The Impact of Therapeutic Ankle Taping on the Lower Extremity Kinematics of Running on Level, Inclined, and Declined Slopes

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Abstract

Overpronation is cited as a common misalignment of the calcaneus resulting from flattening of the medial longitudinal arch, which may contribute to the development of an overuse injury. It has been suggested that taping may control the position and alignment of the calcaneus to correct foot pathologies associated with overpronation. The purpose of this study was to explore the effect of ankle taping with Kinesio Tape® and Leuko Tape P® on the kinematics of the lower extremity while running on level, inclined, and declined slopes.

Healthy male and female participants (n = 40) between the ages of 18 and 30 years were recruited. Each participant ran with a Modified Mulligan Calcaneal Leuko Tape P® technique, Foot Pronation Kinesio Tape® technique, and no tape. Lower extremity kinematics at the ankle, knee, and hip at initial contact, during midstance, and at toe off, as well as, spatio-temporal parameters of contact time (CT), stride frequency (SF), and stride length (SL) were analyzed using Contemplas Templo® 3D motion capture system to determine how each type of tape altered the running stride under each condition.

Significant slope main effects were found for SL (F (1.478, 56.078) = 6.246, p = .007, η_p^2 = .138). Stride length was longer while running on a declined slope when compared to an inclined slope (p = .026). Significant slope main effects were also found for SF (F (2, 78) = 9.74, p = .001, η_p^2 = .200). Stride frequency was decreased while running on a declined slope when compared to a level and inclined slope (p = .028; p = .003). Finally, significant tape main effects were found for peak knee angular displacement during the stance phase of running (F (2, 78) = 3.609, p = .032, η_p^2 = .085). The application of LT produced less knee flexion when compared to KT (p = .048).

Therefore, the application of both KT and LT were found to be beneficial in controlling excessive angular displacement throughout the running stride. As this study provided preliminary results to the effectiveness of anti-pronation taping while running on level, inclined, and declined slopes on neutral foot types, future research is required to explore the effect of tape on overpronated foot types, as well as identify and support differences where slight changes were found.

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Each year, a reported 20-80% of runners are likely to sustain a running related injury (Linton & Valentin, 2018; Novacheck, 1998). Due to the cyclic nature of running, overuse injuries are among the most common running related injuries. Overuse injuries are caused by the repetitive application of relatively small loads over many cycles where even a slight biomechanical abnormality can induce injury (Novacheck, 1998). Hreljac, Marshall, and Hume (2000) stated that rearfoot kinematic variables that have been most often associated with overuse running injuries include the magnitude and rate of foot pronation. Overpronation is often described as a misalignment of the calcaneus resulting from flattening of the medial longitudinal arch (Luque-Suarez et al., 2014). Luque-Suarez et al. (2014) also suggested that flattening of the arch alters the alignment throughout the lower extremity. Many studies have shown that therapeutic taping may control the position and alignment of the calcaneus placing it in an improved biomechanical position by increasing the medial longitudinal arch height (Agrawal & Deshpande, 2015; Hyland, Webber-Gaffney, Cohen, & Lichtman, 2006; Mehta, Basu, Palekar, & Dave, 2017). This improved position has been proposed to better align the lower extremity and further reduce the risk of attaining an overuse injury. Nevertheless, an initial understanding of the running gait cycle is imperative before interpreting the effects of overpronation and prevalence of injury.

Phases of the Running Gait Cycle

The running gait cycle is referred to as the instant of initial contact from one foot and all the motions that occur from that point until the next point of contact of that same foot (Dugan & Bhat, 2005). To be precise, the running gait cycle can be broken down into two phases of movement. These two phases include the stance phase, which accounts for 40% of the gait cycle, and the swing phase, which accounts for 60% (Dugan & Bhat, 2005). Many complex motions occur during each of these phases; therefore, when discussing the running gait cycle, each phase should be broken down further into sub phases.

Stance phase. As seen in Figure 1, the stance phase is subdivided into three phases including the initial contact, midstance, and toe-off phases.

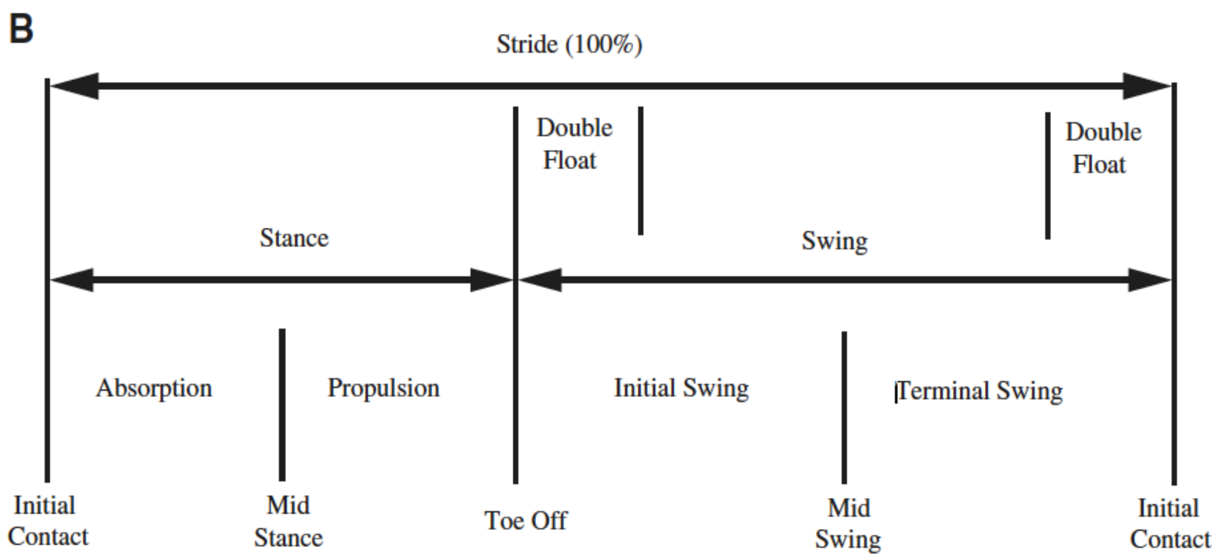

Figure 1. Phases in the running gait cycle. Adapted from "Biomechanics and Analysis of Running Gait", by S. Dugan and K. Bhat, 2005, *Physical Medicine and Rehabilitation Clinics of North America*, *16*, p. 610. Copyright 2018 by Physical Medicine and Rehabilitation Clinics of North America.

As seen in Figure 2 Image 1, the beginning of the running gait cycle occurs at initial contact. At initial contact, the hip and knee are slightly flexed as the foot contacts the ground with the foot in a supinated position to better attenuate the shock from landing (Ferber & Macdonald, 2014; Nicola & Jewison, 2012). The foot contacts the ground in front of the body's centre of gravity with either the heel, midfoot, or forefoot (Novacheck, 1998). When a heelstrike pattern is used, the individual initially lands on the lateral aspect of the heel (Nicola & Jewison, 2012). With a midfoot strike pattern, the individual lands on the middle, medial, or lateral aspect of the foot; and finally, with a forefoot strike pattern, the individual lands on their forefoot.

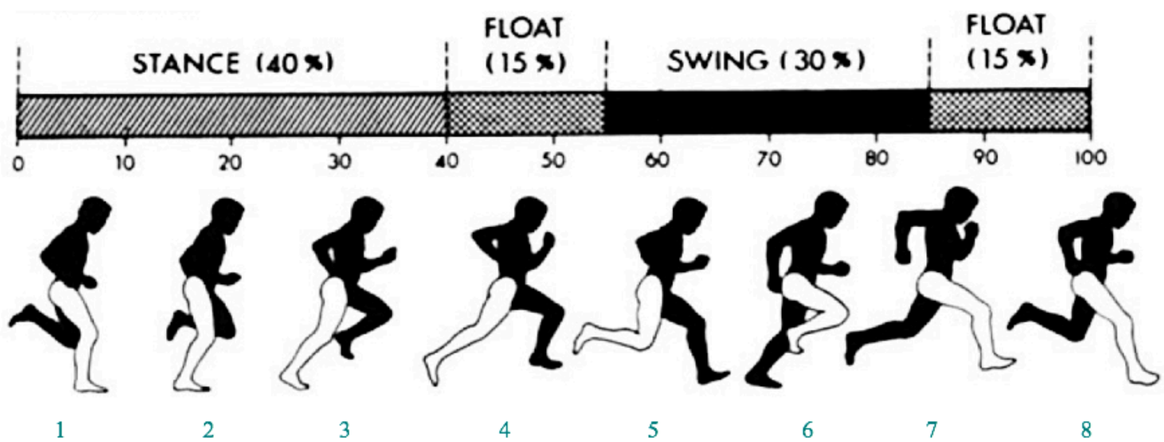

Figure 2. Schematic drawing of the running gait cycle. (1) initial contact phase, (2) midstance phase, (3) toe off phase, (4 and 5) initial swing phase, (6 and 7) float phase, and (8) late swing phase. Adapted from "Foot Biomechanics During Walking and Running", by C. Chan and A. Rudins, 1994, *Mayo Clinic Proceedings*, *69*, p. 458. Copyright, 2018 by Mayo Clinic Proceedings.

During the midstance phase, as seen in Figure 2 Image 2, the foot moves from a supinated position into pronation to attenuate the shock from landing. A distal to proximal transfer of energy from the ankle to the hip occurs causing increased dorsiflexion of the ankle and internal rotation of the tibia. Flexion and adduction also occur at the knee and hip. At the toe off phase, as seen in Figure 2 Image 3, plantarflexion and inversion of the ankle cause the foot to progress into a locked supinated position (Ferber & Macdonald, 2014). At this time, as the opposite leg swings forward, pelvic rotation occurs in the stance leg and causes extension at the knee, external rotation of the tibia, and inversion of the calcaneus (Dugan & Bhat, 2005). These motions create a stiff joint lever in the foot and ankle to propel the runner forward into the swing phase.

Swing phase. The swing phase occurs when the lower extremity swings through the air from toe-off to footstrike (Dugan & Bhat, 2005). The swing phase can be broken into three phases referred to as the initial swing phase (Figure 2 Image 4 and 5), float phase (Figure 2 Image 6 and 7), and terminal swing phase (Figure 2, Image 8). After toe-off, the body is propelled into the float phase (Dugan & Bhat, 2005). Knee flexion also occurs in the swinging leg as a result of the ground reaction forces occurring at toe-off. This knee flexion is resisted by an eccentric contraction of the rectus femoris, and a concentric contraction of the iliopsoas muscles to flex the hip and advance the limb forward. At this time, the opposite limb strikes the ground. Pelvic rotation occurs to push the swinging limb into abduction and placing the opposite limb in external rotation to initiate supination of the foot (Dugan & Bhat, 2005). During the terminal swing phase, the hip continues to flex and adduct to progress the femur of the swinging leg toward the midline. At this time, the knee also reaches full extension to prepare the lower extremity for contact with the ground. Just before initial contact, slight flexion of the knee and dorsiflexion of the ankle occur in the swinging leg to allow the foot to be placed in front of the body's centre of gravity to create stability for weight acceptance (Dugan & Bhat, 2005). As Dugan and Bhat (2005) suggested, proper running biomechanics involve synchronous movements of all the components of the kinetic chain. To appropriately understand how each joint affects the other, it is essential to understand their role within the running gait cycle, respectively.

Spatio-temporal parameters. Running injuries may also be associated with the magnitude and rate of impact of force during the stance phase (Schubert, Kempf, & Herderscheit, 2014). Furthermore, stride frequency (SF) and stride length (SL) can influence the shock of landing and the mechanics of the body while running. As seen in Figure 3, SF refers to the total number of running steps per second (Hz) and SL refers to the distance between each stride (m; Schubert et al., 2014). Therefore, examining the mechanical changes that occur during sloped running along with the effects of overpronation may increase the understanding of these effects across common running surfaces.

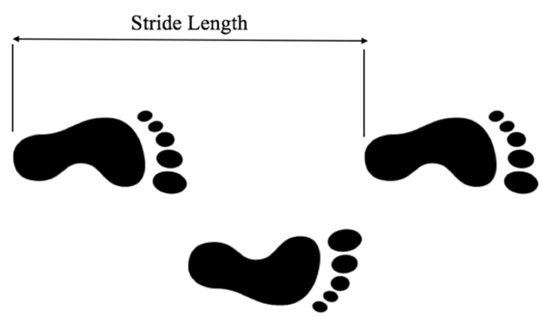

Figure 3. Schematic of Stride Length.

Kinematics.

Kinematics is the study of motion without regards to the cause of motion (Robertson, Caldwel, Hamill, Kamen, & Whittlesey, 2014). Furthermore, this form of analysis is concerned with describing and quantifying both linear and angular positions of bodies as well as time derivatives. When assessing joint angles, or angular displacement, there are two types of measurements commonly used including relative and absolute angles (Hall, 2007). The relative angle is a measurement of the angle between a segment relative to the other body segments articulating at the joint (Hall, 2007). The absolute angle is the angle of inclination of a body segment measured with respect to an absolute reference plane (Hall, 2007). As both forms of measurement are commonly used in kinematic research, variations may be seen in the joint angles reported among different research studies. Nevertheless, an understanding of the approximate angles of the lower extremity during the running stride will allow appropriate interpretation of the average angular displacement for each joint.

Ankle. At initial contact, the ankle is in approximately 12-19^o of dorsiflexion and 2-10^o of external rotation (Ferber & Macdonald, 2014). At this time, the ankle will also range between 5^o of eversion and 5^o of inversion. During the midstance phase, the ankle is in 12-20^o of dorsiflexion, 4-10^o of internal rotation, and 2.5-11^o of eversion (Ferber & Macdonald, 2014; Novacheck, 1998). During the toe-off phase, the ankle will plantarflex approximately 3-10^o and externally rotate 1-11^o (Ferber & Macdonald, 2014; Novacheck, 1998). The ankle will also range from 1^o of eversion to 10^o of inversion (Ferber & Macdonald, 2014; Novacheck, 1998). During the initial swing phase, the ankle will maximally plantarflex to approximately 20^o (Novacheck, 1998). As the leg swings forward during the float phase, the ankle will dorsiflex to approximately 10^o. Finally, during the terminal swing phase, the range of ankle dorsiflexion will slightly decrease to 5^o to provide clearance for landing (Novacheck, 1998). The foot and ankle have been described to serve as a link between the surface of the ground and the remainder of the lower extremity (Dugan & Bhat, 2005). This link allows the foot and ankle to adapt to uneven surfaces, absorb shock from the landing, as well as act as a stiff lever to propel the body forward (Dugan & Bhat, 2005).

Knee. At initial contact, the knee has been described to range from 1^o of extension to 45^o of flexion (Ferber & Macdonald, 2014; Novacheck, 1998). At this time, the knee is also internally rotated approximately 2-10^o and abducted 1-5^o. During the midstance phase, the knee is flexed between 30-48^o, internally rotated between 5-11^o, and ranges between 5^o of abduction to 4^o of adduction. Dugan and Bhat (2005) also stated that during the midstance phase, the knee is in a valgus position of approximately 8-14^o. At toe-off, the knee is approximately flexed between 10-25^o (Ferber & Macdonald, 2014; Novacheck, 1998). The knee is also externally rotated between 1-10^o and abducted 2.5-8^o. During the initial swing phase, the knee will continue to flex until it reaches a maximum of 90^o at midswing. During the terminal swing phase, the knee is in approximately 20^o of flexion. At this time, a small amount of knee flexion occurs to increase the time spent in the air (Nicola & Jewison, 2012). This will further allow for an increase in propulsion and maximize SL during the swing phase. Finally, right before initial contact occurs, the knee is flexed to approximately 25^o. This slight increase in knee flexion before landing is accompanied by an increase in ankle dorsiflexion to allow the foot to clear the ground and achieve initial contact with the rearfoot (Novacheck, 1998).

