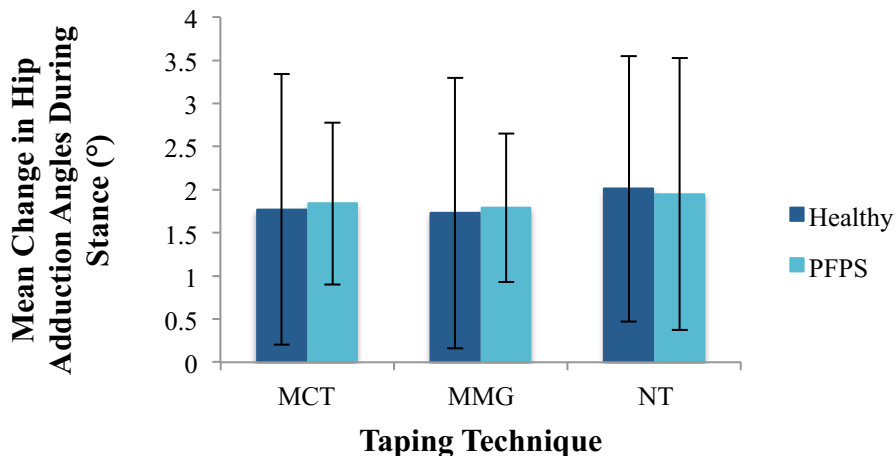


Figure 18. Mean change in hip adduction angles during the stance phase of running ($^{\circ}$) in runners with and without patellofemoral pain syndrome (healthy, PFPS) for each taping technique (Mechanical Correction Technique with Tension in the Base, MCT; McConnell's Medial Glide, MMG; no tape, NT). Error bars denote the standard deviations around the mean.

Furthermore, there was no significant interaction effect between taping technique and group/condition for change in knee adduction angles during stance, $F(2, 60) = 0.107, p = 0.898, \eta_p^2 = 0.004$. There was no significant difference between group/condition and taping technique for mean change in knee adduction angles during stance (Figure 19).

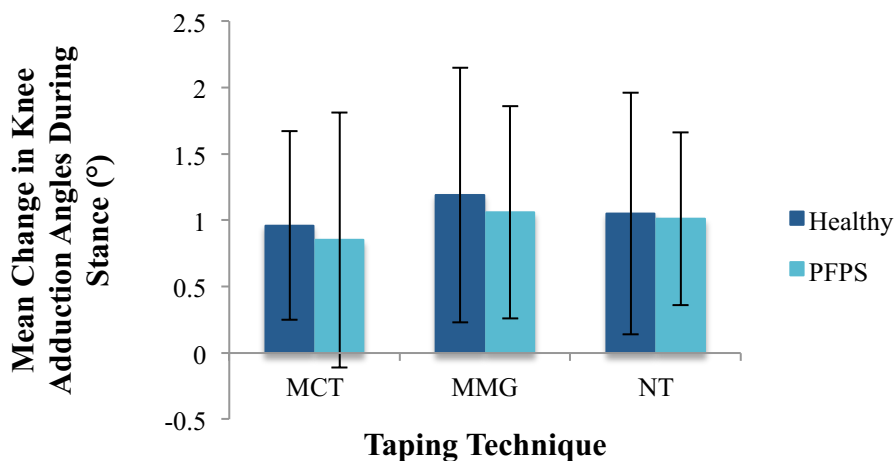


Figure 19. Mean change in knee adduction angles during the stance phase of running ($^{\circ}$) in runners with and without patellofemoral pain syndrome (healthy, PFPS) for each taping technique (Mechanical Correction Technique with Tension in the Base, MCT; McConnell's Medial Glide, MMG; no tape, NT). Error bars denote the standard deviations around the mean.

There was no significant interaction effect between taping technique and group/condition for change in hip medial rotation angles during stance, $F(2, 60) = 0.666, p = 0.517, \eta_p^2 = 0.022$. There was no significant difference between hip medial rotation angles during stance for group/condition or taping technique (Figure 20).

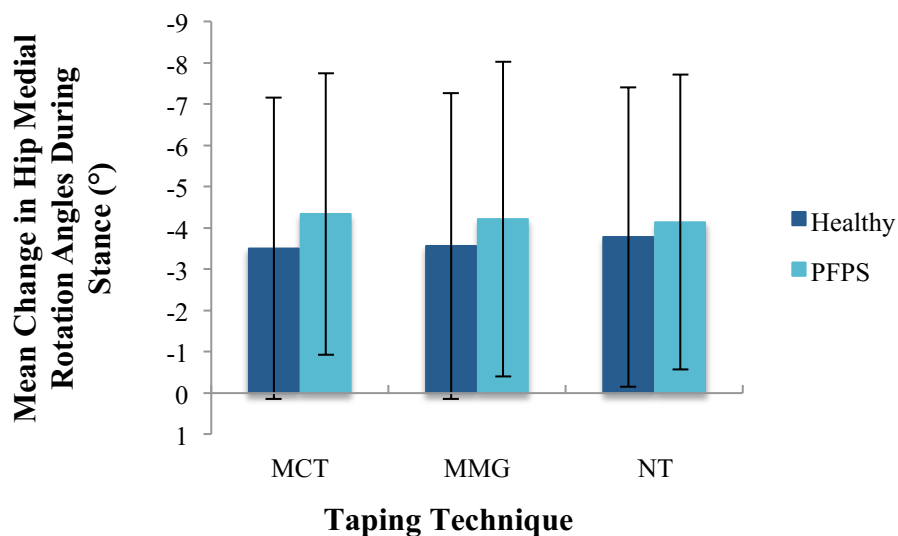


Figure 20. Mean change in hip medial rotation angles during the stance phase of running (°) in runners with and without patellofemoral pain syndrome (healthy, PFPS) for each taping technique (Mechanical Correction Technique with Tension in the Base, MCT; McConnell's Medial Glide, MMG; no tape, NT). Error bars denote the standard deviations around the mean.

Main effects. The mixed factorial ANOVA for change in hip adduction angle during stance did not reveal a significant main effect for taping technique, $F(2, 60) = 1.223, p = 0.302, \eta_p^2 = 0.039$, or group/condition, $F(1, 30) = 0.003, p = 0.960, \eta_p^2 = 0.000$. For change in knee adduction angle during stance, no significant main effect was found for taping technique, $F(2, 60) = 2.211, p = 0.118, \eta_p^2 = 0.069$, or group/condition, $F(1, 30) = 0.110, p = 0.743, \eta_p^2 = 0.004$. Similarly, for change in hip medial rotation angle during stance, no significant main effect was found for taping technique, $F(2, 60) = 0.074, p = 0.928, \eta_p^2 = 0.002$, or group/condition, $F(1, 30) = 0.221, p = 0.642, \eta_p^2 = 0.007$.

Peak Knee Flexion Angle During the Stance Phase of Running

Descriptive statistics. The mean peak knee flexion angles and standard deviations during the stance phase of running are presented for each taping technique and group/condition in Table 10.

Table 10.

Mean Peak Knee Flexion Angles (\pm SD) During the Stance Phase of Running

	Mechanical Correction Technique ($^{\circ}$)	McConnell's Medial Glide ($^{\circ}$)	No Tape ($^{\circ}$)
Healthy	138.95 (\pm 5.21)	138.21 (\pm 5.32)	138.67 (\pm 5.05)
PFPS	137.49 (\pm 5.31)	137.18 (\pm 5.71)	138.03 (\pm 4.88)
Total	138.41 (\pm 5.21)	137.82 (\pm 5.40)	138.43 (\pm 4.92)

Values are presented as mean (\pm SD).

