The Effect of a Bilateral Training Intervention on Sprint Start Performance of Experienced Male Sprinters

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Abstract

Bilateral transference research has recently shown evidence that the training of the preferred and non-preferred leg can improve overall performance, through the development and adaption of motor processes. The current study used a bilateral training intervention on a sprint start to determine if the same effects were exhibited. Twelve male participants, all of whom were county to national level sprinters took part in the study. An intervention group (n=6) undertook an 8-week bilateral training intervention for the sprint start, consistently changing the foot on the front block between preferred and non-preferred leg. A control group (n=6) used the same programme but only with the preferred leg lead. Participants were assessed Pre, Mid and Post intervention over the 8-week period. The lab-based testing assessed a total of ten sprint starts over a five-metre distance, with both the preferred and non-preferred leg performing five trials when positioned at the front block. Results established no significant change (P= > 0.05) in five-metre sprint performance for the preferred (P = 0.136; η_p^2 = 0.181) and non-preferred (P=0.716; η_p^2 = 0.033) lead leg trials across stages between groups. Several significant results across stages (P=<0.05) were found for kinematic and ground reaction force variables. A key interaction (P= < 0.05) was found at the block push off during non-preferred leg trials for the intervention group, where the hip had greater extension. Further changes to performance were found across stages for both groups, for hip, knee, and ankle kinematics, as well as the braking impulse (P= < 0.05). Despite these changes the 8-week intervention implemented did not result in any changes to sprint start performance over the five-metre distance. Future research should look to further assess the application of a bilateral training program to sprint start performance, with further assessment over the acceleration phase after the first two strides.

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1.0 <u>Introduction</u>

Sprint start velocity and acceleration are two of the most important factors that influence the outcome of sprint performance (Ozsu, 2014). Therefore, it is important that athletes make sure they efficiently produce the optimum kinematic performance for the required event, which positively contributes to the acceleration. Sprint start mechanics is an area which continues to develop within biomechanics research, with small adjustments of technical aspects having key implications for performance (Bezodis, Willwacher & Salo, 2019). The sprint start is a complex skill in athletics, with several events requiring the use of blocks to help produce peak optimum accelerative performance of athletes. Athletes use sprint blocks in events from 60m-400m and 60m hurdles to 400m hurdles.

The key success of the sprint start is to achieve maximal acceleration of the body in a horizontal direction, using efficient mechanics to do so. This accelerative phase of the sprint race is where the athlete must push-off from the blocks and is where the kinematic parameters change the most dynamically during a sprint race (Coh & Tomazin, 2006). The requirements for the sprint start can essentially be explained by Isaac Newton in his second law. Newton's second law of acceleration states the acceleration of an object is directly proportional to the resultant force in the same direction. In comparison with the sprint start, the athletes must push from the blocks producing a propulsive ground reaction force to increase horizontal acceleration.

Recently, other areas of sports science, in addition to biomechanics, have also demonstrated significant influence on sprint start performance. Psychological factors can influence the success of a start, such as the effect of ego depletion on athletes start success (Englert & Bertrams, 2014). The study argued that after a depletion task the athlete's reaction times decelerated, leading to what would lead to a drop in performance during a competitive race. The study used kinematic analysis to assess the effect. Further studies also assess the motor performance of athletes, with their being evidence for more experienced athletes having the more successful motor pattern sequences and more optimal motor control for the sprint start (Natta, Boisnoir & Cholet, 2012). This demonstrates a growing field of research with focus on factors and employing inter and transdisciplinary research methods to measure the effects. For example, combining psychological and biomechanical data to form conclusions around the sprint start is an area of increasing significance for performance enhancement. Several studies have adopted this approach to further assess effects on the sprint performance of athletes (Ille et al., 2013; Pilianidis *et al.,* 2012).

The current study adopts a similar approach, assessing the effects on biomechanical performance by changing practice through the adaptations of motor patterns. Research suggests that humans have a pronounced motor functionality laterally that can be reflected as a dominant lateral side of the body, or preferred (Focke et al*.,* 2016). In addition, it has also been long known that performance with one limb has an influence on the other, often leading to an improvement in performance of motor tasks (Stockel & Wang, 2011). Otherwise known as bilateral transfer, past research has explained the transfer of learning to be a result of stronger coactivation signals between the two cerebral hemispheres, which control the left and right side of our body (Teixeira, 2000). Lower limb transfer of learning has previously shown that training with the non-preferred leg benefited when combined with initial training of the preferred leg and vice versa (Stockel & Wang, 2011). In sprinting, past research has supported that teachers and coaches are encouraged to make sure athletes practise sprint starts with the preferred leg (Eikenberry et al., 2008.). However, based on the work of Stockel and Wang (2011), it is suggested that an introduction of a bilateral training intervention could have beneficial implications for sprint start performance. The current literature assesses the implications of using a bilateral training method during the sprint start for sprinters.

Previous research has shown the benefits to performance of practising with both the preferred and non-preferred leg (Haaland & Hoff, 2003). The study found that in football, an experimental group who trained a greater amount with the non-preferred leg over an eight-week period, presented an improvement in non-preferred and preferred leg performance. Further research demonstrating similar results has suggested coaches should look to enhance the use of this training through a systematic bilateral programme to improve athlete’s performance (Stockel & Weigelt, 2012). The paper places a strong emphasis on bilateral practice, with a transfer of learning being beneficial to both performance and acquisition of a motor skills. The study suggests that both the left and right hemisphere specialise for certain motor skills, and bilateral practice allows for a greater transfer of information between each hemisphere. Therefore, bilateral practice is practicing a situation specific action not only with the preferred side but also the non-preferred side (Focke et al., 2016).