Hip. At initial contact, the hip is flexed between approximately 30-40^o (Ferber & Macdonald, 2014; Novacheck, 1998). At this time, the hip is also in 2.5-15^o of internal rotation and may range from 2.5^o of abduction to 8^o of adduction (Ferber & Macdonald, 2014). As mentioned above, variations are commonly seen when analyzing angular displacement depending on the method used (Hall, 2007). Variation may also be seen as a result of individual differences in flexibility and muscular strength (Hall, 2007). During the midstance phase, the hip reaches 25-40^o of flexion, 2.5-15^o of internal rotation, and 2-14^o of adduction. At the point of toe-off, the hip ranges between 2^o of extension to 10^o of flexion (Ferber & Macdonald, 2014). The hip also ranges from 8^o of external rotation to 0.5^o of internal rotation and 4^o of abduction to 4^o of adduction. Finally, in the terminal swing phase, the hip will maximally flex to approximately 60^o and adduct to approximately 15^o (Nicola & Jewison, 2012; Novacheck, 1998). During the late swing phase, the degree of hip flexion will decrease to 30-40^o in order to plant the foot under the centre of gravity at initial contact (Nicola & Jewison, 2012; Novacheck, 1998). During the running gait cycle, proper hip motion can be affected by improper alignment throughout the lower extremity (Dugan & Bhat, 2005).

Overpronation

Foot pronation is a weight bearing, tri-planar movement involving calcaneal eversion and talar adduction and plantarflexion that causes lowering of the medial longitudinal arch height and abduction of the forefoot (Franettovich, Chapman, Blanch, & Vincenzino, 2008). During the first half of the midstance phase, the ankle is in a pronated position and the calcaneus is fixed to the ground in an everted position. As seen in Figure 4, this increase in calcaneal eversion causes the talus to adduct and medially rotate, the tibia to internally rotate, and the knee to flex to absorb the impact of landing (Ferber & Macdonald, 2014).

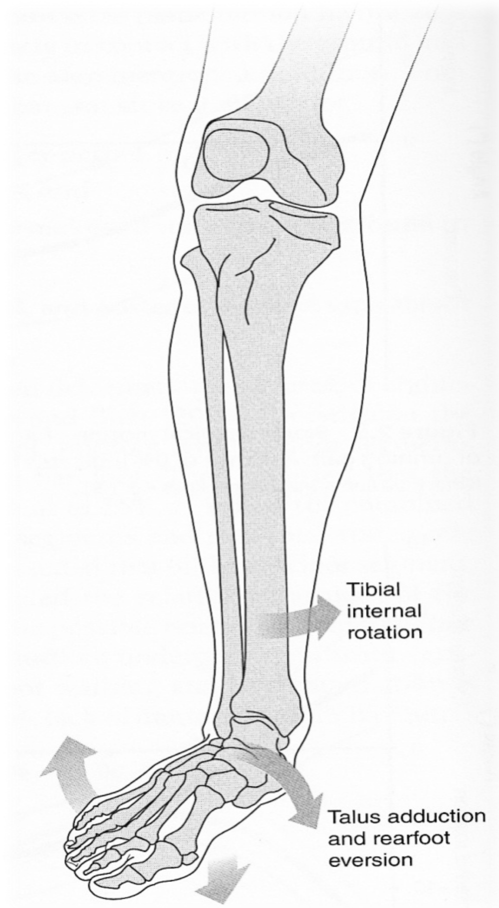

Figure 4. Schematic drawing of the effects of overpronation. Adapted from “Running Mechanics and Gait Analysis” by R. Ferber and D. Macdonald, p.14.

Dugan and Bhat (2005) stated that excessive pronation is the most common problem observed during running analysis. Overpronation during the first half of the midstance phase can be beneficial to absorb the impact of landing and allow the foot to adapt to uneven surfaces. Conversely, overpronation continuing through the second half of the midstance phase may result in a hypermobile and unstable foot (Cheung & Ng, 2007). During the second half of the midstance phase, supination results in a stiff lever at the foot and ankle joint causing the tibia to externally rotate and the knee to extend to propel the body forward (Ferber & Macdonald, 2014).

The lack of motion at the medial longitudinal arch, that is common with overpronation, requires a higher degree of calcaneal eversion to compensate. Furthermore, if this transition is restricted, the hip must excessively internally rotate to maintain proper alignment in the patellofemoral joint. Therefore, overpronation may cause and can be identified by, increased ranges in hip flexion and adduction, knee flexion and abduction, femoral and tibial internal rotation, as well as, dorsiflexion at the ankle (Dugan & Bhat, 2005; Lattanza, Gray, & Kantner, 1988). These alterations have collectively been found to increase an individual's risk of developing an overuse injury (Hintermann & Nigg, 1998). Vincent et al. (2014) suggested that the inclination of the running surface can also change joint mechanics that lead to injury.

Slope

Sloped running results in different mechanical and metabolic effects when compared to level running (Padulo, Powell, Milia, & Ardigo, 2013). Sloped running conditions can include both a positive degree or gradient (incline) or negative degree or gradient (decline). The measurement of slope, presented in units of degrees (^{o}), represents the angle of inclination or declination where 0^o represents a horizontal surface and $\pm 90^o$ represents a completely vertical surface (Larson & Edwards, 2011). Values between the descriptions presented above will depict the angle of the surface. As seen in Figure 5, a measurement of slope displayed as a gradient, or percent (%) grade, can be calculated by taking the value of the vertical height at the highest point of the incline (Y), dividing that number by the length between the ground level and the point of the highest incline (X), and multiplying the resulting value by 100 (Kavanagh, 2010).

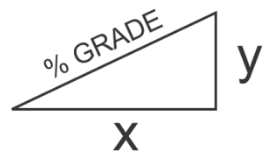

Figure 5. Visual Display of the Calculation for % Grade.

Percent grade is most often used for communicating slopes in transportation and has been used in previous research examining running under incline and/or decline conditions (Hardin et al., 2004; Lussiana, Hébert-Losier, & Mourot 2013; Swanson & Caldwell, 2000). Accordingly, it will be the unit of measurement referred to for this research.

Inclined surface. Swanson and Caldwell (2000) compared the changes in joint kinematics and kinetics during inclined treadmill running with level ground running at the same speed. Participants were asked to run completing three trials on an inclined surface with a grade of 30% at 4.5 m/s, a level trial at the same speed as the incline (4.5 m/s), and a level trial running at a self selected speed (M = 7.61 m/s) that allowed the same SF as the inclined condition. There was an increased SF of 1.78 Hz and decreased SL of 1.26 m for the inclined running trial when compared to the SF of level running at the same speed as the incline which was 1.39 Hz and SL of 1.61 m (Swanson & Caldwell, 2000). Padulo et al. (2013) suggested an increased SF with a shortened SL may decrease the ground reaction force at initial contact and attenuate the shock of landing. As running injuries are associated with the rate and impact of force during the stance phase, running on an incline may be advantageous to decrease the impact on the lower extremity (Schubert et al., 2014). When compared to the level condition running at the self selected speed, the inclined SF for the inclined condition was decreased (1.78 Hz and 1.80 Hz, respectively) and the SL was also decreased (2.12 m and 1.26 m, respectively; Swanson & Caldwell, 2000).

Nevertheless, increases in both SL and SF during the level condition with the self selected speed may be problematic (Padulo et al., 2013). Increases in SL decrease the amount of impacts over time but increase the impact at initial contact for each stride (Padulo et al., 2013). Additionally, increasing SF would amplify the ground reaction forces applied over an increased number of strides (Padulo et al., 2013). Furthermore, increasing both SL and SF would increase both the rate and impact of force during the stance phase and lead to injury (Schubert et al., 2014). Contact time was also greater during the level condition when compared to the inclined condition (.20 s and .18 s, respectively), but less than the level condition at a self selected speed (.14 s; Swanson & Caldwell, 2000). Contact time during the stance phase has been found to increase along with SF but also decrease with increased speeds (Farley & González, 1995; Swanson & Caldwell, 2000). Significant increases in angular displacement at the ankle, knee, and hip were also found when running on the inclined condition at initial contact and toe off when compared to running on the level condition. At initial contact for running on the level condition, the average angular displacement for the ankle was 9.1^{o} of plantarflexion, 21.0^{o} of flexion at the knee, and 25.4^{o} of flexion at the hip. For the inclined condition, the average angular displacement for the ankle was 6.7^{o} of dorsiflexion, 59.7^{o} of flexion at the knee, and 54.3^{o} at the hip (Swanson & Caldwell, 2000). At toe off for running on the level condition, an average angular displacement for the ankle was 21.0^{o} of plantarflexion, 22.0^{o} of flexion at the knee, and 4.6^{o} of extension at the hip. For running on the inclined condition, an angular displacement of 21.7^{o} of dorsiflexion at the ankle, 21.5^{o} of flexion at the knee, and 2.2^{o} of flexion at the hip was reported (Swanson & Caldwell, 2000).

Lussiana et al. (2013) also explored the effect of slope and footwear on running economy and kinematics. Participants were asked to run 5 minute trials at 2.7 m/s at seven sloped conditions of -8%, -5%, -2%, 0%, 2%, 5%, and 8%. Significant decreases in SF were found as the slope decreased, and increases in SF were seen during the uphill conditions. During the declined running conditions, the SF was approximately 2.70 Hz for the -2%, 2.66 Hz for -5%, and 2.65 Hz for -8% sloped conditions. During the inclined conditions, the SF was approximately 2.72 Hz for the 0%, 2.76 Hz for 2%, 2.75 Hz for 5%, and 2.77 Hz for 8% sloped conditions. As mentioned above, increased SF was seen while running on inclined conditions has been shown to decrease the impact at initial contact and, therefore, may be advantageous while running on an incline. Nevertheless, no significant differences were found across the sloped conditions for CT but significant differences were found for flight time between the sloped conditions of -2% and 8%. As the gradient increased, the flight time also increased. The reported flight times were .63 s for the -2%, .55 s for 0%, .55 s for 2%, .56 s for 5%, and .59 s for the 8% sloped conditions. As increases in flight time are often associated with increases in CT, a significant change in CT can suggest a discrepancy in timing and magnitude of activation for the vastus medialis, rectus femoris, biceps femoris, and gastrocnemius medialis muscles while running on an incline. Running on an inclined surface has also been reported to put excessive demands on the triceps surae muscles by increasing the amount of internal mechanical work needed to propel the individual up the incline (Sallade & Koch, 1992). In the presence of tightness in the Achilles tendon, additional functional range of motion can be achieved via compensatory strategies in the ankle by pronating (Sallade & Koch, 1992). Nevertheless, if this pronation is excessive, it may produce strain on the medial structures of the lower limb such as the tibialis posterior and peroneus longus muscles resulting in possible strains and overuse injuries. Along with increases in inclination, running on a declined slope has also been shown to add additional stresses to the lower extremity while running.

Declined surface. Hardin, Van Den Bogert, and Hamill (2004) stated that distance running on a declined surface resulted in increased impact on the lower extremity. To explore this notion, kinematic and physiological changes were evaluated while manipulating treadmill grade, surface, and shoe stiffness. Participants ran two trials on a level and declined surface of -12%. For the level running trial, participants were asked to run 6 minute trials at 3.4 m/s with three shoe conditions (soft, medium, and hard) and three treadmill stiffness conditions (soft, medium, and hard). For the declined running trial, participants were asked to run on a hard surface treadmill at a speed of 3.4 m/s for 30 minutes with kinematic data collected every 5 minutes. At the end of the 30 minute inclined trial, the ankle was in approximately 1^{o} of plantarflexion at initial contact, the knee was flexed 3^{o}, and the hip was flexed 7^{o}. When compared to the soft and hard shoes, results from the hard surface condition in trial 1, ankle dorsiflexion ranged between $2\text{-}3^{o}$, knee flexion was approximately 5^{o}, and hip flexion ranged from approximately $15\text{-}16^{o}$. Nevertheless, significant increases in extension were only found at the hip at initial contact with no significant differences found in knee or ankle angular displacement after 30 minutes of running. These kinematic changes placed the lower extremity into a more vertical position at initial contact and required less muscle activation for support (Hardin et al., 2004). Furthermore, the reduction in impact at landing may be desirable to reduce the risk of injury over time. Therefore, future research should examine the effects of overpronation on the lower extremity kinematics while running on a declined surface to determine the true impact on the prevalence of injury during this type of condition.

DeVita et al. (2008) also reported larger ground reaction forces during declined running. The larger ground reaction forces were suggested to be the result of decreased angular displacement throughout the lower extremity during the downhill stance phase, which further limited the work done by the active muscles. Since it is proposed that pronation during the midstance phase occurs to absorb the impact of landing, this may be beneficial during declined running. Nevertheless, if the foot absorbs an increased amount of force, it may remain pronated for too long extending through the second half of the midstance phase. If the foot remains pronated through the second half of the midstance phase, proper motion into supination would be restricted. Furthermore, an increased amount of force at initial contact can further increase the risk of injury to a higher degree than during level running. As mentioned above, increased degrees of pronation may increase the amount of calcaneal eversion, tibial internal rotation, and knee flexion. Increased ranges of these motions may further restrict ranges of calcaneal inversion, tibial external rotation, and knee extension that are necessary during the second half of the midstance phase to propel the individual forward at toe off. Therefore, considering and implementing a method to control overpronation may be beneficial while running on both an inclined and declined surface to reduce the risk of injury. Furthermore, it has been suggested that the application of a therapeutic taping technique may be beneficial and necessary to control the position and the alignment of the calcaneus to further correct any foot pathologies associated with overpronation (Hyland et al., 2006).

Therapeutic Taping

There are many different methods used to reduce the risk of injury caused by overpronation including the use of foot orthotics, active exercises, appropriate anti-pronation footwear, and the application of therapeutic tape (Cheung, Chung, & Ng, 2011). Cheung et al. (2011) explored the effectiveness of motion controlling footwear, foot orthotics, and the application of an anti-pronation taping technique for controlling excessive foot pronation. Within this study, foot orthotics were found to be the least effective when compared to motion control footwear and the anti-pronation taping technique. Motion control footwear was found to be the most convenient control as it was less dependent on having someone else apply the technique. Nevertheless, anti-pronation taping was found to be the most effective in reducing calcaneal eversion. Anti-pronation taping was also cited as advantageous as it is often applied and monitored by a therapist (Cheung et al., 2011). Seeking a therapist to apply the tape is advantageous as changes in foot posture will be re-evaluated and monitored each time the tape is applied allowing effective management of the injury.

Franettovich et al. (2008) stated that an improved understanding of the underlying mechanisms of anti-pronation tape is likely to facilitate improved knowledge of the technique used. Furthermore, the mechanism underlying the effectiveness of the tape is the ability to directly correct foot posture, control motion, and reduce stress on the plantar surface of the foot. Dugan and Bhat (2005) stated that proper running biomechanics involves synchronous movements of the kinetic chain where the foot serves as a link between the surface and the lower extremity. Therefore, correcting foot posture may also indirectly have an effect on the knee and hip. Throughout the literature, it has been reported that the application of an anti-pronation taping technique had a biomechanical effect that was demonstrated by increasing the navicular and medial longitudinal arch height (Harradine, Herrington, & Wright, 2001; Vincenzino, Franettovich, McPoil, Russell, & Skardoon, 2005). Navicular height is defined as the vertical distance from the floor to the navicular bone in standing (Franettovich et al., 2008). It has been reported that an increase in navicular height corresponds with an increase in medial longitudinal arch height; this is also associated with reductions in tibial internal rotation, calcaneal eversion, and, thereby, a reduction in a pronated foot posture. Furthermore, the application of anti-pronation taping has been found to assist with proper alignment placing the body in a better position to minimize overuse injuries and reduce pain throughout the lower extremity (Harradine et al., 2001; Vincenzino et al., 2005). Although there are many different types of therapeutic tape, two common types used in clinical and sport settings that will be discussed further include Kinesio Tape® (KT) and Leuko Tape P® (LT).