Interaction effect. There was no significant interaction effect between taping technique and group/condition for peak knee flexion angles during stance, $F(2, 60) = 1.226, p = 0.301, \eta_p^2 = 0.039$. There was no significant difference between groups for mean peak knee flexion angles during stance for McConnell's Medial Glide, Mechanical Correction Technique with Tension in the Base, and no tape (Figure 21).

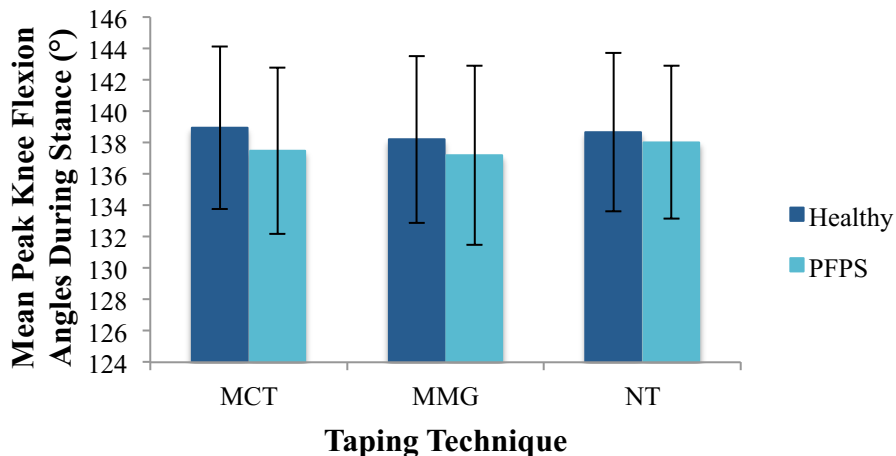


Figure 21. Mean peak knee flexion angles during the stance phase of running (°) in runners with and without patellofemoral pain syndrome (healthy, PFPS) for each taping technique (Mechanical Correction Technique with Tension in the Base, MCT; McConnell's Medial Glide, MMG; no tape, NT). Error bars denote the standard deviations around the mean.

Main effects. The mixed factorial ANOVA for peak knee flexion angle during stance revealed a significant main effect for taping technique, $F(2, 60) = 3.509$, $p = 0.036$, $\eta_p^2 = 0.105$. The post hoc analysis revealed that the mean peak knee flexion angle during stance for McConnell's Medial Glide ($137.82^\circ \pm 5.40$) was significantly smaller than for no tape ($138.43^\circ \pm 4.92$, $p = 0.040$). There was, however, no significant difference between the mean peak knee flexion angle during stance for the Mechanical Correction Technique with Tension in the Base and McConnell's Medial Glide ($p = 0.225$), as well as the Mechanical Correction Technique with Tension in the Base and no tape condition ($p = 1.000$). Furthermore, no significant main effect was found for group/condition, $F(1, 30) = 0.303$, $p = 0.586$, $\eta_p^2 = 0.010$.

Peak Hip and Knee Flexion Angles During the Swing Phase of Running

Descriptive statistics. The mean peak hip flexion angles and standard deviations during the swing phase of running are depicted for each taping technique and group/condition in Table 11. Likewise, the mean peak knee flexion angles and standard deviations during the swing phase

of running are presented for each taping technique and group/condition in Table 12.

Table 11

Mean Peak Hip Flexion Angles (\pm SD) During the Swing Phase of Running

	Mechanical Correction Technique ($^{\circ}$)	McConnell's Medial Glide ($^{\circ}$)	No Tape ($^{\circ}$)
Healthy	59.43 (\pm 4.53)	58.45 (\pm 4.31)	58.89 (\pm 4.34)
PFPS	59.70 (\pm 4.36)	58.33 (\pm 4.45)	59.51 (\pm 4.29)
Total	59.53 (\pm 4.40)	58.40 (\pm 4.29)	59.13 (\pm 4.26)

Values are presented as mean (\pm SD).

Table 12

Mean Peak Knee Flexion Angles (\pm SD) During the Swing Phase of Running

	Mechanical Correction Technique ($^{\circ}$)	McConnell's Medial Glide ($^{\circ}$)	No Tape ($^{\circ}$)
Healthy	85.41 (\pm 13.10)	84.54 (\pm 12.12)	84.44 (\pm 13.49)
PFPS	91.27 (\pm 9.11)	88.36 (\pm 12.27)	88.24 (\pm 12.69)
Total	87.61 (\pm 11.95)	85.97 (\pm 12.13)	85.87 (\pm 13.12)

Values are presented as mean (\pm SD).

Interaction effects. There was no significant interaction effect between taping technique and group/condition for peak hip flexion angles during swing, $F(2, 60) = 0.621$, $p = 0.541$, $\eta_p^2 = 0.020$. There was no significant difference between groups for mean peak hip flexion angles during swing for McConnell's Medial Glide, Mechanical Correction Technique with Tension in the Base, and no tape (Figure 22).

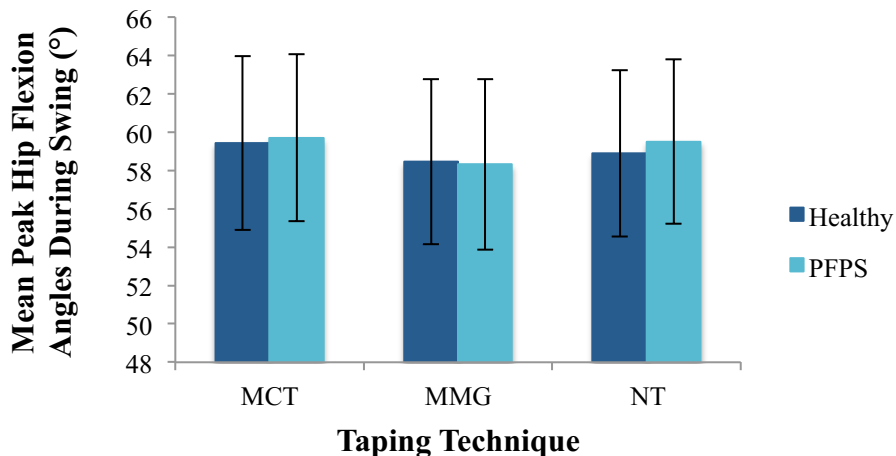


Figure 22. Mean peak hip flexion angles during the swing phase of running (°) in runners with and without patellofemoral pain syndrome (healthy, PFPS) for each taping technique (Mechanical Correction Technique with Tension in the Base, MCT; McConnell's Medial Glide, MMG; no tape, NT). Error bars denote the standard deviations around the mean.

There was also no significant interaction effect between taping technique and group/condition for peak knee flexion angles during swing. $F(2, 60) = 1.374, p = 0.261, \eta_p^2 = 0.044$. There was no significant difference between groups for mean peak knee flexion angles during swing for McConnell's Medial Glide, Mechanical Correction Technique with Tension in the Base, and no tape (Figure 23).