Tools exist such as kinematic assessment to detect these changes in motor performance. Therefore, when assessing athletes' performance, it is important to understand what optimal performance and technique consists of to assess the impact of the intervention. The sprint start requires optimum positioning of the body, to accelerate forward. The key starting position is the set position, which the athlete assumes before the push off from the blocks. This position ultimately effects the success of the first stride from push off from the blocks, as step length and body positioning are key variables which will affect the outcome of the acceleration (Slawinski et al., 2010). The movement is complex, with world class sprinters achieving one-third of their maximum velocity in just 5% of the total race time during the push off from the blocks (Bezodis, Willwacher & Salo 2019). Thus, it is important for sprinters to produce a successful start phase to maximise their performance, as well as to enhance their technique in training to allow for the improvements in performance.

Bezodis, Willwacher and Salo (2019) reviewed the sprint start kinematics, explaining the key components for performance for an individual. For the set position foot plate spacings, foot plate inclination and joint angular kinematics are key parts of performance to review, all having a direct influence on performance success, by altering the parameters of an athletes set position. The paper suggests foot spacing in the set position for athletes to be vital to performance, as too large spacing could mean a longer push off phase. Having the spacings too short reduces the extension capabilities of both hips and rear knee. Athletes in the current study used preferred block spacings, with the main starting block frame moved to make the first push-off onto a force platform a natural movement. This avoids athletes shortening or lengthening strides to hit the platform. The review by Bezodis, Willwacher and Salo (2019) states that the general set position is now considered to involve the hips raised above the shoulder height and the shoulders ahead of the start line. When in the set position it is also important that the body's centre of mass is positioned in line with the starting line (Mero, Komi & Gregor, 1992). Previous research has suggested that there was no optimum set position that applied to athletes due to the difference in the athletes build and physique (Atwater, 1982). More recent research however has established that for 'highly skilled' sprinters an optimal set position does exist, regardless of the stature of the athlete (Harland & Steele, 1997). Therefore, mechanics of the set position in the sprint can use a general model, similar to the above research, to produce what is thought to be optimum start performance.

To develop this, further research has assessed the differences between mechanics for different physiques and structure of athletes, with research showing lots of inter-individual variations (Ozsu, 2014). Past research has determined there to be a significant variance between sprint start performance of top-level sprinters, with those who are faster producing greater force development and having enhanced sprint start motor performance than the slower sprinters of the participation group (Coh et al., 2017). Other factors also have an impact on start performance such as gender, with higher start velocity and acceleration produced by elite male sprinters compared to female sprinters (Debaere, Jonkers & Delecluse, 2013). Therefore, for the current paper, all sprinters were male sprinters and all part of the university athletics team or local athletics club, training for one of the sprint disciplinary events. This is in line with research to reduce the likelihood of variations that effect sprint start performance.

2.0 Literature review

Sprint start research is a growing body of research, with studies still suggesting that coaches lack certain scientific knowledge of the requirements for optimum sprint start performance. It is currently encouraged by researchers that we must bridge the gap between science and coaches (Jones, Bezodis & Thompson., 2009). In the review by Jones, Bezodis and Thompson (2009) it is evident of conflicting coaching ideas surrounding the knowledge of sprint start mechanics, however all coaches agreed that the start phase of a sprint is technically crucial to the outcome of performance. A further paper by Harrison (2010) suggests that isolation drills are predominantly used to train the sprint start, developing the optimum movement and co-ordination patterns of the athlete. Current strategies often take a whole-part-whole approach to coaching and isolating the skill. Utilising the part skill approach allows athletes to acquire motor patterns with more attention to certain performance parameters. Harrison (2010) further supports that coaching practice does not draw research from scientific literature for sprint biomechanics effectively, and that movement and co-ordination patterns can be further improved if the gap is bridged. One area of research that could support improvement is linked to interventions around the theory of bilateral transfer.

2.1 Bilateral transference

It is well established that both unilateral and bilateral training methods can improve horizontal orientated movements, such as sprinting (Moran et al., 2020). However, there is still frequent reporting of bilateral deficits across a variety of sports, with greater occurrence in less experienced athletes with a limited training history (Moran et al., 2020). This indicates that more work is required in less experienced and developing athletes to ensure that their development is not inhibited by these bilateral deficits. Moran et al. (2020) suggests that once sprinters reach upper thresholds in adaptation to exercise, gaining further performance improvement is difficult. Theoretically force production capabilities, of both lateral sides, when similar to each other should exhibit minimal bilateral deficit. Support for this has been shown in the work of Sessa et al. (2018), identifying greater cortical excitability in professional athletes when compared to novices. These adaptations are attributed to repeated practice of sport specific skills, namely sprint starts in this instance, and therefore high repetition is a frequent component of training sessions for professional and developing athletes alike. A further benefit of repeated practice, in sprint starting, is that it has been shown to have positive motor skill and co-coordinative effects which are fundamental to sprint performance (Borysiuk et al., 2018). The same research suggests that the sequence of the activation of arm and leg muscles, during the sprint start, is a manifestation of specific neuromuscular predispositions which are performed at the right time throughout the movement. Thus, the sprint start is a movement that can be learnt and training this will develop precision and accuracy of the movement, benefiting sprint performance (Borysiuk et al., 2018).