Types of therapeutic tape.

Kinesio Tape®. Researchers have examined KT and its effects when applied to the ankle and foot region (Kuni, Kalkum, Schmitt, & Wolf, 2016; Luque-Suarez et al., 2014). It has been purported that the primary purposes of KT are to relieve pain, improve circulation and lymphatic drainage, and reduce the delayed onset of muscle soreness (Csapo & Alegre, 2014). It is also been suggested that KT can increase tactile input and muscular strength of the surrounding area (Fu et al., 2008). In a systematic review by Mostafavifar, Wertz, and Borchers (2012), it was concluded that KT was beneficial in immediate pain reduction and a good adjunct to physiotherapy. Kinesio Tape® was also found to improve muscle function by providing support without restricting motion.

Luque-Suarez et al. (2014) examined the initial effects of controlling pronation with the application of KT in a static position using the Foot Posture Index scale© (FPI). The FPI scale© was used to quantify and categorize the degree to which a foot was positioned in a pronated, supinated, or neutral position (Redmond, 1998). The participant's FPI score was taken 10 minutes, 60 minutes, and 24 hours after the application of tape to explore the effect of KT on foot pronation over time. No significant decrease in pronation was seen as a result of KT application. Nevertheless, the study only included an investigation on the effects of tape to a static foot posture. Neal et al. (2014) stated a there was a poor relationship between measures of static foot posture and predicting the risk of injury during dynamic activity. Therefore, future research should incorporate the effects of an anti-pronation taping technique including both static and dynamic measurements of foot posture to explore the benefits of the tape. The taping technique used also involved a single strip of tape applied from the inferior border of the lateral malleolus wrapped underneath the calcaneus to the medial malleolus. With the elastic properties of the KT, a single strip may not be effective in controlling rearfoot motion while running. Therefore, future research should include participants completing a dynamic task with the application of an alternative taping technique designed to control rearfoot motion in more of a neutral position.

In another study, Kuni et al. (2016) compared the effect of LT, KT, and a soft MalleoTrain® ankle brace on stabilizing midfoot and rearfoot kinematics. Each participant completed a single foot drop landing with the application of each type of tape or ankle brace compared to a barefoot condition. Kinesio Tape® was effective only in controlling rearfoot kinematics in the sagittal plane. Conversely, the LT and bracing conditions were both found to have a restricting effect on rearfoot motion including subtalar inversion and anterolateral rotary subluxation of the talus. Talocrural motion was also influenced by bracing but not with the application of LT. Although both LT and bracing were beneficial in controlling ankle stability, LT was concluded to provide sufficient support to the foot and ankle while still allowing for appropriate mobility.

Leuko Tape P®. Another type of tape that is commonly used to affect the lower extremity biomechanics is LT. Leuko Tape P® is a non-elastic sports tape, that has also been used widely in injury rehabilitation and prevention due to its rigid properties. As a result of the unyielding nature of the tape, its application to the calcaneus is proposed to achieve instant pain relief, as well as, control for excessive calcaneal eversion reducing stress on the plantar fascia (Agrawal & Deshpande, 2015).

Agrawal and Deshpande (2015) compared the effects of a Mulligan calcaneal taping technique with LT to ultrasound therapy or plantar fascial stretching. Participants were included in this study if they reported pain located on the heel or plantar surface and pain with the first few steps of walking. The participant's degree of pain was measured using a self reported Visual Analogue Scale. Participants were then randomly assigned into three treatment groups where they received either ultrasound therapy, a passive plantar fascial stretch, or had LT applied to the calcaneus of their affected foot. After 24 hours, another Visual Analog Scale questionnaire was administered to determine if the participants noticed a change in pain based on their assigned intervention. Significant reductions in pain were reported by participants receiving all three treatment interventions (Agrawal & Deshpande, 2015). As such, it was determined that LT was a good supplement to physical therapy treatment in reducing pain caused by plantar fasciitis. Although this study included an evaluation of the pain-relieving effects of applying tape, there was no method to determine changes in foot posture during static or dynamic conditions. Future research should include measures of foot posture to determine if the decreased pain is the result of the alteration of foot alignment or biomechanics, the actual treatment, or a placebo effect.

Hyland et al. (2006) explored the use of therapeutic tape in relieving the symptoms of plantar heel pain allowing patients to continue with their everyday tasks. The effect of calcaneal taping on plantar heel pain symptoms was explored through the use of self-report pain questionnaires. Participants were split into four groups including a LT intervention group, a plantar fascial stretching group, a sham taping group, and a no treatment/control group. Self report pain questionnaires were administered before and after the treatment to determine the change in plantar heel pain. Participants reported that the use of LT significantly reduced pain when compared to stretching and the use of sham taping (Hyland et al., 2006). Also, the application of tape was beneficial as it provided immediate symptom relief and was easily administered. Although heel pain was reduced, there was no report of any mechanical changes in foot posture making it unclear if these effects were the result of the direct application of tape. Therefore, information regarding changes in the participant's foot posture after the taping intervention may have provided better insights into the effects of the tape.

Mehta et al. (2017) compared LT to KT in treating heel pain. In this study, participants were included if they experienced heel pain with the first couple of steps of prolonged sitting or pain localized to the base of the heel. After they were recruited, participants were randomly assigned into one of two groups where one received the application of a Mulligan calcaneal LT taping technique and the other received the application of a plantar fascial KT taping technique. Participants received two sessions of taping accompanied by physiotherapy treatment on every third day, respectively. During each session, the intensity of the pain was measured using a Visual Analog Scale and the degree of pronation was measured using the Foot Function Index (FFI). The FFI contains a 23 item questionnaire with a rating scale from 1-10 and divided into three subscales for pain, function, and activity limitation (Pourtier-Piotte et al., 2015). The KT was applied to the base of the foot, parallel to the direction of the muscle fibres to facilitate movement and reduce the amount of strain on the plantar fascia. The LT was applied with the calcaneus positioned in external rotation to restrict excessive motion of the foot and maintain a neutral position. A significant decrease in pronation was reported with the use of both types of tape. A more substantial decrease in pain and degree of pronation was found with the application of LT compared to KT (Mehta et al., 2017). It was concluded that the LT technique was more beneficial because it restricted excessive ranges of pronation while still permitting optimal and functional movements. Nevertheless, the KT technique chosen was not intended to correct calcaneal eversion and may not have provided an adequate comparison for testing the mechanical effects of each tape. Future research should compare the current LT technique used to a different KT technique that is intended to restrict excessive motion in the foot. Since running is a dynamic task, some flexibility is beneficial to allow for optimal function while at the same time affecting the overall alignment of the lower extremity. Therefore, it is imperative to explore the effect of therapeutic tape while running to determine the most appropriate type of tape to apply during a dynamic activity.

The effect of therapeutic taping during dynamic activity.

Effects of the application of therapeutic tape to the knee. Pelletier, Sanzo, Kivi, and Zerpa (2017) explored the kinematic effects of applying KT and LT to the knee while running. This study included participants both with a history of patellofemoral pain syndrome and a control group with no injury. Participants were asked to run three trials with KT and LT and one trial with no tape (NT). Results from this study suggested that the application of LT led to significant increases in angular displacement at the hip and knee at initial contact, and peak hip flexion angles during the swing phase. As mentioned above, hip and knee kinematics can be significantly altered by misalignment in the foot and ankle region. This study; however, did not explore the effect of taping applied to the knee on the distal joints including the ankle. Therefore, assessing ankle kinematics at initial contact may have provided better insights into the effectiveness of the tape throughout the lower extremity.

Effects of the application of therapeutic tape to the ankle. Low dye taping is commonly used in the treatment of lower limb symptoms related to excessive pronation (O’Sullivan, Kennedy, O'Neill, & Mhainin, 2008). This taping technique consists of an anchor placed medially over the first metatarsal and extending to the lateral side of the foot and to the fifth metatarsal. A series of mini stirrups are then applied to the base of the foot from the lateral side of the foot across the sole, to the medial part of the anchor. Harradine et al. (2001) explored the effect of low dye taping using Leukoplast zinc oxide tape on foot pronation in a static and dynamic position. Participants were included in this study if they displayed a resting calcaneal position greater than 4^{o} of eversion. During the intervention, the participants walked on a treadmill for 30 minutes. Thirty footfalls were recorded before taping, immediately after taping, and 30 minutes after removing the tape. A reduction in pronation was found immediately after the application of tape. Nevertheless, this reduction was lost after 30 minutes of exercise. Since the taping technique only affected and targeted the medial longitudinal arch height, it was suggested that future research should include a taping technique to control calcaneal eversion. As mentioned above, increased ranges of calcaneal eversion, talar adduction, and plantarflexion can result in overpronation (Franettovich et al., 2008).

Sanzo and Bauer (2015) also explored the effect of low dye taping, but with the application of Zinc Oxide tape. Participants were included in this study if they were diagnosed with plantar fasciitis by their family doctor. During the intervention, participants were asked to walk a distance of 50 feet with and without the application of Zinc Oxide tape at a self selected speed for three trials. Vertical foot pressure was examined via F-Scan (Teckscan Incorporated) in sole sensors by including measurements of plantar pressure and center of pressure for both trials with and without Zinc Oxide tape. Results indicated Zinc Oxide tape was effective in slightly decreasing vertical foot pressure under the rearfoot during the contact phase of gait (Sanzo & Bauer, 2015). Nevertheless, no significant differences were found in the midfoot or forefoot regions (Sanzo & Bauer, 2015). As mentioned above, the lack of motion at the medial longitudinal arch, that is common with overpronation, requires a higher degree of calcaneal eversion to compensate (Franettovich, et al., 2008). Furthermore, using a taping technique to target the source of misalignment in the foot, the medial longitudinal arch may be more beneficial in controlling overpronation.

Vincenzino et al. (2005) also examined if applying tape to control overpronation affected the medial longitudinal arch during running. The taping technique included the traditional low dye protocol using LT with the addition of six reverse heel locks and a calcaneal sling extending up the lower leg. This technique was chosen because it aimed to control calcaneal eversion and talar adduction. It was also believed that adding techniques that extended proximally up the leg would provide better control for pronation during exercise. Participants were recruited if they had a difference in vertical navicular height of greater than 10 mm when measured in a static standing position. Vertical navicular height was measured using a Vernier Caliper as the distance from the top of the navicular bone to the floor. For data collection, the tape was applied to the foot with the lowest vertical navicular height while the contralateral foot was used as a control. Videos were taken with the participant in static standing and while walking and jogging with the application of tape to the ankle. The video footage was edited to obtain frames of the midstance phase for each taping condition to determine the difference in vertical navicular height. Results suggested that there was a significant reduction in pronation with the application of tape (Vincenzino et al., 2005). When compared to the control condition, it was evident that the application of tape induced effects regardless of the symptomatic status. Finally, it was concluded that the measurements taken during the static position displayed a strong linear relationship to the measures of pronation during dynamic activity.

Research Problem

Based on the current literature, the application of therapeutic tape has been shown to decrease levels of pain and decrease the amount of pronation during a static position and when completing a dynamic activity. There is, however, limited research examining the mechanical effects of applying therapeutic tape to the ankle while running, as well as its effects with changes in the slope of the running surface. Exploring the effects of overpronation during these conditions is imperative as they have been shown to increase the amount of strain placed on the lower extremity and further increase the risk of injury. Furthermore, understanding the underlying mechanisms of injury will allow a stronger recognition of associated risk factors (Malisoux, Nielsen, Urhausen, & Theisen, 2014). Therefore, it is important to explore the effect of tape on individuals who are running on sloped surfaces compared to a level surface. Examining the effects of therapeutic tape on foot pronation throughout the running gait cycle may also allow patients, coaches, and clinicians to gain insight into the most effective type of tape and technique to control excessive ranges of pronation. Correcting these excessive ranges may further decrease the risk of developing an overuse injury when running across level, inclined, and declined slopes.

Purpose

The purpose of this study was to explore the effect of ankle taping with KT and LT compared to NT on the kinematics of the lower extremity during running on level, inclined, and declined slopes. Based on the literature presented above, the following research questions were used to guide this study:

Hypotheses

1. There will be an interaction effect between the type of therapeutic taping and slope when measuring CT during the running gait cycle.
2. There will be an interaction effect between the type of therapeutic taping and slope when measuring SF during the running gait cycle.
3. There will be an interaction effect between the type of therapeutic taping and slope when measuring SL during the running gait cycle.
4. There will be an interaction effect between the type of therapeutic taping and slope when measuring ankle, knee, and hip angular displacement at initial contact during running.
5. There will be an interaction effect between the type of therapeutic taping and slope when measuring peak knee angular displacement, peak knee valgus, and change in tibial internal rotation during the stance phase of running.
6. There will be an interaction effect between the type of therapeutic taping and slope when measuring ankle, knee, and hip angular displacement at toe off during running.

Method

Participants

Recruitment. After receiving approval from Lakehead University's Research Ethics Board, 40 healthy male and female participants (males = 18, females = 22) between the age of 18 and 30 years were recruited for this cross-sectional study.

Table 1

Participant Characteristics

	Females			**Males**		
	Age (year)	Height (cm)	Mass (kg)	Age (year)	Height (cm)	Mass (kg)
	25	174.5	62.0	22	187.5	93.5
	23	164.5	50.0	30	181.0	70.0
	23	173.0	49.0	25	210.0	95.0
	24	179.0	143.0	23	178.5	81.0
	24	160.0	61.2	25	185.0	75.0
	23	159.5	60.0	23	172.0	75.0
	20	168.5	60.0	23	180.0	87.0
	23	167.0	63.5	26	181.0	81.0
	22	173.0	63.0	23	183.0	84.0
	23	174.5	88.0	25	187.0	110.0
	24	168.5	70.0	23	180.0	73.0
	20	166.5	50.0	25	173.0	77.0
	22	168.0	51.0	25	183.5	83.0
	25	170.5	64.0	27	189.0	62.0
	25	154.0	57.0	21	180.0	66.0
	18	172.5	57.0	25	180.5	66.0
	18	168.0	56.0	20	180.0	79.0
	23	163.0	70.0	26	178.0	172.0
	23	155.0	61.2			
	20	173.0	63.5			
	19	160.0	68.0			
M	22.3	166.8	65.3	24.3	182.7	85.0
SD	2.2	6.9	19.4	2.3	8.11	24.6

A healthy population was selected as opposed to an injured population as injured runners have been found to introduce compensation strategies in their gait to avoid pain (Novacheck, 1998). Exploring the influence of the effects of therapeutic ankle taping using a healthy population may provide better insight into the effects of the tape. Volunteers were recruited through posters (Appendix A) placed throughout the Lakehead University Sanders Building, posted on various forms of social media, and at retail stores throughout the city (Fresh Air Experience and The Running Room). Presentations were also made to various Kinesiology undergraduate classes at Lakehead University. Potential participants were asked to contact the student researcher if they were interested in participating in the study. Upon expressing interest, a copy of the information letter (Appendix B) and cover letter (Appendix C) were emailed to the potential participant to ensure he/she met the inclusion and exclusion criteria.