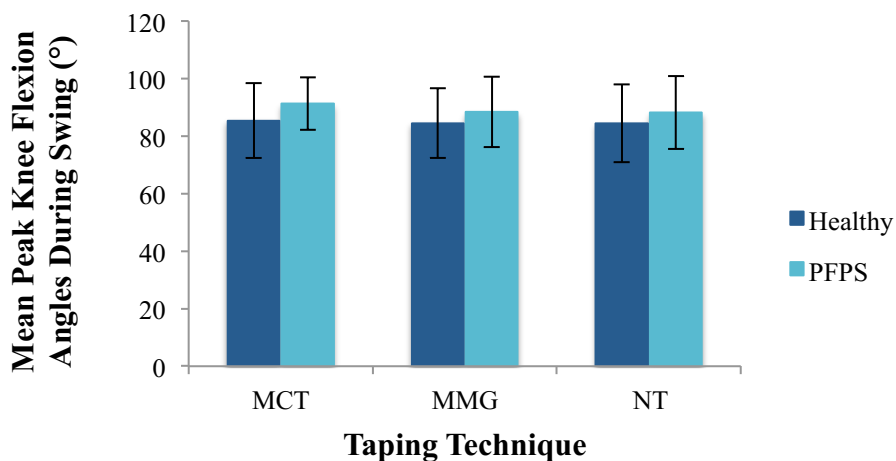


Figure 23. Mean peak knee flexion angles during the swing phase of running (°) in runners with and without patellofemoral pain syndrome (healthy, PFPS) for each taping technique (Mechanical Correction Technique with Tension in the Base, MCT; McConnell's Medial Glide, MMG; no tape, NT). Error bars denote the standard deviations around the mean.

Main effects. The mixed factorial ANOVA for peak hip flexion angle during swing revealed a significant main effect for taping technique, $F(2, 60) = 6.556, p = 0.003, \eta_p^2 = 0.179$. The post hoc analysis revealed that the mean peak hip flexion angle during swing for McConnell's Medial Glide ($58.40^\circ \pm 4.29$) was significantly smaller than for the Mechanical Correction Technique with Tension in the Base ($59.53^\circ \pm 4.40, p = 0.011$), and no tape condition ($59.13^\circ \pm 4.26, p = 0.031$). There was no significant difference, however, between the Mechanical Correction Technique with Tension in the Base and no tape condition ($p = 0.817$). No significant main effect was found for group/condition, $F(1, 30) = 0.027, p = 0.871, \eta_p^2 = 0.001$.

For peak knee flexion angle during swing a significant main effect for taping technique was found, $F(2, 60) = 4.964, p = 0.010, \eta_p^2 = 0.142$. The post hoc analysis revealed that the mean peak knee flexion angle during swing for the Mechanical Correction Technique with Tension in the Base ($87.61^\circ \pm 11.95$) was significantly larger than for McConnell's Medial Glide ($85.97^\circ \pm 12.13, p = 0.042$), and no tape ($85.87^\circ \pm 13.12, p = 0.041$). Conversely, there was no significant difference between McConnell's Medial Glide and no tape ($p = 1.000$). No significant main effect was found for group/condition, $F(1, 30) = 1.017, p = 0.321, \eta_p^2 = 0.033$.

Contact Time and Flight Time During the Running Gait Cycle

Descriptive statistics. The mean contact times and standard deviations during the running gait cycle are shown for each taping technique and group/condition in Table 13. Additionally, the mean flight times and standard deviations during the running gait cycle are presented for each taping technique and group/condition in Table 14.

Table 13

Mean Contact Times (\pm SD) During the Running Gait Cycle

	Mechanical Correction Technique (Seconds)	McConnell's Medial Glide (Seconds)	No Tape (Seconds)
Healthy	0.273 (\pm 0.03)	0.271 (\pm 0.03)	0.272 (\pm 0.03)
PFPS	0.282 (\pm 0.01)	0.280 (\pm 0.01)	0.278 (\pm 0.01)
Total	0.276 (\pm 0.02)	0.275 (\pm 0.02)	0.275 (\pm 0.03)

Values are presented as mean (\pm SD).

Table 14

Mean Flight Times (\pm SD) During the Running Gait Cycle

	Mechanical Correction Technique (Seconds)	McConnell's Medial Glide (Seconds)	No Tape (Seconds)
Healthy	0.450 (\pm 0.04)	0.447 (\pm 0.04)	0.451 (\pm 0.05)
PFPS	0.424 (\pm 0.03)	0.422 (\pm 0.04)	0.431 (\pm 0.04)
Total	0.440 (\pm 0.04)	0.438 (\pm 0.04)	0.443 (\pm 0.04)

Values are presented as mean (\pm SD).

Interaction effects. There was no significant interaction effect between taping technique and group/condition for contact time, $F(2, 60) = 1.245$, $p = 0.295$, $\eta_p^2 = 0.040$. There was no significant difference between mean contact times for group/condition or taping technique (Figure 24).

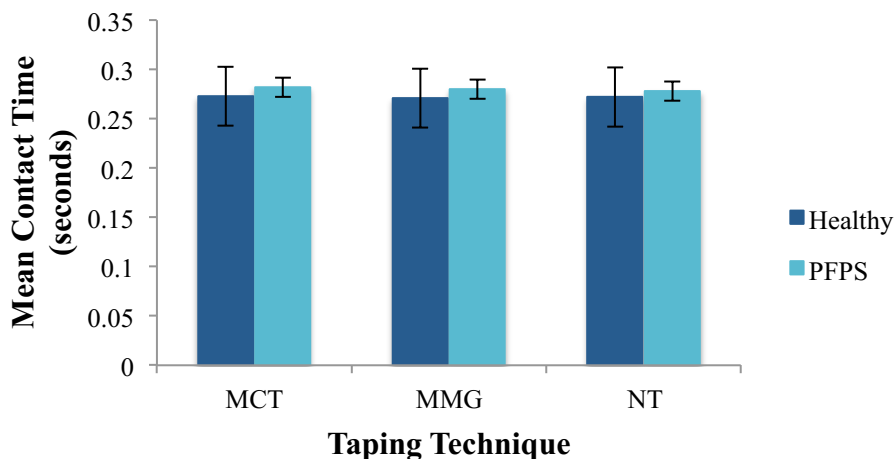


Figure 24. Mean contact times (seconds) in runners with and without patellofemoral pain syndrome (healthy, PFPS) for each taping technique (Mechanical Correction Technique with Tension in the Base, MCT; McConnell's Medial Glide, MMG; no tape, NT). Error bars denote the standard deviations around the mean.

Similarly, there was no significant interaction effect between taping technique and group/condition for flight time, $F(2, 60) = 1.647, p = 0.201, \eta_p^2 = 0.052$. There was no significant difference between groups for mean flight times for McConnell's Medial Glide, Mechanical Correction Technique with Tension in the Base, and no tape (Figure 25).