When leg preference is applied to sprint starting research, literature suggests a significant difference in performance when the preferred and non-preferred leg are used on the front block. Vagenas and Hoshizaki (1986) established far greater take off velocities and sprint times when the preferred leg was placed on the front block. The study concluded that lower limb dynamic strength can determine the optimum leg placement for a sprinter, and thus help determine which leg will lead to optimum performance. The preference of which leg is placed on the front block demonstrates both physical and motor performance-based variables. Dynamic strength demonstrates the physical attribute in the above study for preferred leg adoption for the front block by a sprinter and coach. Motor performance-based preferences for leg preference are significantly affected by the hemispherical activity of the sprinter during performance of the skill. Literature confirms that hemispherical specialisms effect the performance and preference of both handedness and footedness (Eikenberry et al., 2008). This is further explained by the idea of each hemisphere having 'special access' to differing specific motor parameters and capabilities. The right hemisphere is thought to be of advantage with spatial tasks, whilst the left hemisphere has been found to be advantageous for positioning tasks (Eikenberry et al., 2008). The study set out to determine how the asymmetries of hemispheric specialization affect the choice of foot for the sprint start. However, the study determined that it was not able to suggest a specialism in terms of kinematics, due to the right hemisphere's advantageous role in reaction time.

Literature therefore has been exploring how hemispherical activity affects performance out come in sport. During a sprint, the left hemisphere of sprinters brains is used for the specialisation of movement execution, however it is important both hemispheres work in maximum conjunction to optimize performance (Eikenberry et al., 2008). It is further established that the left hemisphere controls the limb trajectory, with the right hemisphere regulating the limb posture and precision (Serrien, Ivry & Swinnen, 2006). Eikenberry et al. (2008) suggest that one lateral side is thought to have special access to the contralateral hemisphere, therefore supporting the specialisation of hemispheres for the different programming of actions, often leading to the manual asymmetries seen in kinematic performance. The same study suggests that with higher orders of action, related to movement complexity, the left premotor and parietal areas show greater involvement than the right hemisphere. Both hemispheres however are essential in supporting major movement variables, including motor attention, temporal processing and spatial attention (Serrien, Ivry & Swinnen, 2006). The above analysis of hemispherical utilization can be further applied and assessed alongside sprint research, with both the left and right hemispheres involved in the movement from the blocks.

As the above studies explain, athletes are thought to be programmed to achieve tasks thorough optimum utilization of hemispherical components to performance. Literature has recently explored how to replicate movements from the preferred leg and how the motor learning process accommodates this theory within the lower limbs. Papers assessing the preferred hand for specialised tasks have established that when a skill is acquired and a motor pattern is utilised by one hemisphere, the contralateral hemisphere acquires an indirect copy of the motor pattern (Stockel & Wang, 2011). The same paper also established that this transfer of skill can be achieved in either direction from left to right hemisphere, or from right to left. The results can be explained through the theory of bilateral transfer (Inui, 2005). This is where capabilities of one limb are transferred to the contralateral side. The above study demonstrates a transference of learning in both directions to each lateral side. This is established by further research providing evidence that after training one limb, improvements are seen in the contralateral untrained limb and that this is an example of bilateral transfer (Pan & van Gemmert, 2013).

Pan and van Gemmert (2013) review in their paper the three models of bilateral transfer which help to provide explanations for results seen within bilateral transference research. The first model is the access model. This model states that a single engram is stored in the dominant hemisphere, and when presented with a task the dominant hemisphere has direct access to the engram. The non-dominant hemisphere only has indirect access through the dominant hemisphere. This model presents the stance that the transfer of learning from one lateral side to the other can only occur from the non-dominant limb to the dominant limb because of the direct access that the dominant limb possesses (Taylor & Heilman, 1980). The paper by Taylor and Heilman (1980) proposed that the left hemisphere was dominant in motor skill retention during and after performance. Therefore, right handedness and footedness tend to dominate motor skill performance preference.

The second theory, also interpreted by Pan and van Gemmert (2013), is the cross-activation model which was established by Parlow and Kinsbourne (1989). This is where the training of the preferred leg results in the production of a second engram in the non-preferred legs controlling hemisphere as well as the preferred, as seen in the access model. The engram in the non-preferred legs hemisphere is thought to be a weaker version of that in the preferred leg hemisphere. When the non-preferred leg is trained the engram is then only produced in the non-preferred legs controlling hemisphere, suggesting that the bilateral transfer only occurs from the preferred to non-preferred leg.

A further model developed by Sainburg (2002) is the dynamic-dominance hypothesis model, suggesting that the key factor that distinguishes the dominant and non-dominant hemisphere is the control of limb dynamics. The model establishes that there is an asymmetry of the hemispheres causing an asymmetry of the leg and hand capability. The model suggests that each hemisphere has access to information possessed by the other lateral hemisphere, but each hemisphere must utilise the specialised information from the opposing hemisphere to work efficiently. The dominant hemisphere is proficient in trajectory control, with the non-dominant hemisphere being proficient in skills involving placement and positioning. The model is therefore the dynamic-dominance model due to the information the opposing hemisphere utilises to perform a task with greater efficiency. Unlike the access model and cross activation model, the current model establishes that the transfer of dominant to non-dominant can also produce a transfer of learning in the direction of non-dominant to dominant. This model by Sainburg (2002) coincides with more recent research, which further supports that the transfer of learning between hemispheres can happen in either direction, supporting the use of bilateral training methods (Stockel & Weigelt, 2012).