Inclusion/exclusion criteria. Volunteers were considered potential participants if they were between the age of 18 and 30 years and ran a minimum of 5 km, 2 times per week. Potential participants were excluded if they did not have any contraindications for exercise as indicated by the completion of the Get Active Questionnaire (see Appendix D) prior to participation in the study. Potential participants were also excluded if they had an injury within the past three months that prevented them from running, if they had an injury at the time of the study (i.e., strains or sprains), or if they were pregnant. Pregnant women were excluded from the study as they may experience increases in hormone levels that may result in increased laxity of the joints and alter their movement patterns (McArdle, Katch, F., & Katch, V., 2008). Finally, potential participants were excluded if they had any skin sensitivities or allergies to tape or other adhesives such as band aids to avoid the possible risk of developing a rash on the skin during and after the laboratory session.

Procedures

Set up. To appropriately conduct a three dimensional (3D) kinematic analysis of running gait, three Basler acA1300 digital cameras were set up on tripods surrounding the right side of a Woodway ELG treadmill at the beginning of each testing day (see Figure 6). Two cameras were set up diagonally to the right side of the treadmill and one camera was positioned perpendicular to the treadmill, so the field of view encompassed the participant's right lower extremity.

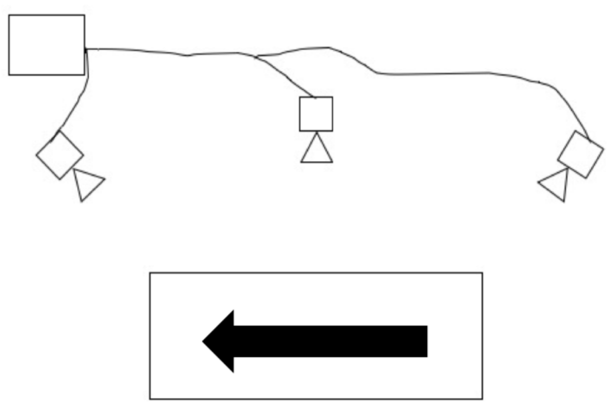

Figure 6. Camera Set Up.

Payton and Bartlett (2008) stated that the use of a proper algorithm will allow the reconstruction of 3D coordinates from two dimensional (2D) image coordinates. The Direct Linear Transformation (DLT) algorithm is the most widely used 3D reconstruction algorithm in sport and exercise biomechanics (Payton & Bartlett, 2008). This method allows more flexibility in the placement of cameras by capturing a 2D image of an object with a set of control points whose 3D coordinates are known (Payton & Bartlett, 2008). To reconstruct the DLT algorithm, a calibration tree was used. As seen in Figure 7, the calibration tree consisted of 8 rods and 32 points extending from the base with a known position along the x, y, and z coordinates.

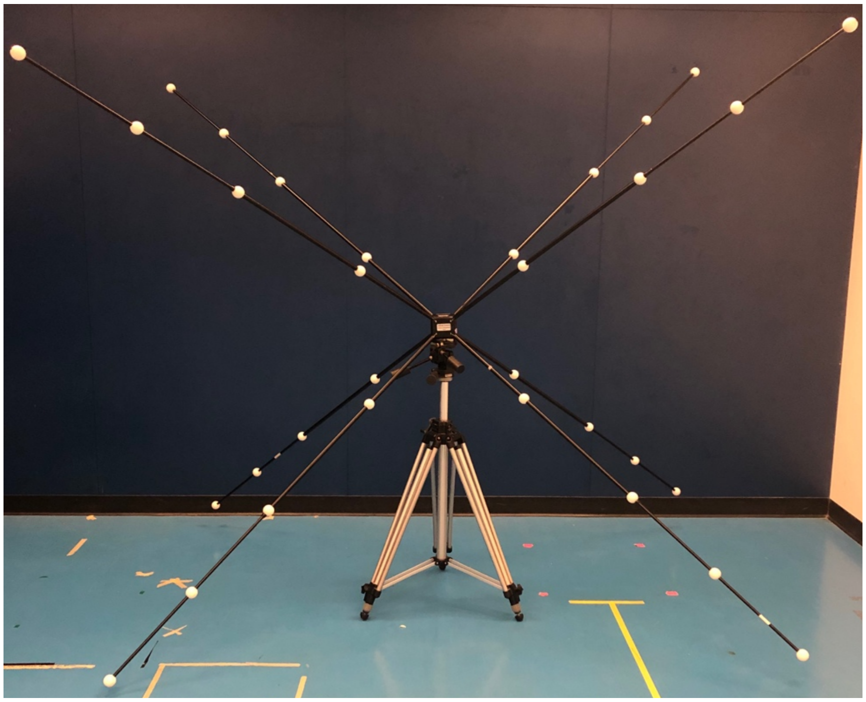

Figure 7. Calibration Tree.

At the beginning of each testing day, a three second video was recorded of the calibration tree, which was placed on the treadmill, to allow the transfer of 2D image coordinates into 3D coordinates (Payton & Bartlett, 2008). Videos were recorded using the Contemplas Templo® motion capture system at a sampling rate of 100 Hz and shutter speed of 1/1000 (Payton & Bartlett, 2008). Vicon Motus© 10.01 software was then used to synchronize the cameras. Due to the high shutter speed used, additional lighting was also placed beside each camera (Figure 8) to increase the amount of light passing through the camera lens during testing.

Figure 8. Camera Lighting.

Data collection. Data collection took approximately 45 minutes to complete. The participant was first asked to read the participant information letter (Appendix B), read and sign the consent form (Appendix C), fill out the Get Active questionnaire (Appendix D), and complete a demographic questionnaire (Appendix E) to ensure his/her eligibility for participation. If the participant did not meet the eligibility criteria, he/she was not permitted to continue with the data collection process of the study. The participant’s static foot type in a weight bearing position was then measured using the FPI scale© for their right foot (see Appendix F). Using a six-item scale with scores for each item ranging from -2 to +2, the participant's foot position was analyzed and scored. A total score ranging from -1 to -4 was indicative of a supinated foot type, -5 to -12 was indicative of a highly supinated foot type, 0 to +5 was indicative of a normal foot type, +6 to +9 was indicative of a pronated foot type, and 10+ was indicative of a highly pronated foot type (Redmond, 1998). Across all participants, 20 displayed a neutral foot type, 17 displayed a pronated foot type, and 3 displayed a highly pronated foot type. The FPI was selected as it has been shown to correlate with dynamic measures of foot function (Neal et al., 2014). This scale also demonstrates good intra-rater reliability (.81-.91) and instrument validity (R^2=.64; Redmond, 1998). The participant was then asked to step onto the treadmill to complete a warm up including a jog at a self-selected speed that represented a comfortable 10 kilometer run with 0% grade for 5 minutes. After the participant completed the warm up, seven reflective markers were placed on the head of the fifth metatarsal, lateral malleolus, calcaneus, femoral epicondyle, and greater trochanter of the right leg (Figure 9; Richards, 2008). The sixth and seventh markers, referred to as wands, were placed in the middle of the lateral aspect of the tibia and femur (Richards, 2008). These markers allowed the Vicon Motus© software to interpret the body position within a 3D space.

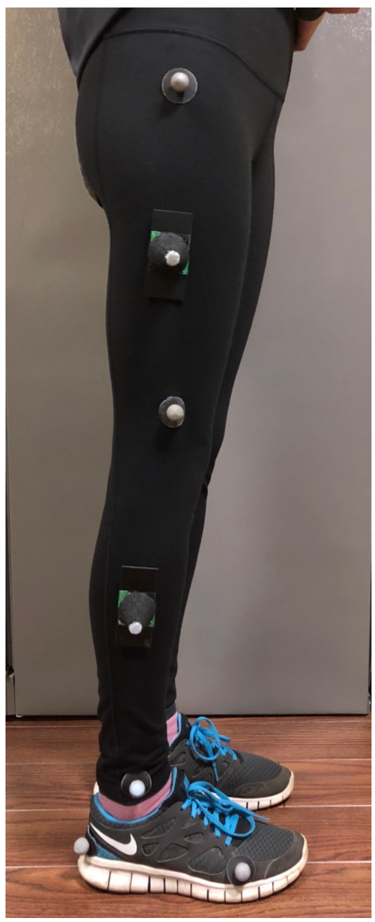

Figure 9. Modified Helen Hayes Marker Set.

After the markers were placed on the participant's right lower extremity, he/she was assigned his/her first taping condition and slope. The order of conditions was predetermined by the researcher using a Latin Square technique.

The taping conditions included trials with the application of KT and LT, and NT. To ensure consistency, the student researcher was the only individual to apply the tape. The student researcher had previous taping experience as a student trainer working with kinesiologists and physiotherapists for Lakehead University and the Thunder Bay Chill soccer teams.

As seen in Figure 10, for the foot pronation KT technique, the participant was asked to sit in a chair with his/her right leg elevated and resting on a chair. Three 20 cm strips of tape were applied to the foot with the ankle held in a relaxed, neutral position. The first piece of tape was anchored on the dorsal surface of the third cuneiform of the lateral midfoot and wrapped laterally under the calcaneus with 50-75% tension around the posterior ankle ending on the apex of the medial malleolus (Kase, Martin, Yasukawa, 2006). The second piece of tape was applied to the dorsal surface of the second cuneiform of the medial midfoot and wrapped around the calcaneus medially around the posterior ankle ending on the apex of the lateral malleolus with 50-75% tension (Kase, Martin, Yasukawa, 2006).. The third piece of tape extended from the dorsal surface of the third cuneiform of the lateral midfoot, wrapped laterally around the posterior aspect of the ankle, over the navicular, and extended up to the medial distal third of the lower leg just above the medial malleolus with 50-75% tension (Kase, Martin, Yasukawa, 2006). Each strip of tape was then rubbed three times in the direction of the tension to activate the adhesive allowing the tape to firmly adhere to the participant’s skin.

Figure 10. Foot Pronation Kinesio Tape® Technique.

As seen in Figure 11 for the Modified Mulligan calcaneal LT technique, the participant was also asked to sit in a chair with his/her right leg elevated and resting on a chair. A 20 cm piece of LT was applied 5 cm above the inferior border of the lateral malleolus and laid diagonally across the lateral surface of the calcaneus. The calcaneus was held in an externally rotated and adducted position while pulling the tape around the posterior aspect of the calcaneus and up and around the ankle medially, anchoring onto the lateral aspect of the tibia (Agrawal & Deshpande, 2015). The tape was then rubbed three times to activate the glue and insure adhesion. After the tape was applied, the participant had the opportunity to walk around to make sure it was applied in a comfortable way. If it was uncomfortable, corrections were made to the taping technique.

Figure 11. Modified Mulligan Calcaneal Leuko Tape P® Technique.

Once the tape was applied, the participant was asked to step onto the treadmill to complete testing for the first taping condition. The participant was asked to run for a total of 3 minutes at a speed which was 10% faster than the self selected speed chosen for the warm up (Queen, Gross, & Liu, 2006). The test speed was calculated by the student researcher and provided to the participant at the beginning of the first trial (M = 2.86 m/s ± .33). Vincent et al. (2014) stated that differences in muscle activation patterns and ground reaction forces exist beginning at 2 m/s. Therefore, the participant's running speed was monitored to ensure it did not fall below this value. The first minute of each tape condition included the first predetermined slope trial (level, incline, or decline). After the first trial was completed, the participant slowed his/her speed and adjusted the treadmill to the next predetermined slope. The second and third trial occurred in sequence with the remaining two predetermined conditions. For the inclined condition, the treadmill slope was increased to 5% and reduced to -5% for the declined condition. A slope of ± 5% was selected as previous research reported that biomechanical changes in running gait occur at and beyond these ranges (Mizrahi et al., 2000; Padulo et al., 2013; Snyder, Kram, & Gottschall, 2012).

After the three trials with the first tape condition were completed, the participant was asked to slow his/her speed to a stop and step off of the treadmill. He/she was then assigned his/her second tape condition and the participant was asked to sit as the second type of tape was applied. This time was also considered as a rest period where the participant remained sitting for a period of approximately 5 minutes while the tape was being applied. For the NT condition, the participant was asked to step off the treadmill for a rest period of 5 minutes; however, NT was applied. The participant was then asked to step back onto the treadmill to complete three trials using the second and third tape condition following the same instructions as the first. After data collection was completed, the participant remained on the treadmill and performed a 2 minute cool down walking at a comfortable speed under the guidance and supervision of the student researcher.

Video collection occurred using the Contemplas Templo® motion capture system. Approximately three seconds and five strides within the last 10 seconds of each trial were used for further analysis (Vincent et al., 2014).

Data processing. Data were analyzed using the Vicon Motus© 10.01 motion analysis software program. Three consecutive running strides were digitized for each participant. The data was smoothed with a Butterworth digital filter before extraction occurred. The optimal cut off frequency ranged from 3 to 9 Hz as determined using the Jackson Knee Method (Jackson, 1979). The Butterworth digital filter was selected based on previous research (Pelletier et al., 2018; Swanson & Caldwell, 2000).

Reliability Assessment

Intra-rater reliability is used to assess the degree to which the same researcher gives consistent estimates of the same phenomenon across time (Payton & Bartlett, 2008). To test the intra-rater reliability for this study, a trial was randomly selected to be digitized twice. Measures of angular displacement for each joint angle listed in Table 2 were then extracted and quantified using the interclass correlation coefficient (ICC). The ICC values for each measurement ranged from .832 – .999 indicating good to excellent intra-rater reliability.

Table 2

Intra-rater Reliability

	ICC	**RMSE**
Hip Angle	.967	.13
Knee Angle	.998	.11
Ankle Angle	.998	.19
Knee Valgus	.832	.01
Tibial Internal Rotation	.999	.01

Data Analysis

Statistical analysis was completed using IBM SPSS©V25 software. Descriptive statistics were calculated for the data obtained from the demographic questionnaire, FPI scale©, and for the independent and dependent variables of interest. Repeated measures factorial analyses of variance (ANOVAs) were performed to examine the interaction effects between the independent variables for each dependent variable to address each of the research questions. The statistical significance was set at $p < .05$. Independent variables included the type of therapeutic tape (KT, LT, or NT) and slope of the running surface (incline, decline, or level). Dependent variables included spatio-temporal measurements of CT, SF, and SL and angular displacement measurements of the hip at initial contact and toe off phases of running, knee flexion at the initial contact and toe off phases of running, peak (maximum) knee angle and peak knee valgus during the stance phase of running, and change in tibial internal rotation during the stance phase of running.

Contact time. Contact time (s) was measured as the amount of time the foot was in contact with the surface for each stride. Contact time was measured by subtracting the time of initial contact of one foot from the time of toe off of that same foot.

Stride frequency. Stride frequency (Hz) was analyzed by counting the number of frames to complete five running strides. The number of strides was then divided by the number of frames to represent the number of strides per second.

Stride length. Calculated using the equation: SL = Velocity (m/s) / SF (Mercer, Devita, Derrick, & Bates, 2003; Padulo et al., 2013). This equation was selected based on previous literature as it demonstrated excellent intra-rater reliability with an ICC ranging from .95-.98 (Mercer, Devita, Derrick, & Bates, 2003; Padulo et al., 2013).

Ankle angle. The ankle angle (^{o}) was measured as the angle between the lower leg and foot segments. A neutral ankle position was represented by 0^o, where positive angles represented ankle plantarflexion and negative values represented ankle dorsiflexion.

Knee angle. The knee angle (^{o}) was measured as the angle between the thigh and lower leg segments. Full knee extension was represented as 0^o degrees, with larger angles indicative of increased angles of knee flexion and negative values indicative of hyperextension.