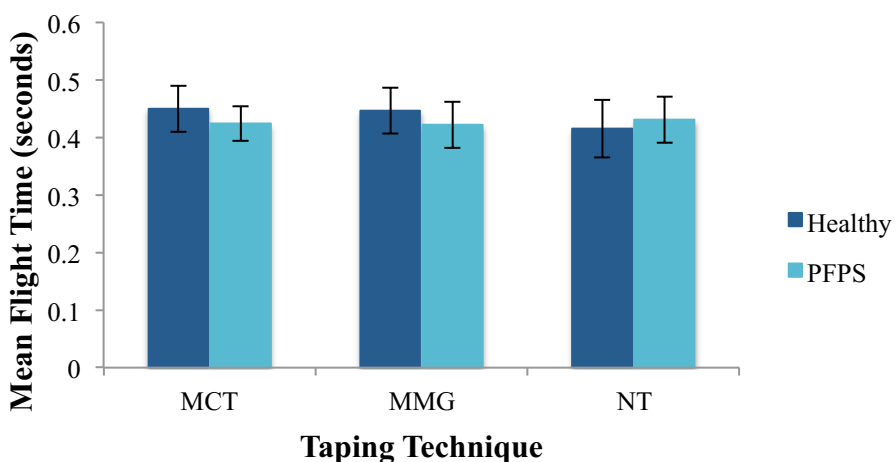


Figure 25. Mean flight times (seconds) in runners with and without patellofemoral pain syndrome (healthy, PFPS) for each taping technique (Mechanical Correction Technique with Tension in the Base, MCT; McConnell's Medial Glide, MMG; no tape, NT). Error bars denote the standard deviations around the mean.

Main effects. The mixed factorial ANOVA for contact time showed no significant main effect for taping technique, $F(2, 60) = 1.623, p = 0.206, \eta_p^2 = 0.051$, or group/condition, $F(1, 30) = 0.850, p = 0.364, \eta_p^2 = 0.028$. However, the mixed factorial ANOVA for flight time revealed a significant main effect for taping technique, $F(2, 60) = 5.016, p = 0.010, \eta_p^2 = 0.143$. The post hoc analysis revealed that the mean flight time for McConnell's Medial Glide ($0.438s \pm 0.04$) was significantly smaller than the mean flight time for no tape ($0.443s \pm 0.04, p = 0.012$). There was no significant difference between the Mechanical Correction Technique with Tension in the Base and McConnell's Medial Glide ($p = 1.000$), as well as the Mechanical Correction Technique with Tension in the Base and no tape condition ($p = 0.099$). Furthermore, no significant main effect was found for group/condition, $F(1, 30) = 2.449, p = 0.128, \eta_p^2 = 0.075$.

Discussion

This study revealed that therapeutic taping had a statistically significant effect on knee and hip flexion angles at initial contact. More specifically, McConnell's Medial Glide (Leukotape) allowed for more knee and hip flexion at initial contact ($164.85^\circ; 67.55^\circ$; as smaller angles were indicative of more flexion), than the Mechanical Correction Technique with Tension in the Base (Kinesio Tape; $166.51^\circ; 68.36^\circ$) and no tape condition ($166.66^\circ; 68.50^\circ$). When comparing these angles to the previous kinematic research, the knee angles seen in this study fell within the range previously reported by Ferber and Macdonald (2014), Hamill and Knutzen (2003), and Novacheck (1998). Conversely, when comparing the hip flexion angles to the previous kinematic research (Ferber & Macdonald, 2014; Hamill & Knutzen, 2003; Novacheck, 1998), all values in this study were slightly larger. This may be explained by different marker placements as well as different angle definitions since none were provided.

Although Leukotape is more rigid, a reduction in knee flexion at initial contact was not observed in this study. In fact, McConnell's Medial Glide was found to increase the amount of knee flexion seen at initial contact. This finding is in accordance with Powers et al. (1997) and Salsich et al. (2002) who found McConnell taping to increase the loading response knee flexion as well as the amount of knee flexion seen during walking and stair ambulation. Perhaps this can be explained by the nature of the McConnell technique itself. As previously outlined by Herrington et al. (2005), McConnell's Medial Glide has been proposed to decrease the joint load and stresses by means of repositioning "the patella within the femoral trochlear groove" and changing "the patella contact pressure and joint reaction force" (p. 605). Additionally, Powers et al. (1997) have suggested that McConnell's Medial Glide might allow the PFJ to be more readily loaded, thereby increasing the amount of force absorbed. The goal of the lower extremity at initial contact is to absorb the impact of the landing and distribute the forces throughout the lower extremity (Nicola & Jewison, 2012). Both Ferber and Macdonald (2014), and Houglum and Bertoti (2012) determined that this is achieved via a flexed hip and knee. Therefore, the increase in knee flexion seen at initial contact for McConnell's Medial Glide in this study may have been attributed to the medial positioning of the patella. This may have caused the patella to be more readily loaded through the activation of the quadriceps and gluteal muscles, allowing for greater knee flexion, and consequently, greater force absorption. Clinically, this may be beneficial to those with PFPS as this proposed mechanism could result in less pain during this portion of the running stride, however, future research is needed to confirm this. Furthermore, the increase in hip flexion seen at initial contact for McConnell's Medial Glide may be a direct result of the increased knee flexion thus facilitating absorption of impact on landing.

There was no statistically significant difference between the Mechanical Correction Technique with Tension in the Base relative to the no tape condition for hip and knee flexion angles at initial contact ($p = 1.000$). This may be attributed to the nature of the tape/technique itself. As previously outlined by K. Kase et al. (2013), Kinesio Tape was designed to mimic human skin and allow partial to full range of motion, resulting in a technique that does not fixate the tissues. Consequently, the elasticity of the tape may have allowed for similar hip and knee flexion angles to be seen at initial contact between the Mechanical Correction Technique and no tape condition.

This study also revealed that therapeutic taping had a statistically significant effect on peak knee flexion angles during stance. McConnell's Medial Glide allowed for more knee flexion during stance (137.82°) than the no tape condition (138.43°). Once again, this finding of increased knee flexion for McConnell taping is in agreement with Powers et al. (1997) and Salsich et al. (2002). This may be explained by the rigidity of the tape, allowing the patella to be repositioned within the femoral trochlear groove (Herrington et al., 2005), to allow for further knee flexion to occur during midstance (regardless of the group/condition of the individuals). However, more knee flexion is considered to be an aggravating factor for those with PFPS, since it results in a greater amount of compression on the PFJ (Aminaka & Gribble, 2005; Campolo et al., 2013; Lan et al., 2010; Mostamand et al., 2010; Osorio et al., 2013). As a result, the increase in knee flexion seen for McConnell's Medial Glide during stance may result in more pain for those with PFPS.

The peak knee flexion angle seen during stance did not differ, however, between the Mechanical Correction Technique with Tension in the Base (138.41°), and no tape condition (138.43° ; $p = 1.000$). As previously mentioned, this may be attributed to the elasticity of the

Kinesio Tape allowing partial to full range of motion to be achieved (K. Kase et al., 2013). It was interesting to note that there was no statistically significant difference between McConnell's Medial Glide (137.82°) and the Mechanical Correction Technique with Tension in the Base (138.41° ; $p = 0.225$). Perhaps this non-significance was attributed to the amount of tension applied to the Mechanical Correction Technique, with the possibility of greater or lesser tension yielding a significant effect. Further research is warranted in order to provide some insight as to why this may have been observed. Nevertheless, all peak knee flexion angles seen during the stance phase of this study fell within the typical kinematic range previously outlined in the literature (Ferber & Macdonald, 2014; Novacheck, 1998). Although therapeutic taping was found to have a significant effect on the amount of peak knee flexion during the stance phase of running, taping did not seem to alter the amount of knee flexion enough to be outside the typical kinematic range.