A study by Haaland & Hoff (2003) explored how training both the preferred and non-preferred leg in training effects the performance in soccer players. A training intervention was implemented where one group would increase the practice of the non-preferred leg for an eight-week period, and a control group who would continue their normal training structure. Results demonstrated that by training the non-preferred side, over an eight-week period, that performance improved for both the preferred and non-preferred sides for several soccer specific drills and tests. For the non-preferred side improvements of up to 25.4% were recorded, with each test showing significantly higher improvements than the control group. For the preferred side improvements of up to 28.6% were recorded, again significantly higher than the control group. The paper concluded that the implications of the results should encourage coaches to further train their athletes non-preferred leg, to improve both the non-preferred and preferred leg performance. The study suggests eight-weeks is a sufficient period of time for performance changes to be assessed.

For the current study this could have positive implications for training the non-preferred leg for the block start, alongside the training of the preferred leg. Within the sprint start itself the performance of the preferred and non-preferred leg is key to performance, with both legs used to push from the blocks during the start. Literature has examined that elite athletes have a greater push-off from the rear block when compared with well-trained athletes (Willwacher et al., 2016). Therefore, maximizing the impulse from the front and rear blocks has benefits to performance as shown in the differences between elite and well-trained athletes. In line with the research by Haaland and Hoff

(2003), training the rear leg on the front block performance of the preferred front block leg could be improved, which suggested that the transfer of learning can happen from both left to right and right to left hemisphere.

Support from further studies provides reasoning for improvements seen in the above studies, stating that by adapting motor patterns there is a change in the connectivity between relevant neural assemblies. These changes are produced through the process of learning a different movement by alterations in the cortical synapse number and synaptic strength (Adkins et al., 2006). For the bilateral training in the current study, it is stated by the research that alterations could take place by the reorganisation of movement representations from within the motor cortex. The evidence is strengthened by the research of Brady (2008) where the reorganisation of the neural system is dependent on the specific task, and simplicity, and the understanding of the athlete. The sprint start conditions mimic that of a competition to restrict the influence of complexities of the task, and also so participants pay further attention to the bilateral training intervention. This was not a new task for athletes with all those in the current study part of a local team or club, with experience of current methods of sprint start training.

Nakasaka et al. (2002) further established that the motor sequences are effector-specific, with different effectors performing different sequences generally. Information of the motor sequence is processed implicitly and is slowly acquired before optimum performance. The study noted that the retention of the motor skill is supported by the by a motor sequence mechanism so that it can be performed even without additional awareness. The review of literature by Nakasaka et al. (2002) suggested that the cerebellum is necessary for motor skills and that it stores and retains the motor skills as part of the long-term memory. The motor learning of a skill uses a separate co-ordination pattern to that of a spatial skill with the motor skill learned by two sets of cortexes, which are basal ganglia and cortex cerebellum. Motor skills therefore are acquired from both experience and knowledge through neural networks. The current study will attempt to utilise these systems through a repeated intervention of bilateral training to build on the experience of adaptions to training for the preferred and non-preferred leg. This will then determine if the theory of bilateral transference applies to the current research, by assessing if there are changes through the experience of using both the preferred and non-preferred leg on the front starting block in sprint start training.

2.2 Sprint start mechanics.

The crouched start has been used by coaches and athletes since the late 1800s (Kolker, 1968). At the time this was thought to allow the sprinter to have more balance, but in fact gave the sprinters added spring from their legs (Kolker, 1968). Since then, the advancement in technology has allowed for a greater assessment of different parameters of the sprint start (Coh et al., 1998). Several variables effect the sprint start, including gender and anthropometric features (Mirkov et al., 2020). Several studies have attempted to find the optimum angles required, however often give a variation of the range in which athletes should attempt to position themselves (Mero et al., 1983; Bezodis, Salo & Trewartha, 2014). This is because of the anthropometric features mentioned, where each individual needs to the find their own optimum angles to produce the greatest horizontal acceleration.

The sprint start requires specific movements to be initiated from the onset of the starting stimulus. From the set position, athletes will go through the push off phase, with studies identifying that the hip, knee and ankle joints are utilised to generate energy for the push off from the block plates (Brazil et al., 2018). Further research suggests that from the push off phase a good start involves short push times, high horizontal velocities, high force impulses, high rates of force development and a high horizontal power output (Schrodter, Bruggemann & Willwacher, 2017).

The next phase of the start is the mid-stance, where athletes make the first ground contact and begin to push through the ground for the second stride. This stance is reliant on a successful push off for optimum performance, to be able to efficiently utilise the hip, knee and ankle to produce sufficient propulsion for the next stride (Bezodis, Willwacher & Salo, 2019). The review explains that during the first touchdown, the centre of mass of the athlete is in front of the foot on the ground. This phase is vital to utilise ground reaction forces to produce a high propulsive impulse from the ground, for athletes to push forward. The review further explains that the link between touchdown kinematics and ground reaction features of this early acceleration, is not fully understood, suggesting more research is needed to assess the balance of step distance and ground reaction forces. The athlete will then leave the ground in propulsion for the second stride. The combination of a successful set position, push off phase and touchdown, is a key determinant of the overall success of the sprint start (Bezodis, Willwacher & Salo, 2019). The set position, Toe-off from the blocks, mid-stance and second stride take-off will be measures of our study to assess performance.