Hip angle. The hip angle (^{o}) was measured as angle between the Y plane (Figure 12) and the thigh segment, where positive values represented angles of hip flexion and negative values represented angles of hip extension.

Knee valgus angle during stance. Knee valgus (°) was measured as the angle between the thigh segment (greater trochanter), patella, and lower leg segment (lateral malleolus) in reference to the YZ plane (Figure 12). The degree of knee valgus was extracted during the middle of the midstance phase when the participant reached a point of maximum knee flexion before extending at toe off. Values of 0º represented a neutral angle, negative values represented knee valgus, and positive values represented knee varus.

Change in tibial internal rotation angle during stance. In the case of tibial internal rotation, a moving plane was created between the knee (patella) and the lower leg (tibial wand). As a result, the tibial internal rotation angle (°) was defined as the angle between the moving plane (tibia) and XZ reference plane (Figure 12) from the moment of initial contact to the peak angle seen during stance. This angle was calculated by subtracting the peak tibial internal rotation angle from the tibial internal rotation angle at initial contact. Negative values were indicative of tibial internal rotation and positive values were indicative of tibial external rotation.

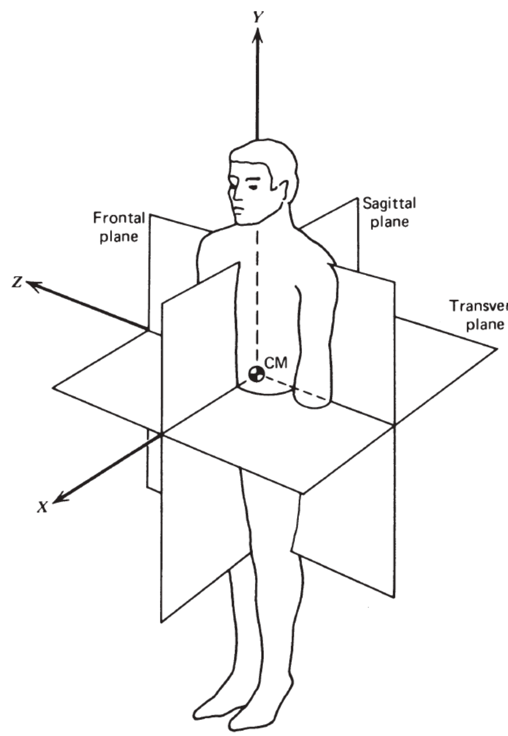

Figure 12. Spatial coordinate system for all data and analyses. Adapted from "Biomechanics and Motor Control of Human Movement" by D. Winter (4^{th} ed.), p.47.

Results

The analysis focused on exploring the effect of therapeutic ankle taping with KT and LT compared to NT on the kinematics of the lower extremity during running on level, inclined, and declined slopes.

Hypothesis 1: There Will be an Interaction Effect Between the Type of Therapeutic Taping and Slope When Measuring Contact Time During the Running Gait Cycle

Descriptive statistics. The mean (± SD) across participants for CT during the stance phase of running are presented for the type of therapeutic tape and slope in Table 3.

Table 3

Mean Contact Time (± SD) During the Stance Phase of Running

	Foot Pronation KT Tape Technique (s)	Modified Mulligan Calcaneal LT Technique (s)	No Tape (s)
Level	.24 (± .03)	.24 (± .02)	.24 (±.03)
Incline	.24 (± .03)	.24 (± .03)	.24 (± .03)
Decline	.24 (± .03)	.24 (± .02)	.24 (± .02)

Values are presented as mean (± SD).

Interaction effects. The repeated measures factorial ANOVA revealed that there was no significant interaction effect between the type of therapeutic tape and slope on mean CT during the stance phase of running, F (4, 156) = .62, p = .650.

Main effects. The repeated measures factorial ANOVA for mean CT during the stance phase of running did not reveal a significant main effect for the type of therapeutic tape, F (2, 78) = 1.17, p = .317. Similarly, for mean CT during the stance phase of running, no significant main effect was found for slope, F (2,78) = 2.02, p = .139.

Hypothesis 2: There Will be an Interaction Effect Between the Type of Therapeutic Taping and Slope When Measuring Stride Frequency During the Running Gait Cycle

Descriptive statistics. The mean (± SD) across participants for SF during the running gait cycle are presented for the type of therapeutic tape and slope in Table 4.

Table 4

Mean Stride Frequency Values (± SD) During the Running Gait Cycle

	Foot Pronation KT Tape Technique (Hz)	**Modified Mulligan Calcaneal LT Technique (Hz)**	**No Tape (Hz)**
Level	1.57 (± .08)*	1.57 (± .09)*	1.57 (± .08)*
Incline	1.58 (± .09)*	1.57 (± .09)*	1.58 (± .08)*
Decline	1.56 (± .08)	1.56 (± .09)	1.56 (± .08)

Values are presented as mean (± SD).

*Significantly different from declined running ($p < .05$).

Interaction effects. The repeated measures factorial ANOVA revealed that there was no significant interaction effect between the type of therapeutic tape and slope on mean SF during the running gait cycle, $F\ (4, 156) = .87$, $p = .482$.

Main effects. The repeated measures ANOVA for SF during the running gait cycle revealed a significant main effect for slope with a low effect size, $F\ (2, 78) = 9.74$, $p = .001$, $\eta_p^2 = .200$. Post hoc analysis revealed that the SF while running on a declined slope (1.56 Hz ± .013, $p = .028$) was decreased when compared to the SF while running on a level slope (1.57 Hz ± .013, $p = .028$) and an inclined slope (1.58 Hz ± .013, $p = .003$). There was no significant difference in SF between the inclined and level slope ($p = .072$). There was also no significant main effect on SF during the running gait cycle for the different types of therapeutic tape, $F = (2, 78) = .16$, $p = .853$.

Hypothesis 3: There Will be an Interaction Effect Between the Type of Therapeutic Taping and Slope When Measuring Stride Length During the Running Gait Cycle

Descriptive statistics. The mean (± SD) across participants for SL during the running gait cycle are presented for the type of therapeutic tape and slope in Table 5.

Table 5

Mean Stride Length Values (± SD) During the Running Gait Cycle

	Foot Pronation KT Tape Technique (m)	Modified Mulligan Calcaneal LT Technique (m)	No Tape (m)
Level	1.82 (± .20)	1.82 (± .20)	1.82 (± .20)
Incline	1.81 (± .20)*	1.82 (± .19)*	1.81 (± .20)*
Decline	1.83 (± .21)	1.83 (± .21)	1.84 (± .21)

Values are presented as mean (± SD).

*Significantly different from declined running ($p < .05$).

Interaction effects. The repeated measures factorial ANOVA revealed that there was no significant interaction effect between the type of therapeutic tape and slope on SL during the running gait cycle, F (4, 156) = 2.27, $p = .064$.

Main effects. The repeated measures ANOVA for SL during the running gait cycle revealed a significant main effect for slope with a low effect size, F (1.48, 56.08) = 6.25, $p = .007$, $\eta_p^2 = .138$. Post hoc analysis revealed that SL when running on the declined slope (1.83 m ± .03, $p = .026$) was longer than the SL when running on the inclined slope (1.82 m ± .03, $p = .026$). There was no significant difference, however, for the SL between running on the level slope and declined slope ($p = .076$) and between the level and inclined slope ($p = .205$). There was also no significant main effect on SL during the running gait cycle for the different types of therapeutic tape, F = (1.63, 63.46) = 1.03, $p = .349$.

Hypothesis 4: There Will be an Interaction Effect Between the Type of Therapeutic Taping and Slope When Measuring Mean Ankle, Knee, and Hip Angular Displacement at Initial Contact During Running

Descriptive statistics. The mean (± SD) across participants for ankle angular displacement at initial contact during running are presented for the type of therapeutic tape and slope in Table 6.

Table 6

Mean Ankle Angular Displacement (± SD) At Initial Contact During Running

	Foot Pronation KT Tape Technique (°)	Modified Mulligan Calcaneal LT Technique (°)	No Tape (°)
Level	4.2 (± 10.6)	1.9 (± 5.7)	2.1 (± 5.4)
Incline	3.9 (± 4.7)	2.8 (± 5.2)	3.7 (± 4.9)
Decline	1.2 (± 6.0)	1.2 (± 5.8)	1.8 (± 5.7)

Values are presented as mean (± SD).

The mean (± SD) across participants for knee angular displacement at initial contact during running are presented for the type of therapeutic tape and slope in Table 7.

Table 7

Mean Knee Angular Displacement (± SD) At Initial Contact During Running

	Foot Pronation KT Tape Technique (°)	Modified Mulligan Calcaneal LT Technique (°)	No Tape (°)
Level	16.6 (± 5.4)	15.0 (± 5.1)	16.5 (± 4.7)
Incline	21.2 (± 5.5)	21.8 (± 10.0)	20.7 (± 4.4)
Decline	14.7 (± 5.5)	17.1 (± 5.0)	14.6 (± 5.1)

Values are presented as mean (± SD).

The mean (± SD) across participants for hip angular displacement at initial contact during running are presented for the type of therapeutic tape and slope in Table 8.

Table 8

Mean Hip Angular Displacement (± SD) At Initial Contact During Running

	Foot Pronation KT Tape Technique (^{o})	**Modified Mulligan Calcaneal LT Technique (^{o})**	**No Tape (^{o})**
Level	20.0 (± 4.2)	19.5 (± 3.9)	20.0 (± 3.9)
Incline	23.6 (± 4.2)	23.0 (± 4.6)	23.7 (± 4.5)
Decline	17.7 (± 4.3)	17.3 (± 4.4)	17.5 (± 3.8)

Values are presented as mean (± SD).

Interaction effects. The repeated measures factorial ANOVA revealed that there was no significant interaction effect between type of therapeutic tape and slope on mean ankle angular displacement at initial contact during running, F (1.55, 60.60) = 1.77, p = .185. There was also no significant interaction effect between the type of therapeutic tape and slope on mean knee angular displacement at initial contact during running, F (1.80, 70.20) = .14, p = .853. Finally, there was no significant interaction effect between the type of therapeutic tape and slope on mean hip angular displacement at initial contact during running, F (2.84, 110.66) = .11, p = .946.

Main effects. The repeated measures factorial ANOVA for mean ankle angular displacement at initial contact during running also did not reveal a significant main effect for the type of therapeutic tape, F (1.63, 63.46) = 2.27, p = .121. The repeated measures factorial ANOVA for mean knee angular displacement at initial contact during running did not reveal a significant main effect for the type of therapeutic tape, F (1.65, 64.48) = .73, p = .460. The repeated measures factorial ANOVA for mean hip angular displacement at initial contact during running did not reveal a significant main effect for the type of therapeutic tape, F (1.55, 60.34) = 1.42, p = .249.

Hypothesis 5: There Will be an Interaction Effect Between the Type of Therapeutic Taping and Slope When Measuring Peak Knee Angular Displacement, Peak Knee Valgus, and Change in Tibial Internal Rotation During the Stance Phase of Running

Descriptive statistics. The mean (± SD) across participants for peak knee angular displacement during the stance phase are presented for the type of therapeutic tape and slope in Table 9.

Table 9

Peak Knee Angular Displacement (± SD) During the Stance Phase of Running

	Foot Pronation KT Tape Technique (^{o})	**Modified Mulligan Calcaneal LT Technique (^{o})**	**No Tape (^{o})**
Level	38.7 (± 6.6)*	38.0 (± 6.4)	38.2 (± 5.7)
Incline	39.7 (± 6.1)*	38.4 (± 6.2)	40.1 (± 5.5)
Decline	38.1 (± 5.8)*	37.3 (± 6.3)	38.2 (± 5.7)

Values are presented as mean (± SD).

*Significantly different from LT ($p < .05$).

The mean (± SD) across participants for peak knee valgus during the stance phase are presented for the type of therapeutic tape and slope in Table 10.

Table 10

Peak Knee Valgus Angular Displacement (± SD) During the Stance Phase of Running

	Foot Pronation KT Tape Technique (^{o})	**Modified Mulligan Calcaneal LT Technique (^{o})**	**No Tape (^{o})**
Level	-2.4 (± 6.7)	-1.9 (± 6.7)	-2.5 (± 7.0)
Incline	-2.2 (± 7.1)	-1.1 (± 7.3)	-.9 (±7.1)
Decline	-1.3 (± 7.1)	-1.4 (± 7.2)	-1.9 (± 7.0)

Values are presented as mean (± SD).

The mean (± SD) across participants for change in tibial internal rotation angle during the stance phase are presented for the type of therapeutic tape and slope in Table 11.

Table 11

Mean Change in Tibial Internal Rotation Angular Displacement (± SD) During the Stance Phase of Running

	Foot Pronation KT Tape Technique (°)	**Modified Mulligan Calcaneal LT Technique (°)**	**No Tape (°)**
Level	-8.9 (± 8.4)	-10.8 (± 7.3)	-9.3 (± 7.7)
Incline	-10.8 (± 6.6)	-11.2 (± 6.5)	-10.0 (± 6.4)
Decline	-11.2 (± 7.0)	-10.6 (± 6.7)	-10.3 (± 6.8)

Values are presented as mean (± SD).

Interaction effects. The repeated measures factorial ANOVA revealed that there was no significant interaction effect between the type of therapeutic tape and slope on peak knee angular displacement during the stance phase of running, F (3.14, 122.31) = 1.12, p = .345. There was also no significant interaction effect between the type of therapeutic tape and slope on peak measures of angular displacement, F (4,156) = 1.40, p = .246. Finally, there was no significant interaction effect between the type of therapeutic tape and slope on mean measures of angular displacement, F (4, 156) = 1.39, p = .239.

Main effects. The repeated measures factorial ANOVA for peak knee angular displacement during the stance phase of running revealed a significant main effect for the type of therapeutic tape with a low effect size, F (2, 78) = 3.61, p = .032, η_p^2 = .085. Post hoc analysis revealed a significant increase in peak knee flexion during the stance phase of running with the application of KT (38.83 ± .93, p = .048) when compared to LT (37.92 ± .94, p = .048). Nevertheless, there was no significant difference when comparing KT to NT (p = 1.00), or LT and NT (p = .059). There was also no significant main effect for peak knee valgus during the stance phase of running for the type of therapeutic tape on measures of angular displacement,

F (1.64, 63.98) = .90, p = .393. Similarly, for mean change in tibial internal rotation during the stance phase of running, there was no significant main effect for the type of therapeutic tape on measures of angular displacement, F (2, 78) = 1.82, p = .169.

Hypothesis 6: There Will be an Interaction Effect Between the Type of Therapeutic Taping and Slope When Measuring Ankle, Knee, and Hip Angular Displacement at Toe Off During Running

Descriptive statistics. The mean (± SD) across participants for ankle angular displacement at toe off during running are presented for the type of therapeutic tape and slope in Table 12.

Table 12

Mean Ankle Angular Displacement (± SD) At Toe Off During Running

	Foot Pronation KT Tape Technique (^{o})	**Modified Mulligan Calcaneal LT Technique (^{o})**	**No Tape (^{o})**
Level	-5.6 (± 15.2)	-7.2 (± 9.9)	-10.0 (± 7.2)
Incline	-5.7 (± 10.2)	-5.4 (± 10.3)	-7.6 (± 7.9)
Decline	-6.8 (± 11.0)	-6.6 (± 10.3)	-8.8 (± 9.2)

Values are presented as mean (± SD).

The mean (± SD) across participants for knee angular displacement at toe off during running are presented for the type of therapeutic tape and slope in Table 13.