Therapeutic taping was also found to have a statistically significant effect on peak knee and hip flexion angles during the swing phase. In fact, McConnell's Medial Glide (85.97°) and the no tape condition (85.87°) allowed for more knee flexion during swing than the Mechanical Correction Technique with Tension in the Base (87.61°). The greater knee flexion associated with McConnell's Medial Glide is once again in agreement with Powers et al. (1997), and Salsich et al. (2002). However, an increase in knee flexion results in greater PFJ compression (Aminaka & Gribble, 2005; Campolo et al., 2013; Lan et al., 2010; Mostamand et al., 2010; Osorio et al., 2013). As a result, the increased knee flexion during swing associated with McConnell's Medial Glide may clinically lead to individuals with PFPS experiencing more pain. Nevertheless, all of the peak knee flexion angles observed during the swing phase of this study were well within the expected typical range reported by the literature (Novacheck, 1998).

Therefore, although therapeutic taping resulted in a significant effect, the peak knee flexion angles were not changed enough to exceed the outlined typical range.

According to Houglum and Bertoti (2012), momentum produced at toe off causes the lower limb to accelerate forward, resulting in large amounts of hip and knee flexion throughout mid-swing. This study found McConnell's Medial Glide to be comparable to the no tape condition for peak knee flexion angles during the swing phase. Perhaps this large amount of knee flexion required during swing causes the technique to be no longer effective in repositioning the patella, ultimately, emulating the no tape condition. However, McConnell's Medial Glide and the no tape condition still allowed for a larger amount of knee flexion than the Mechanical Correction Technique with Tension in the Base. The concept of a large amount of knee flexion required during swing as well as the nature of Kinesio Tape may provide an explanation for this. While Kinesio Tape is known for its elastic properties (K. Kase et al., 2013), the large amount of knee flexion seen during swing may have caused the tape to stretch, eliminating the elasticity and making it quite rigid. As a result, the now rigid Mechanical Correction Technique may have limited the amount of knee range of motion seen during swing.

Surprisingly, therapeutic taping affected the hip slightly differently than the knee during swing. McConnell's Medial Glide allowed more hip flexion (58.40°) than the Mechanical Correction with Tension in the Base (59.53°), however, McConnell's Medial Glide also allowed for more knee flexion than the no tape condition (59.13°). The reason for this remains unclear. As a result, further research is required to determine the exact mechanism responsible for this difference. When comparing the peak hip flexion angles seen during the swing phase of this study to those previously reported by Novacheck (1998), the angles in this study were marginally

larger. This may be due to a small sample size, differences in peak hip flexion angle definitions, or slight changes in marker placements.

Another interesting occurrence was that group/condition did not have a statistically significant effect on hip and knee flexion angles throughout the running gait cycle in this study. While the previous literature has suggested that aggravating activities for those with PFPS include movements with knee flexion (Aminaka & Gribble, 2005; Campolo et al., 2013; Lan et al., 2010; Mostamand et al., 2010; Osorio et al., 2013), no differences in hip or knee flexion angles were noted between healthy individuals and those with PFPS.

Furthermore, therapeutic taping in the present study did not have a statistically significant effect on peak hip and knee adduction angles during stance, as well as change in hip adduction, knee adduction, or hip medial rotation angles during stance. Therefore, no differences were found between McConnell's Medial Glide, the Mechanical Correction Technique with Tension in the Base, and no tape condition. Since both therapeutic taping techniques are solely applied from the lateral to medial aspect of the patella, the hip and knee joints ability to perform adduction and medial rotation movements should not be impacted; thereby, explaining the findings presented in the study.

This study also revealed no statistically significant difference between group/condition for peak hip and knee adduction angles during stance, as well as change in hip adduction, knee adduction, or hip medial rotation angles during stance. The peak hip adduction angles found in this study, however, fell within the expected typical range reported by Ferber and Macdonald (2014), and were comparable to the values seen in a previous study investigating the lower extremity kinematics associated with PFPS (Dierks et al., 2008).

While several studies have investigated the peak hip adduction angles associated with PFPS during the stance phase of running, inconsistent findings have been reported. The findings of this study are in agreement with those found by Souza and Powers (2009), as no differences in peak hip adduction angles during stance were noted between groups. This finding is contradictory to those reported by Willson and Davis (2008) and Noehren et al. (2012) who found that females with PFPS had more peak hip adduction, as well as Dierks et al. (2008) who reported that individuals with PFPS had less peak hip adduction during stance. These differences may be attributed to different marker placements, the participants' gender, and/or differences in defining the peak hip adduction angles.

Furthermore, the peak knee adduction angles seen in this study were slightly larger than the typical range seen during running (Ferber & Macdonald, 2014). This slight difference may have been attributed to the pathological population being included in this study. There was only one study that investigated the effects of PFPS on peak knee adduction angles during the stance phase of running (Dierks et al., 2008). This study by Dierks et al. (2008), similarly revealed no differences between groups, although, the peak knee adduction angles seen in the current study were slightly larger. This may be explained by different marker placements as well as small sample size. No kinematic ranges for change in hip adduction, knee adduction, and hip medial rotation angles during stance have been reported.

When looking at the effects of therapeutic taping on stride characteristics, mixed results were seen. Therapeutic taping did not significantly affect the amount of time runners spent in contact with the ground; however, it did affect the amount of time runners spent in the air. This was evident between McConnell's Medial Glide and the no tape condition, where shorter flight times were associated with McConnell's Medial Glide. These findings may be explained by what

occurred throughout the stance and swing phases. While differences were seen for hip and knee flexion angles throughout the stance phase of running, they were seemingly not large enough to elicit a change in the amount of time the runners spent in contact with the ground.

On the other hand, shorter flight times associated with McConnell's Medial Glide may have been attributed to the increased hip and knee flexion angles seen during swing for McConnell's Medial Glide. More specifically, the larger amount of knee flexion seen may have allowed the shank to be closer to the body. This would theoretically result in a minute decrease in the amount of time required to swing the leg forward throughout the latter part of the swing phase. Additionally, the combination of increased hip and knee flexion seen during swing for McConnell's Medial Glide could have allowed the body to be more quickly propelled forward through the air. This decrease in flight time seen may also be beneficial during running, in terms of being a more efficient runner. Group/condition did not, however, have a significant effect on the stride characteristics investigated in this study.

There was no significant interaction effects found in this study. Therefore, the effect of therapeutic taping was not conditional upon the group/condition of the participants. As this study is the first to investigate the effects of therapeutic taping on lower extremity kinematics in those with and without PFPS during running, further research is required to clarify the proposed mechanisms, confirm or deny the findings of this study, as well as conclusively identify the effects of therapeutic taping during running.

Conclusion

The purpose of this study was to investigate the effectiveness of therapeutic patellar taping techniques on lower extremity kinematics throughout the running gait cycle in runners with and without PFPS. While therapeutic patellar taping techniques were found to influence

lower extremity kinematics and stride characteristics differently throughout the running gait cycle, McConnell's Medial Glide was always associated with more hip and knee flexion. Significant taping effects were found for hip and knee flexion angles at initial contact, and peak hip flexion angles during swing, with McConnell's Medial Glide producing more flexion than the Mechanical Correction Technique with Tension in the Base, and no tape condition. Similarly, peak knee flexion angles during stance and flight time revealed significant taping effects, with McConnell's Medial Glide resulting in more flexion and shorter flight times than the no tape condition. A significant taping effect was also seen for peak knee flexion angles during swing; however, McConnell's Medial Glide and no tape condition resulted in more knee flexion than the Mechanical Correction Technique with Tension in the Base. While this study has provided preliminary evidence regarding the effectiveness of therapeutic patellar taping techniques on lower extremity kinematics during running, additional research is needed to determine the exact effects of therapeutic patellar taping techniques on lower extremity kinematics in runners with and without PFPS.