To assess changes to performance, it is key to understand the mechanics and requirements of a successful sprint start. In the current study kinetic and kinematic analysis is conducted to assess effects of the intervention on sprint start performance. The sprint start is strongly dependent on motor and biomechanical factors (Coh, Tomazin & Stuhec, 2006). Optimum angles of an athlete's joints during a sprint start can be assessed by the general models of research of an athlete's optimal sprint start technique. Harland and Steele (1997) reviewed the sprint start, forming a model which is suggested coaches use with their athletes. The angle of the knee is a key factor that influences the success of a sprint start, with the optimum angle of the front knee thought to be between 90 and 130 degrees when in the set position. With this angle the ability to project the bodies centre of mass forward at approximately 40-45 degrees, from the set position, is thought to contribute to the optimum mechanics required for successful sprint start performance (Harland & Steele, 1997). To support this Coh, Tomazin and Stuhec (2006) concluded that during the first three steps a sprinters total body centre of mass rises gradually in the vertical direction, to maximize the horizontal component of the block velocity. The same study further supports that the set position directly effects the maximization of the block velocity, with the transition of the block velocity to block acceleration success depending on the execution of the first step. The success of the first step has a key influence on overall performance of the race, which is why coaches view this as a critical factor of performance, with the first step as its own phase of a race (Jones, Bezodis & Thompson, 2009).

Evidence suggests that the front leg is thought to have the greatest contribution to performance from the set position, pushing off from the blocks, but the rear leg also demonstrates great importance during the push off (Milanese, Bertucco & Zancanaro, 2014). The study determines that elite sprinters show a greater rear block impulse at push off from the blocks compared to well-trained sprinters. Differences in force application has also been established in further literature, concluding that male and females have a significant difference in the force impulse from the front and rear block, with the front block having a far greater force impulse during the push off from the set position (Coh et al*.,* 1998). Evidence from the study suggests, that elite males produce greater force impulses than the elite female sprinters. This is thought to be the case again due to the different anthropometric features of males and females. The rear leg contributes around 24-34% of the total block phase impulse (Bezodis, Walton & Nagahara, 2019). This is significantly less than the front leg. The differences of impulse, between well trained and less trained sprinters, has been established to be a result of well-trained athletes possessing a higher stabilization ability reducing the imbalances of force generation between both sides (Moran et al., 2020). Therefore, the use of both legs during the sprint start is key to performance, and by developing the push from the rear leg performance has shown greater enhancement.

To further the review of key joint mechanics the hip extensors are key to executing the push off from the front and rear block. As already examined past papers have determined that elite sprinters can generate a greater push off from the rear block. The maximum utilisation of the hip extensors has been determined to be the biggest factor for improving performance of the push off in joint kinematics, with elite athletes producing far greater velocities at the hip than slower athletes (Bezodis, Salo & Trewartha, 2015). It is therefore considered that a greater extension at the rear hip improves performance of the start. The study claims that sprinters need to be encouraged to maximise extension at both hips during the block phase. The main determining factor of the first few strides is the success of the initial push off from the blocks and the joint kinematics to do so. An earlier study by Bezodis, Salo and Trewartha (2014) established that positive hip extensor energy was absorbed at the blocks, and as the resultant moment progressed it becomes more flexor dominant for the toe-off phase from the blocks.

Research further supports that elite athletes produce a greater force impulse from the rear block than well trained athletes when pushing off the blocks from the set position (Willwacher et al., 2016). The study supports that rear block horizontal push off forces need to be maximized to improve performance and therefore produce greater sprint start performance. Within this study the application of force against the rear block, when comparing 154 sprinters, was thought to be the biggest predictive factor that affected block start performance. This research was supported by Bezoids, Walton and Nagahara (2019), who also suggested that a greater magnitude of rear block force was an important predictor for the start performance, and that it may be further beneficial for a longer proportion of the block phase to push with the rear leg. It is recognized within the study however that there will be a limit to this, and future research should focus on determining the optimum for a successful sprint start. The same study suggests the front leg is thought to be the main contributor of the two limbs to sprint start performance, with the front block force contributing around 66-74% of the total block phase impulse. The study concluded that it is important to utilize the front block push during the time where the rear block push comes to the end of the phase, and this is something coaches can use to work on technique of the sprint start. Greater resultant joint movements at the hip and knee, and greater joint power of the knee are associated with enhancing the greatest average force production from the blocks (Bezodis, Walton & Nagahara, 2019).

The above study has interesting implications for coaches to train athletes. The key point being to increase the force impulse on the back block to an optimum impulse to produce the greater start performance. An interesting concept of the sprint start is both the front and rear ankle from the push off have the same action, where there is a flexion-extension movement revealing a stretch shortening cycle (Slawinski et al., 2010). Even with the same mechanics there are differences in the length of the flexion during a sprint start push off according to the same literature. The rear ankle is in flexion for about 50% of the push off phase with the front ankle only in flexion for around 20% of the phase. Both still however exhibit an eccentric to concentric contraction of the gastrocnemius muscle. The study suggests that this flexion lasting for a sizeable proportion of the block start, could be detrimental to performance.