Table 13

Mean Knee Angular Displacement (± SD) At Toe Off During Running

	Foot Pronation KT Tape Technique (^{o})	**Modified Mulligan Calcaneal LT Technique (^{o})**	**No Tape (^{o})**
Level	19.5 (± 8.1)	19.1 (± 8.3)	17.8 (± 7.3)
Incline	18.5 (± 8.3)	19.5 (± 9.0)	18.9 (± 7.8)
Decline	20.1 (± 8.0)	20.5 (± 7.4)	20.7 (± 7.5)

Values are presented as mean (± SD).

The mean (± SD) across participants for hip angular displacement at toe off during running are presented for the type of therapeutic tape and slope in Table 14.

Table 14

Mean Hip Angular Displacement (± SD) At Toe Off During Running

	Foot Pronation KT Tape Technique (^{o})	**Modified Mulligan Calcaneal LT Technique (^{o})**	**No Tape (^{o})**
Level	-13.5 (± 10.8)	-12.4 (± 11.3)	-14.0 (± 11.6)
Incline	-13.0 (± 10.7)	-12.7 (± 12.4)	-13.2 (± 11.3)
Decline	-13.1 (± 12.7)	-13.1 (± 11.6)	-13.8 (± 11.2)

Values are presented as mean (± SD).

Interaction effects. The repeated measures factorial ANOVA revealed that there was no significant interaction effect between the type of therapeutic tape and slope on mean ankle angular displacement at toe off during running, F (3.10, 120.69) = .64, p = .594. There was also no significant interaction effect between the type of therapeutic tape and slope on mean knee angular displacement at toe off during running, F (3.11, 121.34) = 2.23, p = .068. Finally, there was no significant interaction effect between the type of therapeutic tape and slope on mean hip angular displacement at toe off during running, F (2.73, 106.28) = .44, p = .708.

Main effects. The repeated measures factorial ANOVA for mean ankle angular displacement at toe off during running revealed that there was no significant main effect for the type of therapeutic tape, F (1.66, 64.71) = 3.23, p = .055. There was also no significant main effect of the type of therapeutic tape for knee angular displacement at toe off during running, F (2, 78) = .69, p = .507. Finally, there was no significant main effect for the type of therapeutic tape for hip angular displacement at toe off during running, F (1.82, 70.79) = 1.24, p = .293.

Discussion

The results of this study indicated that there was no change in CT while running on level, inclined, and declined slopes with the application of therapeutic tape. When comparing the results of the current study to previous research, Lussiana et al. (2013) also did not find a significant change in CT while running on level, inclined, and declined slopes. Conversely, Swanson and Caldwell (2000) found decreases in CT while running on an inclined slope. Nonetheless, Swanson and Caldwell (2000) also had participants run at an average speed of 7.61 m/s and an incline of 30% whereas participants in the current study ran at an average speed of 2.86 m/s and a grade of 5%. Farley and González (1996) stated that as individuals increase their running speed, the vertical displacement of the centre of mass decreases during the stance phase. As a result, CT also decreases. Additionally, as treadmill slope increases, ground reaction forces decrease (Swanson & Caldwell, 2000). Furthermore, decreases in CT with an increased slope may be beneficial in reducing the amount of time that ground reaction forces are being applied to the runner. Nevertheless, a 5% inclined slope may not be large enough to require a change in CT at a relatively slow running speed. As no changes in CT were found, results may suggest that there were no adverse effects from the application of therapeutic tape on the lower extremity using the methods of taping included within this current study. As changes in CT can provide important descriptive information regarding the body's ability to adjust to changes in speed and slope, additional changes caused by the application of therapeutic tape may alter the running stride in a way that can decrease the metabolic efficiency.

There was no significant interaction effect between the type of therapeutic tape and slope for mean SF during the running gait cycle. Thus, SF was found to be significantly smaller while running on the declined slope (1.56 Hz ± .013, $p = .028$) when compared to the level (1.57 Hz ±

.013, p = .028) and inclined slope (1.58 Hz ± .013, p = .003). Previous research has also identified decreases in SF while running on a -5% slope, but the reported SF was larger when compared to the current study (2.7 Hz; Lussiana et al., 2013). As participants in the current study ran an average of 2.86 m/s, Lussiana et al. (2013) reported that participants ran at an average speed of 2.7 m/s. Therefore, it was found that SF decreases with increased running speeds. As participants within the current study were required to run at a self-selected speed that would represent a comfortable 10 kilometer run, they may not have reached speeds fast enough to require a shortened SF. Additionally, Hamill, Derrick, and Holt (1995) found that increases in ground reaction forces at initial contact can result from an increase in running speed or from running on a declined slope. Therefore, a decreased SF would be beneficial while running on a declined slope to reduce the number of impacts over the duration of a run as the loads resulting from repeated impacts may increase the risk of overuse injuries. As no significant differences were found between the therapeutic taping and NT conditions, results suggest that there was no effect of anti-pronation taping on stride frequency while running. This is beneficial because if changes did occur, they may have affected the SF in an adverse way that could either increase the shock of landing or alter electromyography (EMG) and kinetics of the lower extremity (Schubert et al., 2014). Although measurements of EMG and kinetics were not included within this current study, it is believed that alterations within those variables could be indicated by a change in SF (Schubert et al., 2014).

There was no interaction effect between therapeutic taping and slope on mean SL during the running gait cycle. Nevertheless, SL was significantly larger when running on a declined slope (1.83 m ± .03, p = .026) as compared to running on an inclined slope (1.82 m ± .03, p = .026). Similarly, previous research also found an increase in SL when running on a declined surface when compared to an inclined surface without the application of therapeutic tape (Derrick et al., 1998; Swanson & Caldwell, 2000). As shock attenuation has also been found to increase along with SL, such changes in SL may be beneficial while running on a declined slope (Hardin et al., 2004). These changes might be beneficial as running on a declined slope has been found to result in increased impact on the lower extremity (Hardin, 2004). Furthermore, as decreases in SF were also found while running on a declined slope when compared to a level and inclined slope, it is suggested that the participants within the current study adopted necessary adaptations to reduce the degree of impact while running on the declined slope over the duration of the testing session. Significant changes in SL and SF have been reported to be the result of increased angular displacement throughout the lower extremity (Schubert et al., 2014). Therefore, insignificant differences with application of KT and LT compared to NT indicate that the application of therapeutic tape did not alter the angular displacement at the ankle, knee, and hip in an adverse way that would have affected SF and SL.

There was no significant interaction effect between the type of therapeutic tape and slope for mean ankle, knee, and hip angular displacement at initial contact during running. When comparing the results of this current study to previous research, a decrease in angular displacement was found in the ankle (12-19^{o} of dorsiflexion), and hip (30-40^{o} of flexion) while running on a level slope (Ferber & McDonald, 2014; Novacheck, 1998). A decrease in angular displacement was also found at the ankle (9^{o} plantarflexion) and hip (25^{o} of flexion) while running on an inclined slope (Swanson & Caldwell). Finally, an increase in angular displacement was found in previous literature at the knee (5^{o} of flexion) while running on a declined slope when compared to this current study (Lussiana et al., 2013). This may be explained by differences in angle definition and marker placement among the studies. Differences in angular displacement when compared to previous research may also result from differences in running slope. As the previous studies mentioned above had participants running on different slopes than the current study, caution should be taken when comparing differences in angular displacement. Nonetheless, at initial contact, the hip and knee are slightly flexed as the heel contacts the ground with the foot in a supinated position to better attenuate the shock from landing (Ferber & McDonald, 2014; Nicola & Jewison, 2012). Dugan and Bhat (2005) also stated that angular displacement at the ankle, knee, and hip is a key function in shock absorption at initial contact. Furthermore, along with dorsiflexion at the ankle joint, knee and hip flexion help to dissipate the force of the impact with the surface. Since the foot is typically in a position of supination at this point of the running gait cycle, the application of anti-pronation taping may not have had an effect. Additionally, the degree of pronation or supination were not measured directly during the running gait cycle, exact conclusions cannot be drawn regarding the foot motion at this point of the running gait cycle. Therefore, as an equal number of participants within this study displayed a neutral and pronated foot type, it can be assumed that the effects of overpronation may not have affected the angular displacement at the ankle, knee, and hip at initial contact.

There was no significant interaction effect between the type of therapeutic tape and slope for peak knee angular displacement at initial contact during running. Nevertheless, there was a significant main effect of the type of therapeutic tape on peak knee angular displacement during the stance phase of running. Furthermore, the application of LT decreased the amount of knee flexion during the stance phase of running when compared to KT and was approaching significance when compared to NT. Due to the rigid properties of the tape, it was expected that LT would be more beneficial in controlling excessive angular displacement when compared to KT and NT. As increased knee flexion during the stance phase has been reported to be the result of increased overpronation, LT may be more beneficial in controlling excessive ranges of knee flexion during the stance phase (Dugan & Bhat, 2005; Lattanza et al., 1988). When running on an inclined slope, the application of LT decreased the degree of knee flexion when compared to KT and NT. Hamill et al. (1995) also stated that the musculoskeletal system is able to attenuate shock by manipulating kinematics. Furthermore, pronation and increased knee flexion are two key mechanisms that the body uses to attenuate shock. As it was suggested that individuals increase their degree of pronation and knee flexion during the stance phase of running to maintain a metabolically optimal SF, decreasing the degree of peak knee flexion may be beneficial in controlling excessive ranges of pronation throughout the stance phase (Hamill et al., 1995). When running on a declined slope, the application of LT also decreased the degree of peak knee flexion. Moreover, running on a declined slope has been found to increase ground reaction forces due to a decrease in angular displacement throughout the lower extremity (Hamill et al., 1995). Therefore, as decreases in peak knee flexion with the application of therapeutic tape were beneficial while running on an inclined surface, they may have restricted the necessary movement to attenuate the shock of landing on a declined surface. Nevertheless, as these differences were slight and the values still fell within the ranges of previous research, the application of therapeutic tape while running on a declined slope was not found to affect the lower extremity in an adverse way (Ferber & McDonald, 2014; Novacheck, 1998). Additionally, as an equal number of participants in this study demonstrated a neutral and pronated foot type, it is believed that the application of therapeutic tape was beneficial in controlling excessive ranges of peak knee flexion during the stance phase of running for not only a pronated foot type, but a neutral foot type as well.

There was no significant interaction effect between the type of therapeutic tape and slope when measuring peak knee valgus and change in tibial internal rotation during the stance phase of running. As increased knee valgus and change in tibial internal rotation are often caused by overpronation, increased angular displacement was expected during the NT trials and decreases were expected with the application of therapeutic tape (Dugan & Bhat, 2005). As previous research exploring the influence of therapeutic ankle taping has found a decrease in pronation while running, it can be suspected that the taping conditions used in this current study did not support the foot and ankle enough to produce significant results for knee valgus and change in tibial internal rotation (Vincenzino, et al., 2005). As mentioned above, Vincenzino et al. (2005) used the traditional low dye taping technique with the addition of six reverse heel locks and a calcaneal sling extending up the lower leg. Furthermore, they believed that the addition of techniques that extended up the lower extremity would provide better control for pronation during exercise. As the foot absorbs up to 2.2 times the amount of body weight with every impact, a complex taping technique to control the position of the calcaneus that extends up the lower leg may have been more beneficial in supporting and reinforcing the effects of the tape (Dugan & Bhat, 2005; Vincenzino et al., 2005).

There was also no significant interaction effect between the type of therapeutic tape and slope on measures of ankle, knee, and hip angular displacement at toe off during running. When compared to other research, values at the ankle and knee fell within ranges previously described (Ferber & McDonald, 2014; Novacheck, 1998). Nevertheless, previous research has shown that the hip is positioned anywhere between 2^{o} of extension and 10^{o} of flexion (Ferber & McDonald, 2014). As the results of this study ranged between 12.4^{o} – 14^{o} of extension, differences in angular displacement can indicate that either the angles were defined differently as compared to the current study. As mentioned earlier, at the toe off phase of running, the hip and knee are extended with the ankle in a locked and supinated position to create a stiff joint lever to propel the individual through the swing phase. Dugan and Bhat (2005) stated that each of the factors contributing to the formation of a rigid foot is critical in generating the force that is required at that instant of the running gait cycle. As there was no effect of therapeutic tape on angular displacement at the ankle, knee, and hip during this phase of running, it can be suggested that the application of anti-pronation tape did not restrict the foot from moving through proper ranges of supination. This can be expected as previous research involving the use of foot orthotics has reported a decrease in pronation during the first half of the midstance phase, but no effect on foot eversion during the second half of the midstance phase (Mündermann, Nigg, Humble, & Stefanyshyn, 2003). Additionally, foot pronation extending through the second half of the midstance phase can restrict necessary motion into supination. As the purpose of applying therapeutic tape is to directly correct foot posture, control motion, and reduce stress on the plantar surface of the foot, no effect of tape on lower extremity kinematics can also suggest that the foot and ankle were already stable enough to support the body on their own (Franettovich et al., 2008). Furthermore, these results may have also occurred as only healthy participants were included within this study. If injured participants were included, they may have had a larger benefit from the supporting properties of the therapeutic tape.

Practical Application

Based on the results of the study, it is suggested that the application of LT was beneficial during the stance phase of running. As LT is rigid in nature, its unyielding properties were found to support increased knee flexion during the stance phase of running on level, inclined, and declined slopes. As increased knee flexion during the stance phase of running has been found as a result of overpronation, the application of LT may be beneficial in controlling excess ranges and prevent the risk of overuse injury. Nevertheless, the application of therapeutic tape did not have an effect on peak knee valgus and change in tibial internal rotation. As increased knee valgus and tibial internal rotation are also often caused by overpronation, an alternate taping technique may be more beneficial in reinforcing the effects of the tape. Furthermore, Vincenzino et al. (2005) found a decrease in pronation while running with the application of a traditional low dye taping technique with the addition of six reverse heel locks and a calcaneal sling extending up the lower leg. As the taping techniques included within this current study only included applying one or three pieces of therapeutic tape, more significant reductions in angular displacement at the ankle, knee, and hip may have been found with the use of additional strips of tape, or an alternate taping technique to create a strong base of support at the ankle.

Conclusion

The purpose of this study was to explore the effect of ankle taping with KT and LT compared to NT on the kinematics of the lower extremity during running on level, inclined, and declined slopes. For the spatio-temporal variables, significant increases in SL were found while running on a declined slope when compared to an inclined slope with and without the application of therapeutic tape. Significant decreases in SF were also found when running on a declined slope when compared to running on a level and inclined slope with and without the application of therapeutic tape. Finally, for the angular displacement variables, significant decreases in peak angular displacement at the knee during the stance phase of running were found with the application of LT when compared to KT. Furthermore, the application of LT was found to be beneficial in reducing peak knee flexion during the stance phase of running. As this study provided preliminary results to the effectiveness of anti-pronation taping while running on level, inclined, and declined slopes on neutral foot types, future research is required to explore the effect of tape on overpronated foot types or in specific clinical populations experiencing lower extremity pain or dysfunction, as well as identify and support differences where slight changes were found.

Limitations

Limitations of this study are related to the foot types included, precise marker placement, and the type of population selected. As foot posture was not part of the exclusion criteria for this study, there were no participants included that demonstrated a supinated foot type. As LT also decreased the degree of peak knee flexion during the stance phase of running with a neutral foot type, we were unable to relate the effect to individuals with a supinated foot type. Furthermore, as the application of therapeutic tape did not affect lower extremity kinematics at times of the running gait cycle where supination was a key factor, it may have increased the flexibility of an already supinated foot type. Consequently, caution should be taken when generalizing the results of this study to individuals with a supinated foot type. Marker placement was also a limitation of this study. As the same researcher applied each marker for every participant based on the modified Helen Hayes guidelines, markers of the hip and foot were placed over the participant's shorts and shoes. Furthermore, as direct access to these bony landmarks was not available, it is possible that the positioning of these markers was slightly altered across participants. Finally, as this study involved only healthy individuals, they may not have run with abnormal mechanics that would increase the degree of overpronation and result in injury. Therefore, exploring the effect of therapeutic ankle taping on a population with a lower extremity dysfunction may provide better insights to the effect of tape in reducing the risk of an overuse injury.