Practical Application

Based on the conclusions of this study, it is suggested that tape is better than no tape during running. Furthermore McConnell's Medial Glide seems to be the best option, since it allowed for more flexion at initial contact, which may allow for greater activation of the quadriceps and gluteal muscles, as well as greater force absorption, which is likely to decrease the amount of stress placed on the PFJ. McConnell's Medial Glide also allowed for shorter flight times, which may increase overall running efficiency.

Limitations

While the current study appeared to have significant findings, several limitations need to be addressed. The sample size was relatively small ($n = 32$), with only a few pathological males ($n = 4$). This unequal depiction, however, is representative of the PFPS population, which seems to be more prevalent in female runners (Wirtz et al., 2012). Consequently, caution should be taken when generalizing the findings of this study. A larger sample size, equal gender representation, as well as the examination of gender to determine its effect on therapeutic patellar taping and lower extremity kinematics is recommended.

Another limitation was the marker placements. While markers were positioned over the skin where possible, foot and hip markers were positioned over the shoes and shorts. The positioning of the foot and hip markers, therefore, may have slightly altered the angles throughout the running gait cycle. While it is not possible to remove the skin movement artifact (unless using bone markers), it is recommended to place markers directly over the skin when possible to limit any additional movement artifact.

A further limitation of this study was that running shoes were not standardized across participants, due to the high cost required. Different running shoes have different cushioning properties, which could have influenced the amount of hip and knee flexion seen throughout the running gait cycle. As a result, the use of a standardized running shoe is recommended.

Delimitations

A delimitation of this study was that all participants received the standardized McConnell's Medial Glide technique. As previously mentioned, not all individuals with PFPS present with a lateralization of the patella, and therefore, do not all require McConnell's Medial Glide technique. However, the medial glide is the most commonly used and required component

of McConnell Taping among individuals with PFPS, and was used in order to standardize the technique to determine its effect on lower extremity kinematics during running. While it would have been ideal to include only individuals requiring a medial glide, this was not feasible due to the limited population with PFPS at the time of testing. As a result, caution must be taken when interpreting and generalizing the results.

Another delimitation of this study was the running speed of 3.22 m/s. While this speed was standardized among participants and selected since it was the mean speed within the range previously identified by biomechanical PFPS running studies (Ferber et al., 2011; Heiderscheit, Hamill, & Van Emmerik, 2002; Noehren et al., 2012; Souza & Powers, 2009; Willson & Davis, 2008; Wirtz et al., 2012), therapeutic patellar taping techniques may affect lower extremity kinematics differently at other running speeds. As a result, caution must be taken when interpreting and generalizing the findings of this study.

Assumptions

A few assumptions were made throughout this study. This included markers being consistently placed in the same location on each anatomical landmark of interest, as well as consistent application of the therapeutic patellar taping techniques between participants. It was also assumed that all participants were honest in stating that they were healthy or had knee pain associated with PFPS, and that the participants with PFPS were correctly diagnosed. Furthermore, it was assumed that the scale used to weigh the participants was accurate. As a result of all these assumptions made throughout this study, caution must once again be taken when interpreting the results.

Future Research

It is evident that there is a clear need for further research investigating the effects of therapeutic patellar taping techniques on lower extremity kinematics in runners with PFPS. While this study focused on the effects of therapeutic patellar taping techniques on lower extremity kinematics during a short run at 3.22 m/s, future studies may want to investigate the effects at various running speeds as well as during a prolonged run. Furthermore, McConnell's Medial Glide was found to be associated with increased knee flexion throughout the running gait cycle. Since increased knee flexion results in greater PFJ compression (Aminaka & Gribble, 2005; Campolo et al., 2013; Lan et al., 2010; Mostamand et al., 2010; Osorio et al., 2013), future research may want to investigate this further by looking at the effects of therapeutic patellar taping techniques on pain. Future research may also want to look at the effects on lower extremity kinematics at the hip, knee, and ankle in combination with kinetics and EMG activity during running. Additionally, PFPS affects both males and females. Therefore, research comparing the effects of therapeutic patellar taping techniques and gender on lower extremity kinematics in runners with PFPS is warranted.

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Appendix A

Recruitment Flyer

PARTICIPANTS WANTED FOR STUDY

“The Effects of Therapeutic Patellar Taping Techniques on Lower Extremity Kinematics During Running in Individuals with and without Patellofemoral Pain Syndrome”



Conducted by: Ariel Pelletier (MSc Kinesiology Student)

Supervisors: Dr. Paolo Sanzo and Dr. Derek Kivi

School of Kinesiology, Lakehead University

Participants:

- Men and women aged 18 – 45 who are healthy **or** have patellofemoral pain syndrome
 - No current knee pain/knee pain within the past 6 months (healthy individuals only)
 - No lower extremity injury/surgery within the past 6 months
 - No lower extremity osteoarthritis
- Running experience (At least 30 mins/day, for a minimum of 3 days/week)

You will initially be asked to complete a Physical Activity Readiness Questionnaire (Par-Q+) and answer a few questions via e-mail to ensure you are eligible to participate. If you qualify, you will be asked to participate in 1 testing session that will take place at Lakehead University, in the School of Kinesiology’s Exercise Physiology lab. It will require approximately 1 hour of your time. The testing will be completed under 3 different conditions: no tape, Leukotape and Kinesio Tape. You will be asked to participate in a 5 minute warm-up, run for 45 seconds at a speed of 3.22 m/s, and complete a 5 minute cool down for each condition.

For more information about the study, or to volunteer, please contact:

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ampellet@lakeheadu.ca

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Appendix B

Recruitment Letter

Dear Potential Participant,

You are being invited to participate in the following thesis project that is being conducted by myself, Ariel Pelletier, a second year Masters of Science in Kinesiology student at Lakehead University under the supervision of Dr. Paolo Sanzo, Assistant Professor, and Dr. Derek Kivi, Associate Professor in the School of Kinesiology at Lakehead University. The title of the study is “The Effects of Therapeutic Patellar Taping Techniques on Lower Extremity Kinematics During Running in Individuals with and without Patellofemoral Pain Syndrome”. The purpose of this study is to investigate the effects of therapeutic patellar taping techniques (McConnell’s Medial Glide and Mechanical Correction Technique with Tension in the Base) on lower extremity kinematics during the different phases of running in runners with and without patellofemoral pain syndrome (PFPS).

You are being asked to participate in this study because you are an experienced runner (who runs for at least 30 minutes a day, a minimum of 3 days a week) between the age of 18 and 45 who is healthy or has been diagnosed by a healthcare professional with PFPS. This study will attempt to identify how therapeutic patellar taping affects hip and knee joint movements during running. As a result, you will not be able to participate if you meet any of the following exclusion criteria: 1) have current knee pain or a history of knee pain within the past 6 months (healthy group only); 2) have an injury affecting your lower extremity or have had any lower extremity surgeries within the past 6 months; 3) have a known and uncontrolled cardiovascular pathology or neuropathy; 4) have osteoarthritis in your lower extremity; 5) have a known allergy to adhesives such as Band Aids or tape; and 6) are pregnant.