The ankle joint is therefore key to executing a successful sprint start. The ankle produces a combination of dorsi- flexion and planter flexion during a sprint start from the blocks. The ankle is thought to store elastic energy when in the set position, then produce positive ankle power which is explained by the plantar flexor stretch-shortening cycle. The front and rear ankle joints have the same movement pattern to form the stretch-shortening cycle of the plantar flexors. It was determined from research that these lower limb movements are the most responsible for kinetic energy in the sprint start with the upper limbs only contributing 22% of the kinetic energy to the total body (Slawinki et al., 2010). Ankle power output is a vital part of a sprint race especially when it is considered that the elastic energy is higher from the push off, from the front leg on the blocks, than any of the following ground contacts (Lai et al., 2016). It is suggested that this is a result of the stored elastic energy within tendons and that by maximizing the energy for each step phase, of the acceleration, it enhances performance due to higher propulsive forces produced through the ankle. For both lower limbs it is important for the ankle to train the flexion-extension cycle. No study has been conducted on the performance of the start if the rear foot cycle is improved by training the non- preferred foot on the front block. The study by Slawinki et al. (2010) noted higher forces exerted from the cycle on the forward push off leg through the plantar flexor stretch-shortening cycle. It is suggested therefore that using the rear foot in training, on the front block, could improve the effectiveness of the rear foots stretch-shortening cycle during a sprint start. It is yet to be determined if bilateral transfer of performance where the capabilities of the non-preferred limb become similar to those seen in the preferred limb will occur. It could also be suggested that this would affect the capabilities of the preferred leg, through neural adaptions of motor transfer as suggested by Sainburg (2002). This can be supported by Haaland and Hoff (2003) who provide evidence that an improvement in performance after a bilateral training intervention, can positively affect the performance of the preferred leg.

For start performance it is also key to understand the mechanics during the first stride touchdown. The amount of contact time is thought to significantly affect performance, with greater contact times during first stride touchdown associated with slower performances (Coh & Tomazin, 2006; Bezodis, Willwacher & Salo, 2019). A greater horizontal impulse is also associated with greater performance benefits, with past literature assessing the balance of braking and propulsive impulses for the first stride. Literature suggests than an increased horizontal net impulse, through the combination of braking and propulsive impulses, is a key parameter that separates faster and slower athletes (Morin et al., 2015). There is much discussion however about the braking impulse, with evidence suggesting that a higher braking impulse could have a negative effect on performance (Hunter et al., 2005). The same paper however does suggest that a higher braking impulse can be beneficial to performance, as this is normally associated with a greater amount of stored elastic energy at the ankle for the propulsive impulse. This is further examined by Morin et al. (2015) who suggest that during the first two strides the braking impulses are higher than at any other phase of the sprint, and that braking less does not necessarily lead to performance benefits. The current study will assess these ground reaction force variables and their contribution to performance.

Collectively the above research supports that there are key kinetic and kinematic parameters that affect to sprint start outcome. Through the implementation of a research informed bilateral training intervention, the current study will assess if there are any beneficial or negative adaptions to sprint start performance through kinetic and kinematic analysis. Non-preferred and preferred leg performance in the start position will be assessed to attempt to determine changes in mechanics of lateral performance over an eight-week testing period. It will also attempt to determine what effect this has on a five-metre sprint performance, through the implementation of a bilateral training intervention for athletes.

3.0 Aims and Hypothesis

The aim of the research is to determine whether a bilateral training intervention will alter sprint start mechanics and ultimately performance. To our knowledge, there is currently no research assessing the application of a bilateral training intervention on sprint starts, where athletes are encouraged to repetitively train both legs from the front block. The study will assess the implications of a bilateral training intervention undertaken by an experimental group over time, in comparison to a control group maintaining standard sprint start training regimes. Both preferred and non-preferred leg performance for both groups will be assessed through timing gate data, joint kinematics, and force platform data to determine if there are any implications to mechanics and performance from the intervention.

Due to the lack of sport specific research into bilateral transference interventions on sprint mechanics, no direction hypothesis could be presumed, and so null hypothesis testing was deemed most appropriate. The stance of the null hypothesis was, ‘there is no significant difference in sprint mechanics or performance between the control and intervention groups across measured variables over an 8-week period’.

4.0 Method

4.1 Participants

Twelve participants were recruited. All participants were competitive sprinters from the university athletics team or local athletics club with two or more years of sprint training experience. There were disparities between participants due to the number of athletes who fulfilled this criteria in the local area willing to take part in our study. All participants had previously competed at county to national level in sprint disciplinary events (Mean 100m Personal bests = 11.607 ± SD= 0.45). The age of participants ranged from 18-28 years (Mean = 21.25, ± SD= 3.166). Participants body mass ranged from 63.1kg-82.2kg (Mean = 72.933, ± SD= 5.758). Participants Height ranged from 167cm-185cm tall (Mean= 177.168, ± SD= 5.523). The recruited sample size (n=12) was based on previous research of sprint start performance (Schot & Knutzen, 1992; Stadler, Wolff & Schuler, 2020). For consistency purposes, only male participants were examined, as previous findings suggest that males and females display kinematic differences in push-off technique from the set position (Coh et al., 1998), Ethical approval was obtained prior to any data collection or recruitment from the Canterbury Christ Church University ethics committee (Ref. 18/SAS/35C, Declaration of Helsinki).

4.2 Experimental overview

Participants were asked to complete ten sprint starts, with previous research suggesting that athletes could perform ten trials without fatigue or deviation in performance (Stefanyshyn & Nigg, 1998; Charalambous et al., 2012). Between trials, three minutes of rest were provided to allow athletes to recover. The selection of the rest (>5 minute) was based on past literature (Stefanyshyn & Nigg, 1998; Charalambous et al., 2012; Slawinski et al., 2017) as well as from pilot testing. Participants trials were measured over a five-metre distance, in line with previous research assessing the effects of sprint start training on performance (Coh et al., 1998; Slawinski et al., 2017). Trials were always on the same day as a training day for each participant, so the testing session was used instead of a training session, so not to interfere with participants training schedules. Testing sessions were completed for the pre stage before intervention, and post stage at the eight-week period of intervention. At four weeks a mid stage assessment also took place to assess changes to performance. Participants were asked before each testing session of any injury to ensure they were fit and able to be tested by completing a PAR-Q before each session. This was completed before each session over the eight-week period of the research, where an injury could have occurred. See figure 1 for experimental set up.