Delimitations

A delimitation of this study was the type of therapeutic tape and taping conditions used. As there are many different types of taping conditions that can be used with KT and LT, the taping conditions selected within this current study were found to provide significant reductions in pain and overpronation within the literature (Agrawal & Deshpande, 2015; Luque-Suarez et al., 2014). Furthermore, as only two types of taping conditions were used within this current study, caution should be taken while generalizing these results to the effects of KT and LT when using different taping conditions.

Another delimitation of this study was that potential participants were excluded if they had an injury within the past three months that would have altered their running stride at the time of the study. Although completing this study on an injured population would be ideal to understand the effects of tape on a population that demonstrates a pronated foot type, injured runners may have been found to introduce compensation strategies and altered running patterns in their gait to avoid pain. As a result, caution must be taken when generalizing these results.

Finally, a delimitation of this study was that although participants ran with a self selected running speed, running velocity was monitored to not fall below 2 m/s. This running speed was selected as Vincent et al. (2014) stated that differences in muscle activation patterns and ground reaction forces exist beginning at 2 m/s. Also, since a range of running speeds were selected by the participants, the therapeutic taping techniques may have affected the lower extremity kinematics at the different speed. Therefore, caution should be taken when generalizing these results.

Assumptions

A few assumptions were made throughout this study. It was assumed that the markers were placed in the same spot of the bony landmarks for each participant and the tape was applied in the same way for each participant. It was also assumed that the participants were experienced treadmill runners and were familiar with running on inclined and declined slopes at their selected speed. Finally, it was assumed that the measuring tape and scale used to measure height and mass were accurate for each participant.

Future Research

Although significant differences were found in this study, there is still a warrant for future research. Future research should explore the effect of therapeutic ankle taping on the muscle activity of the vastus medialis, rectus femoris, biceps femoris, and gluteus medius muscles. As these muscles have been found to maximally contract during the stance phase to absorb the shock from landing, increased activity extending through the second half of the midstance phase may indicate the presence of overpronation (Schache et al., 2010). Future research should also include EMG and kinetic analysis simultaneously with kinematics to provide a wealth of information regarding musculoskeletal coordination while running. As large differences in running kinematics may not have been found within the current research study, alterations from the application of therapeutic tape may be seen in the kinetics and muscle activity of the lower extremity. Furthermore, as slight differences were noticed with the application of therapeutic tape, future research should also explore the link between the ankle, knee, and hip joints to understand their effect on each other with and without the application of therapeutic tape. Exploring this link further would provide better insights to what an appropriate type of intervention would be to reduce the risk of injury caused from overpronation. Additionally, as this study attempted to infer the effect of overpronation on the angular displacement of the ankle, knee, and hip, future research should include a specific analysis of the foot to have a better understanding of its effect on the lower extremity. Finally, as this study included healthy individuals, exploring the effect of therapeutic ankle taping on a population with an overpronated foot type, lower extremity pain, and/or dysfunction may provide better insights to the effects of tape on controlling abnormal running mechanics that have led to injury.

References

Agrawal, S., & Deshpande, M. (2015). Effectiveness of mulligan's taping for the short term management of plantar heel pain – Randomised control trial. *International Journal of Biomedical and Advance Research, 6*(07), 531-536.

Chan, C., & Rudins, A. (1994). Foot biomechanics during walking and running. *Mayo Clinic Proceedings, 69*, 448-461.

Cheung, R., Chung, R., & Ng, G. (2011). Efficacies of different external controls for excessive foot pronation: A meta-analysis. *British Journal of Sports Medicine, 45*(9), 743-751.

Cheung, R., & Ng, G. (2007). Efficacy of motion control shoes for reducing excessive rearfoot motion in fatigued runners. *Physical Therapy in Sport, 8*(2), 75-81. doi:https://doi.org /10.1016/j.ptsp.2006.12.002

Csapo, R., & Alegre, L. (2015). Effects of kinesio taping on skeletal muscle strength - A meta-analysis of current evidence. *Journal of Science and Medicine in Sport, 18*(4), 450-456.

Derrick, T., Hamill, J., & Caldwell, G. (1998). Energy absorption of impacts during running at various stride lengths. *Medicine & Science in Sports & Exercise, 30*(1), 128-135.

DeVita, P., Janshen, L., Rider, P., Solnik, S., & Hortobagyi, T. (2008). Muscle work is biased toward energy generation over dissipation in non-level running. *Journal of Biomechanics, 41*(16), 3354-3359. doi:10.1016/j.jbiomech.2008.09.024

Dugan, S., & Bhat, K. (2005). Biomechanics and analysis of running gait. *Physical Medicine and Rehabilitation Clinics of North America, 16*(2005), 603-621.

Farley, C., & González, O. (1995). Leg stiffness and stride frequency in human running. *Journal of Biomechanics, 29*(2), 181-186.

Ferber, R., & Macdonald, S. (2014). *Running mechanics and gait analysis.* Champaign, IL:

Human Kinetics.

Franettovich, M., Chapman, A., Blanch, P., & Vincenzino, B. (2008). A physiological and psychological basis for anti-pronation taping from a critical review of the literature. *Sports Medicine, 38*(8), 617-631.

Fu, T., Wong, A., Pei, Y., Wu, K., Chou, S., & Lin, Y. (2008). Effect of kinesio taping on muscle strength in athletes - A pilot study. *Journal of Science and Medicine in Sport, 11*(2), 198-201.doi:10.1016/j.jsams.2007.02.011

Hall, S. (2007). *Basic Biomechanics.* New York, NY: The McGraw-Hill Companies.

Hamill, J., Derrick, T., & Holt, K. (1995). Shock attenuation and stride frequency during running. *Human Movement Science, 14*(1995) 45-60.

Hardin, E., Van Den Bogert, A., & Hamill, J. (2004). Kinematic adaptations during running: Effects of footwear, surface, and duration. *Medical Science Sports Exercise, 36*(5), 838-844.

Harradine, P., Herrington, L., & Wright, R. (2001). The effect of low dye taping upon rearfoot motion and position before and after exercise. *The Foot, 11*(2001), 57-60. doi:10.1054/foot.2000.0656

Hintermann, B., & Nigg, B. (1998). Pronation in runners. *Sports Medicine, 26*(3), 169-176. doi: 0112-1642/98/0009-0169/$04.00/0

Hreljac, A., Marshall, R., & Hume, P. (2000). Injury potential in runners. *Medicine & Science in Sports & Exercise. (32)*9, 1635-1641. doi: 10.1097/00005768-200009000-00018

Hyland, M., Webber-Gaffney, A., Cohen, L., & Lichtman, P. (2006). Randomized controlled trial of calcaneal taping, sham taping, and plantar fascia stretching for the short-term management of plantar heel pain. *Journal of Orthopedic Sports Physical Therapy, 36(*6), 364-371.

Jackson, K.M. (1979). Fitting of mathematical functions to biomechanical data. *IEEE Transactions on Biomedical Engineering, 26*(2), 122-124.

Kase, K., Martin, P., & Yasukawa, A. (2006). *Kinesio® taping in pediatrics: fundamentals and whole body taping (2nd ed.).* Minneapolis, MN: Orthopedic Physical Therapy Products.

Kavanagh, B. (2010). *Surveying with construction applications.* Upper Saddle River, NJ: Pearson.

Kuni, B., Mussler, J., Kalkum, E., Schmitt, H., & Wolf, S. (2016). Effect of kinesiotaping, non-elastic taping and bracing on segmental foot kinematics during drop landing in healthy subjects and subjects with chronic ankle instability. *Physiotherapy Journal, 102*(3), 287-293. doi:https://doi.org/10.1016/j.physio.2015.07.004

Larson, R., & Edwards, B. (2011). *Calculus: Early transcendental functions.* Boston, MA: Brooks/Cole.

Lattanza, L., Gray, G., & Kantner, R. (1988). Closed versus open kinematic chain measurements of subtalar joint eversion: Implications for clinical practice. *Journal of Orthopaedic & Sports Physical Therapy, 9*(9), 310-314.

Linton, L., & Valentin, S. (2018). Running with injury: A study of UK novice and recreational runners and factors associated with running related injury. *Journal of Science and Medicine in Sport, (2018), 1-5.* doi:https://doi.org/10.1016/j.jsams.2018.05.021

Luque-Suarez, A., Gijon-Nogueron, G., Baron-Lopez, F., Labajos-Manzanares, M., Hush, J., &

Hancock, M. (2013). Effects of kinesiotaping on foot posture in participants with pronated foot: A quasi-randomised, double-blind study. *Physiotherapy, 100*(2014), 36-40.

Lussiana, T., Hébert-Losier, K., & Mourot, L. (2015). Effect of minimal shoes and slope on vertical and leg stiffness during running. *Journal of Sport and Health Science, 4*(2015), 195-202. doi: http://dx.doi.org/10.1016/j.jshs.2013.09.004

Malisoux, L., Nielsen, R., Urhausen, A., & Theisen, D. (2014). A step towards understanding the mechanism of running-related injuries. *Journal of Science and Medicine in Sport, 18*(2015), 523-528. doi:http://dx.doi.org/10.1016/j.jsams.2014.07.014

McArdle, W., Katch, F., & Katch, V. (2008). *Exercise physiology: Nutrition, energy, and human performance (8th ed.).* Philadelphia, PA: Wolters Kluwer Health.

Mehta, S., Basu, S., Palekar, T., & Dave, N. (2017). Effect of kinesio taping versus mulligan taping in treatment of heel pain. *International Journal of Pharmacology and Biology Sciences, 8*(3), 377-386.

Mercer, J., DeVita, T., Derrick, T., & Bates, B. (2003). Individual effects of stride length and frequency on shock attenuation during running. *Medicine & Science in Sports & Exercise, 35*(2), 307-313. doi:10.1249/01.MSS.0000048837.81430.E7

Mizrahi, J., Verbitsky, O., & Isakov, E. (2000). Fatigue-induced changes in decline running. *Clinical Biomechanics, 16*(2001), 207-212.

Mostafavifar, M., Wertz, J., & Borchers, J. (2012). A systematic review of the effectiveness of kinesio taping for musculoskeletal injury. *Clinical Focus: Pain Management, 40*(4), 33-40. doi: 10.3810/psm.2012.11.1986

Mündermann, A., Nigg, B., Humble, N., & Stefanyshyn, D. (2003). Foot orthotics affect lower extremity kinematics and kinetics during running. *Clinical Biomechanics*, *18*(2003), 254-262. doi:10.1016/S0268-0033(02)00186-9

Neal, B., Griffiths, I., Dowling, G., Murley, G., Munteanu, S., Franettovich-Smith, M.,…Barton, C. (2014). Foot posture as a risk factor for lower limb overuse injury: A systematic review and meta-analysis. *Journal of Foot and Ankle Research, 7*(55), 1-13. doi:10.1186/s13047-014-0055-4

Nicola, T., & Jewison, D. (2012). The anatomy and biomechanics of running. *Clinics in Sports Medicine, 31*(2), 187-201.

Novacheck, T. (1998). The biomechanics of running. *Gait and Posture, 7,* 77-95.

O'Sullivan, K., Kennedy, N., O'Neill, E., & Mhainin, U. (2008). The effect of low-dye taping on rearfoot motion and plantar pressure during the stance phase of gait. *BMC Musculoskeletal Disorders, 9*(111). doi:10.1186/1471-2474-9-111

Padulo, J., Powell, D., Milia, R., & Ardigo, L. (2013). A paradigm of uphill running. *PLoS ONE, 8*(7): e69006. doi:https://doi.org/10.1371/journal.pone.0069006

Payton, C., & Bartlett, R. (2008). Biomechanical Evaluation of Movement in Sport and Exercise. New York, NY: Routledge

Pelletier, A., Sanzo, P., Kivi, D., & Zerpa, C. (2017). The effect of patellar taping on lower extremity running kinematics in individuals with patellofemoral pain syndrome. *Physiotherapy Theory and Practice.* doi:10.1080/09593985.2018.1457114

Pourtier-Piotte, C., Pereira, B., Soubrier, M., Thomas, E., & Coudeyre, E. (2015). French validation of the foot function index (FFI). *Annals of Physical and Rehabilitation Medicine, 58*(2015), 276-282. doi:http://dx.doi.org/10.1016/i.rehab.2015.07.003

Queen, R., Gross, M., & Liu, H. (2006). Repeatability of lower extremity kinetics and kinematics for standardized and self-selected running speeds. *Gait Posture, 23,* 282-287. doi: 10.1016/j.gaitpost.2005.03.007

Redmond, A. (1998). The foot posture index. Retrieved from: https://www.leeds.ac.uk/medicine /FASTER/z/pdf/FPI-manual-formatted-August-2005v2.pdf

Richards, J. (2008). *Biomechanics in clinic and research*. Philadelphia, PA: Churchill Livingstone Elsevier.

Robertson, G., Caldwell, G., Hamill, J., Kamen, G., & Whittlesey, S. (2014). *Research methods in biomechanics.* Champaign, IL: Human Kinetics.

Sallade, J., & Koch, S. (1992). Training errors in long distance running. *Journal of Athletic Training, 27*(1), 50-53.

Sanzo, P., & Bauer, T. (2015). The effects of low dye taping on vertical foot pressure in subjects with plantar fasciitis. *International Journal of Prevention and Treatment, 4*(1), 1-7. doi: 10.5923/j.ijpt.20150401.01

Schache, A., Blanch, P., Dorn, T., Brown, N., Rosemond, D., & Pandy, M. (2011). Effect of running speed on lower limb joint kinetics. *Official Journal of the American College of Sports Medicine, 43*(7), 1260-1271. doi: 10.1249/MSS.0b013e3182084929

Schubert, A., Kempf, J., & Heiderscheit, B. (2014). Influence of stride frequency and length on running mechanics: A systematic review. *Sports Health, 6*(3), 210-217. doi:10. 1177/1941738113508544

Snyder, K., Kram, R., & Gottschall, J. (2012). The role of elastic energy storage and recovery in downhill and uphill running. *Journal of Experimental Biology, 215*(13), 2283-2287. doi:10.1242/jeb.066332

Swanson, S., & Caldwell, G. (2000). An integrated biomechanical analysis of high speed incline and level treadmill running. *Medicine & Science in Sports & Exercise, 32*(6), 1146-1155.

Vincent, H., Herman, D., Lear-Barnes, L., Barnes, R., Chen, C., Greenberg, S., & Vincent, K.

(2014). Setting standards for medically-based running analysis. *Current Sports Medicine Reports, 13*(4), 275-283. doi:10.1249/JSR.0000000000000071

Vincenzino, B., Franettovich, M., McPoil, T., Russell, T., & Skardoon, G. (2005). Initial effects of anti-pronation tape on the medial longitudinal arch during walking and running. *British Journal of Sports Medicine,* 39, 939-943. doi:10.1136/bjsm.2005.019158

Winter, D. (2009). *Biomechanics and Motor Control of Human Movement (4th ed.).* Hoboken, NJ: John Wiley & Sons, Inc.