Prior to participating you will be required to sign a Consent Form and complete a Physical Activity Readiness Questionnaire (Par-Q+). Testing will occur in one session and will take place at Lakehead University, in the School of Kinesiology’s Exercise Physiology lab, SB-1025. It will require approximately 1 hour of your time. Your height and weight will initially be measured using a scale and tape measure. The testing will be completed under three different conditions: no tape, Leukotape (McConnell’s Medial Glide), and Kinesio Tape (Mechanical Correction Technique with Tension in the Base). Retroreflective markers and tape will then be placed on your hip, thigh, knee, calf, ankle, and foot to facilitate the analysis of the 3-dimensional motion during running. Two high-speed cameras, which will be recording each trial, will be positioned on the side of your affected or selected leg. You will then be asked to participate in a five-minute treadmill warm up, prior to the application of your initial chosen taping condition. You will then be asked to run on the treadmill at a speed of 3.22 m/s for 45 seconds. Once completed, you will be given a five-minute recovery period, during which the next taping intervention will be applied. The same procedure (45 seconds at 3.22 m/s) will be followed for the remaining taping interventions. Once you have completed all trials, you will be asked to engage in a 5 minute cool down run prior to leaving.

Potential risks for participation in this study are minimal. Risks may include the possibility of an adverse reaction to the tape such as, irritation, itching, redness, or a rash on your skin, as well as strains or sprains, and/or slightly aggravated knee pain from running. The potential risks will be minimized by excluding those allergic to adhesives, using Hypafix (a hypoallergenic adhesive under the tape), recruiting participants who run regularly, incorporating a warm up and cool down, as well as allowing participants to voluntarily stop the testing at any time.

This study will potentially benefit you, the participant, health care professionals, as well as other researchers as the findings will reveal information about the effectiveness of different therapeutic patellar taping techniques and their effect on hip and knee kinematics during running. The information from this study can be used to promote or discourage the use of tape.

There are no payments, incentives, or reimbursements for participation in this study. Furthermore, participation in this study is voluntary; therefore, you have the right to withdraw at any time. Any information that you provide will be confidential. Additionally, you have the right to decline to answer any questions. Only the researcher, and her supervisors, Dr. Paolo Sanzo, and Dr. Derek Kivi will have access to the recorded data and personal information. All information will be securely stored in a locked filing cabinet and a password protected computer for a minimum period of five years in the office of Dr. Paolo Sanzo within the School of Kinesiology at Lakehead University.

The results from this study will be presented in a paper as well as oral presentation. Furthermore, an abstract and/or the final paper may be submitted to a scientific conference or journal for publication, with the possibility of a presentation. Full anonymity and confidentiality will be observed during the course of the research, in the paper, as well as in the presentation of your results. If requested, you will be provided with a copy of the aggregate results, as well as your own results upon the completion of the study.

If you have any questions or would like to participate in the study please contact me at ampellet@lakeheadu.ca. You may also contact my supervisors, Dr. Paolo Sanzo, at psanzo@lakeheadu.ca or 807-343--8647, or Dr. Derek Kivi at dkivi@lakeheadu.ca or 807-343-8645, should you have any questions or concerns. This research has been approved by the Lakehead University Research Ethics Board. If you have any questions related to the ethics of the research and would like to speak to someone outside of the research team, please contact Sue Wright at the Research Ethics Board at 343-8283 or swright@lakeheadu.ca.

Thank you for your cooperation.
Sincerely,

Ariel Pelletier
MSc Kinesiology Student
Lakehead University

Appendix C

Consent Form

I, _____, agree to participate in the study titled “The Effects of Therapeutic Patellar Taping Techniques on Lower Extremity Kinematics During Running in Individuals with and without Patellofemoral Pain Syndrome”. The study is being conducted by Ariel Pelletier, a Masters of Science in Kinesiology student at Lakehead University, and supervised by Dr. Paolo Sanzo, Assistant Professor, and Dr. Derek Kivi, Associate Professor within the School of Kinesiology at Lakehead University in fulfillment of the requirement of the MSc Kinesiology Thesis program.

I have read and understand the recruitment letter. I understand that I will be required to run at 3.22 m/s in order to assess hip and knee movements under three conditions: no tape, Leukotape, and Kinesiotape, and that my performance will be recorded using high-speed cameras. I understand that testing will be completed at a mutually convenient time and will take approximately 1 hour.

I understand that the potential risks in this study are minimal but may include the possibility of an adverse reaction to the tape such as irritation, itching, redness or a rash on the skin, as well as sprains or strains, and/or slightly aggravated knee pain from running. These potential risks will be minimized by excluding those allergic to adhesives, using Hypafix (a hypoallergenic adhesive under the tape), recruiting participants who run regularly, having participants engage in a warm up and cool down, as well as by allowing the participants to stop the test at any time.

I understand that by participating in this study knowledge may be gained about the effectiveness of different therapeutic patellar taping techniques on hip and knee movements during running. The information from this study can be used to promote or discourage the use of tape.

I understand that there are no payments, incentives, or reimbursements for participation in this study. I also understand that my participation in this study is voluntary and that I may withdraw at any time. I understand that my identity will remain anonymous and all data will be kept confidential. Only Ariel Pelletier, Dr. Paolo Sanzo, and Dr. Derek Kivi will have access to this data. Furthermore, I understand that the results from this study will be presented in a paper and oral presentation, and that an abstract and/or the final paper may be submitted to a scientific conference or journal for publication, with the possibility of a presentation. No identifiable characteristics will be used in the final paper or in the presentation results. All information will be securely stored in a locked filing cabinet and a password protected computer for a minimum period of five years in the office of Dr. Paolo Sanzo within the School of Kinesiology at Lakehead University.

I understand that I will be provided with a copy of the aggregate results, as well as my own results at the completion of the study, if requested.

Participant Signature

Date

Witness

Date

If you wish to receive a copy of the aggregate results, as well as your own results upon the completion of the study, please provide an email address so you can be contacted.

Appendix D

Direct Linear Transformation (DLT) Method

The DLT method is achieved by using the 2D coordinates to develop a set of two equations to solve for the 11 DLT parameters (L_{1-11}) for each of the camera's views (Robertson et al., 2004).

The equations are:

$$x + \delta x = \frac{L_1X + L_2Y + L_3Z + L_4}{L_9X + L_{10}Y + L_{11}Z + 1},$$

$$y + \delta y = \frac{L_5X + L_6Y + L_7Z + L_8}{L_9X + L_{10}Y + L_{11}Z + 1}$$

where x and y are the 2D coordinates of each control point; δx and δy are the errors associated with the coordinates; X , Y , and Z are the 3D coordinates of each control point; and L_{1-11} are the unknown DLT parameters (Pourcelot et al., 2000). However, this results in more equations than unknowns (Payton & Bartlett, 2008; Robertson et al., 2004). Therefore, a least squares technique will be used to solve the DLT parameters and calculate the 3D coordinates of each digitized point (Payton & Bartlett, 2008; Robertson et al., 2004).