4.3 Intervention

All testing took place over an eight-week period at Canterbury Christ Church University. Previous evidence suggests that eight weeks allows enough time for a bilateral transfer to occur, therefore the duration was thought to be sufficient for the current study (Haaland & Hoff 2003; Focke et al., 2016). Following the pretesting session participants in the intervention group started their intervention for the eight-week period.

The bilateral training intervention group was observed by the researcher at their sessions at their local athletics track. Training sessions were observed three times per week, with the researcher working in conjunction with the sprint coach. The intervention involved before each repetition swapping the lead and trail leg round, so that the left and right foot both had experience of being the lead leg from push off. Towards the end of the warmup, three all-out effort runs from a three-point start were performed. The distance participants were asked to run was over ten metres. Participants were instructed to run with the non-preferred leg positioned at the front. During the main part of sessions, set by their coach, athletes would rotate blocks or start foot for longer repetitions before each run. Repeated practice has previously shown to cause motor adaption in sprint athletes when adapting the exercise (Borysiuk et al., 2018). Sessions over varying distances comprised of either six, eight or ten repetitions, to allow for a 50% split of front leg placement for the preferred and non- preferred leg, similar to previous bilateral intervention studies (Haaland & Hoff, 2003; Fisher & Wallin, 2014). Again, this allowed for both the preferred and non-preferred leg to be used as the lead leg push-off. This was randomised for each individual, with which foot would start as the lead leg. Randomization of the order athletes used each leg was utilised with previous research suggesting an influential effect of which lateral side is used first to learning and acquisition of movement (Stockel & Weigelt, 2012). During the fourth and the eighth week of the programme, the testing was used to replace a single session so to not overtrain athletes, and not to interfere with training schedules. The control group did not alter their training around the bilateral intervention. Athletes would use the preferred leg for their sessions and completed the three driving runs at the end of the warmup, over the ten-metre distance. The only time control group participants performed with the non-preferred leg in front at push off was during one of three laboratory assessments over the eight-week period.

4.4 Procedure

Participants had their height measured (cm) using a stadiometer (Model 220, Seca Gmbh, Germany) and mass (kg) recorded before each testing session, due to possible fluctuations over an eight-week period, using a precision balance scale (Ravencourt model 848, Ravencourt limited, UK).

Participants warmed up on a treadmill (ELG 70/250 sport, Woodway, Waukesha, USA) under the supervision of the researcher. The warm-up consisted of a five-minute jog, and participants were asked every minute to rate exertion of the warmup aiming to be between level 13-14 on the 6-20 RP scale. After five minutes participants would complete three sets of 10 second intervals, where participants would produce a maximal sprint effort. Between each 10 second maximal effort there was a 45 second rest. Warm up protocol was based on evidence of a short intense warm up being beneficial to sprint performance (Tillaar, Lerberg & Heimburg, 2019). Stretching of participants was monitored and recorded, to ensure each individual was consistent in warm up preparation for trials, reducing the effect of different stretching routines to performance (Fletcher & Annes, 2007).

Once this was completed participants were instructed to assume the anatomical reference position. Ten 19mm Retro-reflective markers (in house, Canterbury Christ Church University, England) were placed on key anatomical reference positions on the body for the video analysis of the results.

Markers were placed at the Acromion Process of the Scapula, Greater trochanter, lateral epicondyle of the femur, Lateral Malleolus of the fibula, and the lateral phalange. These points allowed for the assessment of lower limb activity during trials.

For the trials five metres was assessed to determine start time performance. Participants set up their blocks, to which they felt was there optimum measurement for performance. The block measurements were then measured by the researcher and recorded to make sure the distance remained constant for all trials in all three testing sessions, to keep kinematic results consistent with identical block set up in each session. Participants then had two practice trials from each leg to familiarise themselves with the lab-based sprint start, before pre, mid and post sessions. Participants were then informed whether the first trial would be from their non-preferred or preferred leg. This was done in a random order to increase the validity of results by removing the influence of a learning order. This was maintained throughout the process to reduce the effect of fatigue. When past the five-metre point athletes had ten-metres before making contact with a crash mat. The crash mat was used to ensure athletes did not begin decelerating before passing the final timing gate. A pilot study supports the setup of the crash mat, supporting no changes in results from a trial on athletics track to lab-based conditions (Sandamas, Gutierrez-Farewik & Arndt, 2019).

The procedure for the instructional and starts was that which mimicked race conditions. Participants were first asked to assume the *on your marks position*. This involved the participants setting their feet in the blocks and placing hands behind the marked line and then remaining still for the next instruction. The next instruction is the *set position* which involves the participants raising their hips, ready to perform a drive out of the blocks. Once hips are raised the participants must remain motionless in accordance with IAAF rules until the participants hear the go stimulus. Within this study verbal instruction of *go* was used. The participant then propels the centre of mass forward and drives past the five-metre mark, ensuring they do not decelerate before this point. The go commands in accordance with the IAAF rule of fair start (rule 162.10) determined the athlete held the set position for the scientist to be satisfied that a fair start is produced.

The blocks were swapped round, when required, to prepare for next trial in a random order and participants had a minimum of three minutes rest between each trial run. To reduce the effect of fatigue on results. No feedback of times or performance were given during trials to avoid any external factors influencing results and the motivation of the athlete. Once all trials are completed participants would complete a cool down on the treadmill for five minutes at a low intensity.