Appendices

Appendix A

Recruitment Poster

Appendix B

Information Letter

Lakehead UNIVERSITY

School of Kinesiology
t: (807) 343-8544
f: (807) 343-8944
kinesiology@lakeheadu.ca

Dear Potential Participant,

Thank you for expressing an interest in the following study titled "The Impact of Therapeutic Ankle Taping on the Lower Extremity Kinematics of Running on Level, Inclined, and Declined Slopes". My name is Dominique Cava and I am a first year graduate student in the School of Kinesiology at Lakehead University. I will be completing this study under the supervision of Dr. Derek Kivi and Dr. Paolo Sanzo. You have been invited to participate in this study because you are between the ages of 18 and 30 years, are a recreational runner that runs a minimum of five kilometers two to three times per week, are familiar with running on a treadmill, have been injury free for the past six months, currently have no ankle pain, are not pregnant, and have no skin sensitivities or allergies to Kinesio Tape® and Leuko Tape P® or other adhesives such as band aids.

The purpose of this study is to examine the impact of the application of therapeutic ankle taping on the lower extremity kinematics while running on level, inclined, and declined slopes. This will be determined through a laboratory analysis of the running gait cycle with and without the selected types of tape involving level surface conditions (0% grade) and slopes of 5% and -5% grade.

As a participant, you will be asked to come to room SB-1025 of the Sanders Building at Lakehead University to complete a single testing session which will take approximately 60 minutes. Since this study will take place in an exercise setting, you will be asked to wear tight fitting, dark clothing that will allow appropriate access to the lower extremity for accurate analysis, as well as athletic running shoes. You will first be asked to complete a consent form, a Get Active questionnaire, and demographic questionnaire. The purpose of the Get Active questionnaire is to ensure you can participate in exercise in a safe way without increasing your risk of injury. The purpose of the demographic questionnaire is to collect descriptive information regarding the participants who complete the study and used to interpret and explain any results that are found. You will then have your foot posture analysed with the Foot Posture Index scale© to determine if your arch assumes a pronated (flatfoot) or supinated (high-arch) position while weight bearing.

You will then be asked to complete a 5 minute warm up running at a speed that would represent a comfortable ten kilometer run. The purpose of this warm up is to familiarize yourself with the treadmill and the inclined and declined conditions. The first 3 minutes of the warm up will include running on a level surface, and the remaining 2 minutes will include a minute of running on a +5% incline and a minute of running on a -5% decline. Between each condition, you will be asked to slow your speed, so you can appropriately adjust the treadmill slope. After your warm up is completed, you will be asked to slow your speed and step off the treadmill. Reflective markers will be placed on your right leg to allow for identification of your leg movements during each running trial. You will then be asked to complete three, 3 minute running trials (one with Kinesio Tape®, one with Leuko Tape P®, and one without tape). During each 3 minute taping condition, the running surface will be adjusted each minute to include level, inclined, and declined conditions. These conditions will be prearranged by the student researcher and provided to you before beginning each taping condition. After you complete your first taping condition, you will be asked to slow your speed and step off the treadmill where you will be assigned your second taping condition. This will be considered as a rest period where you will have the tape applied for your next tape condition. If your next condition is the "no tape" condition, you will be asked to sit and rest for a period of 5 minutes before stepping back on the treadmill. The second and third taping conditions will be completed with the same instructions as the first. Once the third taping condition is completed, you will be asked to slow your speed and remain on the treadmill walking at a comfortable speed on a 0% incline for a period of 2 minutes as a cool down.

Due to the nature of the study, there are possible risks of participating just as there may be with any form of physical activity. These risks may include minor discomfort or fatigue in the lower extremity throughout the running trials and the delayed onset of muscle soreness after completing the study. These risks will be minimized through the use of a warmup; as well as, the cool down walking at a comfortable speed. There may also be a risk of skin irritation due to the adhesives present in the tape. To minimize this risk, you will be asked to inform the student researcher if you have any skin sensitivities or allergies prior to the application of tape. Furthermore, although there is little to no risk of muscle strain associated with the application of tape, you will have the opportunity to walk around after the tape has been applied to ensure it is applied in a comfortable way. If the tape is uncomfortable, corrections will be made and if discomfort is experienced from the tape during the testing session, you have the right to withdraw at any time.

It is imperative that as a participant, you understand your rights before participating in this study. Participation is completely voluntary and you will have the right to withdraw at any time. Only myself, Dominique Cava, and my supervisors, Dr. Derek Kivi and Dr. Paolo Sanzo will have access to the recorded video data and personal information; you will remain anonymous in the written thesis document and all personal information will remain anonymous and confidential. This will be ensured as you will receive a unique identification number upon enrollment in the study. Only myself and my supervisors will have access to your personal information and recorded data. The final report will include participant's data in a collective form where an average value will be calculated to represent the participants as a whole, ensuring each participant's identity remains confidential. The final report will also be presented to the public through a verbal presentation and potentially a graduate school conference at Lakehead University and/or other national and international conferences. This data also has the potential to be published in an academic journal. After the completion of the study, all data will be stored in Dr. Sanzo's office at Lakehead University for a period of five years in accordance with Lakehead University policy.

If you choose to be part of the study and complete the running analysis, you may improve the understanding on how the application of tape may alter an individual's running stride. You will also acquire information about your running stride and how the application of tape may alter your lower limb kinematics.

If requested, you will have access to your own results after the completion of the study. Please contact me via email (given below) if you are interested in participating in this research study. If you have any questions related to the ethics of the research and would like to talk to someone other than the researchers, you can also contact Sue Wright at the Research Ethics Board at (807) 343-8283 or research@lakeheadu.ca.

Thank you for your consideration,

Dominique Cava
Email : dscava@lakeheadu.ca
Phone : (807) 629-9500

Dr. Derek Kivi

Email : dkivi@lakeheadu.ca

Dr. Paolo Sanzo
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Appendix C

Consent Form

Lakehead UNIVERSITY

School of Kinesiology
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I ____________________________________ agree to participate in the study titled "The Impact of Therapeutic Ankle Taping on the Lower Extremity Kinematics of Running on Level, Inclined, and Declined Slopes". The study is being conducted by Dominique Cava, a second year MSc graduate student, with Dr. Derek Kivi and Dr. Paolo Sanzo as faculty advisors. I have read and understand the participant recruitment letter, and I understand that I will be asked to complete a Get Active Questionnaire.

I understand that prior to testing, I will be asked to complete a demographic questionnaire and have my foot posture index calculated. I will then complete a warm up on the treadmill in SB-1025 in Lakehead University's Sanders Building. The running analysis will involve running three trials under three taping conditions (Kinesio Tape®, Leuko Tape P®, and no tape). Within each running trial, the running surface will also be manipulated and include level, inclined, and declined conditions (0%, 5%, and -5%). Prior to each trial, I will have the predetermined tape condition applied to my foot. I will be asked to perform three slope trials with each tape condition and my running stride will be digitally recorded for a biomechanical analysis of the video. Within each trial, I understand that the running surface will be manipulated and include level, inclined, and declined conditions. I understand that each trial will be video recorded and give my consent for my trial videos to be used for further analysis. I will then be asked to complete each of the three trials with 5 minutes rests in between each trial. Testing will take approximately 60 minutes to complete.

I understand that there are risks associated with any form of physical activity and that I may experience minor discomfort or fatigue in the lower extremity throughout the running trials and the delayed onset of muscle soreness after completing the study. I also understand that I will have the opportunity to walk around after the tape has been applied to ensure it is applied in a comfortable way. I accept all of these risks by participating in this study and understand that I have the right to withdraw from the study at any time if I experience discomfort. By completing in this study, I may also obtain information about my running stride and how the application of ankle taping may alter my lower limb kinematics on level, inclined, and declined slopes.

I understand that participation in this study is completely voluntary and I can withdraw my participation at any time. I understand that all personal information that I provide will remain confidential as only the researchers, Dominique Cava, Dr. Kivi, and Dr. Sanzo will have access to this data. No identifiable characteristics will be used in the final report or in the presentation of the results and the data will be securely stored in the office of Dr. Sanzo for a period of five years.

I understand that I will have access to my own data if requested, by contacting the student researcher.

I wish to receive a copy of my results via email. (Circle one and if yes, please provide your email on the line below)

Yes No

Signature of Participant Date

Signature of Researcher Date

Appendix D

Get Active Questionnaire

CSEP | SCPE
THE GOLD STANDARD IN EXERCISE SCIENCE AND PERSONAL TRAINING

Get Active Questionnaire

CANADIAN SOCIETY FOR EXERCISE PHYSIOLOGY –
PHYSICAL ACTIVITY TRAINING FOR HEALTH (CSEP-PATH®)

Physical activity improves your physical and mental health. Even small amounts of physical activity are good, and more is better.

For almost everyone, the benefits of physical activity far outweigh any risks. For some individuals, specific advice from a Qualified Exercise Professional (QEP – has post-secondary education in exercise sciences and an advanced certification in the area – see csep.ca/certifications) or health care provider is advisable. **This questionnaire is intended for all ages – to help move you along the path to becoming more physically active.**

☐ I am completing this questionnaire for myself.

☐ I am completing this questionnaire for my child/dependent as parent/guardian.

PREPARE TO BECOME MORE ACTIVE

The following questions will help to ensure that you have a safe physical activity experience. Please answer **YES** or **NO** to each question before you become more physically active. If you are unsure about any question, answer **YES**.

YES	NO	
		1 Have you experienced **ANY** of the following (A to F) **within the past six months**?
○	○	**A** A diagnosis of/treatment for heart disease or stroke, or pain/discomfort/pressure in your chest during activities of daily living or during physical activity?
○	○	**B** A diagnosis of/treatment for high blood pressure (BP), or a resting BP of 160/90 mmHg or higher?
○	○	**C** Dizziness or lightheadedness during physical activity?
○	○	**D** Shortness of breath at rest?
○	○	**E** Loss of consciousness/fainting for any reason?
○	○	**F** Concussion?
○	○	**2** Do you currently have pain or swelling in any part of your body (such as from an injury, acute flare-up of arthritis, or back pain) that affects your ability to be physically active?
○	○	**3** Has a health care provider told you that you should avoid or modify certain types of physical activity?
○	○	**4** Do you have any other medical or physical condition (such as diabetes, cancer, osteoporosis, asthma, spinal cord injury) that may affect your ability to be physically active?

NO to all questions: go to Page 2 – ASSESS YOUR CURRENT PHYSICAL ACTIVITY

YES to any question: go to Reference Document – ADVICE ON WHAT TO DO IF YOU HAVE A YES RESPONSE

CSEP | SCPE
THE GOLD STANDARD IN EXERCISE SCIENCE AND PERSONAL TRAINING

Get Active Questionnaire

ASSESS YOUR CURRENT PHYSICAL ACTIVITY

Answer the following questions to assess how active you are now.

1 During a typical week, on how many days do you do moderate- to vigorous-intensity aerobic physical activity (such as brisk walking, cycling or jogging)? ____ DAYS/WEEK

2 On days that you do at least moderate-intensity aerobic physical activity (e.g., brisk walking), for how many minutes do you do this activity? ____ MINUTES/DAY

For adults, please multiply your average number of days/week by the average number of minutes/day: ____ MINUTES/WEEK

Canadian Physical Activity Guidelines recommend that adults accumulate at least 150 minutes of moderate- to vigorous-intensity physical activity per week. For children and youth, at least 60 minutes daily is recommended. Strengthening muscles and bones at least two times per week for adults, and three times per week for children and youth, is also recommended (see csep.ca/guidelines).

GENERAL ADVICE FOR BECOMING MORE ACTIVE

Increase your physical activity gradually so that you have a positive experience. Build physical activities that you enjoy into your day (e.g., take a walk with a friend, ride your bike to school or work) and reduce your sedentary behaviour (e.g., prolonged sitting).

If you want to do **vigorous-intensity physical activity** (i.e., physical activity at an intensity that makes it hard to carry on a conversation), and you do not meet minimum physical activity recommendations noted above, consult a Qualified Exercise Professional (QEP) beforehand. This can help ensure that your physical activity is safe and suitable for your circumstances.

Physical activity is also an important part of a healthy pregnancy.

Delay becoming more active if you are not feeling well because of a temporary illness.

DECLARATION

To the best of my knowledge, all of the information I have supplied on this questionnaire is correct.
If my health changes, I will complete this questionnaire again.

I answered NO to all questions on Page 1

Sign and date the Declaration below

I answered YES to any question on Page 1

Check the box below that applies to you:

- ☐ I have consulted a health care provider or Qualified Exercise Professional (QEP) who has recommended that I become more physically active.
- ☐ I am comfortable with becoming more physically active on my own without consulting a health care provider or QEP.

Name (+ Name of Parent/Guardian if applicable) [Please print] | Signature (or Signature of Parent/Guardian if applicable) | Date of Birth

Date | Email (optional) | Telephone (optional)

With planning and support you can enjoy the benefits of becoming more physically active. A QEP can help.

☐ Check this box if you would like to consult a QEP about becoming more physically active.
(This completed questionnaire will help the QEP get to know you and understand your needs.)

Appendix E

Demographic Questionnaire

ID number: ___________________

Age (Years): ________________________

Height (cm): ______________________

Mass (Kg): _____________________

Sex: Male Female Other

Skin sensitivities or allergies to tape, or other adhesives: Yes No

Years of running experience: ______________________________

Average number of kilometers run per week:

____

Average speed for a 5 km run:

____

Previous injuries (injury and approximate year):

____

____

____

Appendix F

Foot Posture Index Scoring

For this procedure, participants will stand in a relaxed position with their feet shoulder width apart. The researcher will palpate, view, and/ or measure the participant's foot posture in various locations to determine a final score between -12 and +12 to quantify the degree to which the foot is pronated, supinated, or in a neutral static position. Locations on the foot that will be analysed and the analysis criteria are as follows below:

1. Talar head palpation

Score	-2	-1	0	1	2
	Talar head palpable on lateral side/ but not on medial side	Talar head palpable on lateral side/ slightly palpable on medial side	Talar head equally palpable on lateral and medial side	Talar head slightly palpable on lateral side/ palpable on medial side	Talar head not palpable on lateral side/ but palpable on medial side

2. Supra and infra lateral malleolar curvature

Score	-2	-1	0	1	2
	Curve below the malleolus either straight or convex	Curve below the malleolus concave, but flatter/ more shallow than the curve above the malleolus	Both infra and supra malleolar curves roughly equal	Curve below malleolus more concave than curve above malleolus	Curve below malleolus markedly more concave than curve above malleolus

3. Calcaneal frontal plane position

Score	-2	-1	0	1	2
	More than an estimated 5^{o} inverted (varus)	Between vertical and an estimated 5^{o} inverted (varus)	Vertical	Between vertical and an estimated 5^{o} everted (valgus)	More than an estimated 5^{o} everted (valgus)

4. Bulging in the region of the talo-navicular joint (TNJ)

Score	-2	-1	0	1	2
	Area of TNJ markedly concave	Area of TNJ slightly, but definitely concave	Area of TNJ flat	Area of TNJ bulging slightly	Area of TNJ bulging markedly

5. Height and congruence of the medial longitudinal arch

Score	-2	-1	0	1	2
	Arch high and acutely angles towards the posterior end of the medial arch	Arch moderately high and slightly acute posteriorly	Arch height normal and concentrically curved	Arch lowered with some flattening in the central portion	Arch very low with severe flattening in the central portion- arch making ground contact

6. Abduction/ adduction of the forefoot on the rearfoot

Score	-2	-1	0	1	2
	No lateral toes visible. Medial toes clearly visible	Medial toes clearly more visible than lateral	Medial and lateral toes equally visible	Lateral toes clearly more visible than medial	No medial toes visible. Lateral toes clearly visible