Appendix E

Physical Activity Readiness Questionnaire for Everyone (PAR-Q+)

PAR-Q+






The Physical Activity Readiness Questionnaire for Everyone

Regular physical activity is fun and healthy, and more people should become more physically active every day of the week. Being more physically active is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS




Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1) Has your doctor ever said that you have a heart condition OR high blood pressure?	<input type="checkbox"/>	<input type="checkbox"/>
2) Do you feel pain in your chest at rest, during your daily activities of living, OR when you do physical activity?	<input type="checkbox"/>	<input type="checkbox"/>
3) Do you lose balance because of dizziness OR have you lost consciousness in the last 12 months? Please answer NO if your dizziness was associated with over-breathing (including during vigorous exercise).	<input type="checkbox"/>	<input type="checkbox"/>
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)?	<input type="checkbox"/>	<input type="checkbox"/>
5) Are you currently taking prescribed medications for a chronic medical condition?	<input type="checkbox"/>	<input type="checkbox"/>
6) Do you have a bone or joint problem that could be made worse by becoming more physically active? Please answer NO if you had a joint problem in the past, but it <u>does not limit your current ability</u> to be physically active. For example, knee, ankle, shoulder or other.	<input type="checkbox"/>	<input type="checkbox"/>
7) Has your doctor ever said that you should only do medically supervised physical activity?	<input type="checkbox"/>	<input type="checkbox"/>

 **If you answered NO to all of the questions above, you are cleared for physical activity. Go to Page 4 to sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.**

-  Start becoming much more physically active – start slowly and build up gradually.
-  Follow Canada's Physical Activity Guidelines for your age (www.csep.ca/guidelines).
-  You may take part in a health and fitness appraisal.
-  If you have any further questions, contact a qualified exercise professional such as a Canadian Society for Exercise Physiology - Certified Exercise Physiologist® (CSEP-CEP) or a CSEP Certified Personal Trainer® (CSEP-CPT).
-  If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional (CSEP-CEP) before engaging in this intensity of activity.

 **If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.**

 **Delay becoming more active if:**

-  You are not feeling well because of a temporary illness such as a cold or fever - wait until you feel better
-  You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the **ePARmed-X+** at www.eparmedx.com before becoming more physically active
-  Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or qualified exercise professional (CSEP-CEP or CSEP-CPT) before continuing with any physical activity program.

PAR-Q+

FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1. **Do you have Arthritis, Osteoporosis, or Back Problems?**
If the above condition(s) is/are present, answer questions 1a-1c If **NO** go to question 2
- 1a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments) YES NO
-
- 1b. Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)? YES NO
-
- 1c. Have you had steroid injections or taken steroid tablets regularly for more than 3 months? YES NO
-
2. **Do you have Cancer of any kind?**
If the above condition(s) is/are present, answer questions 2a-2b If **NO** go to question 3
- 2a. Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and neck? YES NO
-
- 2b. Are you currently receiving cancer therapy (such as chemotherapy or radiotherapy)? YES NO
-
3. **Do you have Heart Disease or Cardiovascular Disease? This includes Coronary Artery Disease, High Blood Pressure, Heart Failure, Diagnosed Abnormality of Heart Rhythm**
If the above condition(s) is/are present, answer questions 3a-3e If **NO** go to question 4
- 3a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments) YES NO
-
- 3b. Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction) YES NO
-
- 3c. Do you have chronic heart failure? YES NO
-
- 3d. Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure) YES NO
-
- 3e. Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months? YES NO
-
4. **Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes**
If the above condition(s) is/are present, answer questions 4a-4c If **NO** go to question 5
- 4a. Is your blood sugar often above 13.0 mmol/L? (Answer **YES** if you are not sure) YES NO
-
- 4b. Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, and the sensation in your toes and feet? YES NO
-
- 4c. Do you have other metabolic conditions (such as thyroid disorders, pregnancy-related diabetes, chronic kidney disease, liver problems)? YES NO
-
5. **Do you have any Mental Health Problems or Learning Difficulties? This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome**
If the above condition(s) is/are present, answer questions 5a-5b If **NO** go to question 6
- 5a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments) YES NO
-
- 5b. Do you **ALSO** have back problems affecting nerves or muscles? YES NO





PAR-Q+

- 6. Do you have a Respiratory Disease?** *This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure*
- If the above condition(s) is/are present, answer questions 6a-6d If **NO** go to question 7
- 6a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments) YES NO
- 6b. Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy? YES NO
- 6c. If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week? YES NO
- 6d. Has your doctor ever said you have high blood pressure in the blood vessels of your lungs? YES NO
-
- 7. Do you have a Spinal Cord Injury?** *This includes Tetraplegia and Paraplegia*
- If the above condition(s) is/are present, answer questions 7a-7c If **NO** go to question 8
- 7a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments) YES NO
- 7b. Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting? YES NO
- 7c. Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)? YES NO
-
- 8. Have you had a Stroke?** *This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event*
- If the above condition(s) is/are present, answer questions 8a-8c If **NO** go to question 9
- 8a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments) YES NO
- 8b. Do you have any impairment in walking or mobility? YES NO
- 8c. Have you experienced a stroke or impairment in nerves or muscles in the past 6 months? YES NO
-
- 9. Do you have any other medical condition not listed above or do you have two or more medical conditions?**
- If you have other medical conditions, answer questions 9a-9c If **NO** read the Page 4 recommendations
- 9a. Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months? YES NO
- 9b. Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)? YES NO
- 9c. Do you currently live with two or more medical conditions? YES NO

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.

PAR-Q+




 **If you answered NO to all of the follow-up questions about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:**

-  It is advised that you consult a qualified exercise professional (e.g., a CSEP-CEP or CSEP-CPT) to help you develop a safe and effective physical activity plan to meet your health needs.
-  You are encouraged to start slowly and build up gradually - 20-60 min of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
-  As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
-  If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional (CSEP-CEP) before engaging in this intensity of activity.

 **If you answered YES to one or more of the follow-up questions about your medical condition:**

You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+** at www.eparmedx.com and/or visit a qualified exercise professional (CSEP-CEP) to work through the ePARmed-X+ and for further information.

 **Delay becoming more active if:**

-  You are not feeling well because of a temporary illness such as a cold or fever - wait until you feel better
-  You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the **ePARmed-X+** at www.eparmedx.com before becoming more physically active
-  Your health changes - talk to your doctor or qualified exercise professional (CSEP-CEP) before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The PAR-Q+ Collaboration, the Canadian Society for Exercise Physiology, and their agents assume no liability for persons who undertake physical activity. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- Please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that a Trustee (such as my employer, community/fitness centre, health care provider, or other designate) may retain a copy of this form for their records. In these instances, the Trustee will be required to adhere to local, national, and international guidelines regarding the storage of personal health information ensuring that they maintain the privacy of the information and do not misuse or wrongfully disclose such information.

NAME _____ DATE _____

SIGNATURE _____ WITNESS _____

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER _____

For more information, please contact
www.eparmedx.com or
Canadian Society for Exercise Physiology
www.csep.ca

Citation for PAR-Q+
 Warburton DER, Jamnik VL, Bredin SSD, and Gledhill N on behalf of the PAR-Q+ Collaboration. The Physical Activity Readiness Questionnaire (PAR-Q+) and Electronic Physical Activity Readiness Medical Examination (ePARmed-X+). Health & Fitness Journal of Canada 42(3-23), 2011.

Key References

1. Jamnik VL, Warburton DER, Makizuki J, McKenzie DC, Shephard RJ, Stone J, and Gledhill N. Enhancing the effectiveness of clearance for physical activity participation: background and overall process. APHM 36(S1):S5-S13, 2011.
2. Warburton DER, Gledhill N, Jamnik VL, Bredin SSD, McKenzie DC, Stone J, Charlesworth S, and Shephard RJ. Evidence-based risk assessment and recommendations for physical activity clearance; Consensus Document. APHM 36(S1):S268-S298, 2011.

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+ Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or BC Ministry of Health Services.