Speed data, of the five metre trials, was collected using timing lights (In house, Canterbury Christ Church University, England). Participants performed each trial using the same starting blocks (Olympic E-99-0130, Neuff Athletic Equipment, UK, IAAF Approved). Participants blocks were adjusted, and maintained at the same distance for each individual, to ensure that the first foot strike would land central on the surface of the force platform without the athlete altering the kinematic process and thus allowing for a more natural optimum movement.

To assess first stride touchdown and ground reaction forces a force platform (Kistler piezo-electric force platform, 9287BA, Kistler Instruments Ltd Switzerland) was used to measure how participants utilise ground reaction forces. Participants performed trials barefoot to make sure results were not affected by different shoe and spike configurations (Kerrigan et al., 2009).

To measure angles a camera on both the left and right side of the sagittal plane of motion of the participant (Casio High speed camera x3, EX-FH100, London England) was used. Cameras used a frame rate of 50fps with a five-frame analysis before and after movement to allow for accurate measurements. Cameras assessed the angle of the hip, knee and ankle over the first two strides as well as the linear velocities of the athlete in the sagittal plane of motion. The current study uses 2D analysis of performance variables to assess the impact of the bilateral training intervention. The advantage of using a 2D analysis is that coaches are more interested in the data due to the nature of the skill (Bezodis, Kerwin & Salo, 2008). Several papers researching sprint starts use 2D analysis to assess the athlete's performance from the sagittal plane of motion, assessing several horizontal components of performance effectively (Coh et al., 1998; Sajwan & Yardev, 2014).

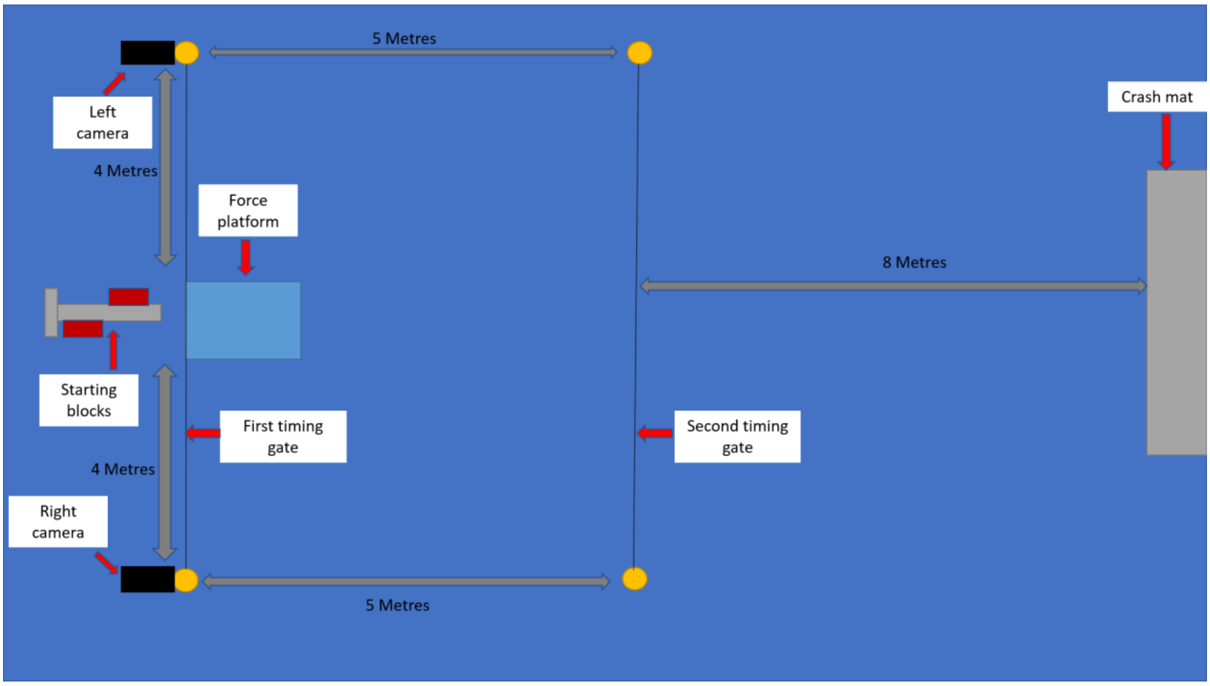

Figure 1: Laboratory set up.

4.5 Data analysis

Video data was analysed using Quintic (Quintic Biomechanics, 9.03 v9a, Quintic Consultancy, Ltd, England). Horizontal and vertical velocity (m/s) was assessed from the shoulder between the set position and the toe-off from the blocks. The shoulder was also used to assess the horizontal and vertical acceleration (m/s^2) from the same stage. The velocity and acceleration, from toe-off at the blocks, was calculated through the camera that was to the right of participants only. This was due to the left camera in two sessions jumping frames, therefore making data inadequate at measuring trials velocities of key joints with that specific camera.

Angles of the ankle, knee and hip were analysed. Several past papers determine the three joints to have a major influence on the success of the sprint start (Slawinki et al., 2010; Bezodis, Willwacher &

Salo, 2019). To assess angles the markers were placed at the Acromion Process of the Scapula, Greater trochanter, lateral epicondyle of the femur, Lateral Malleolus of the fibula, and the lateral phalange. Repeatability of marker placement was taken into account, with the same researcher applying the markers using the same measurement process in each session. The process of locating these key anatomical reference points was a combination of measurements supported by previous research which can be used on large cohorts with good reliability and accuracy over time (Weinhandl & O'Connor, 2010; Seth et al*.,* 2016; Malus et al., 2021).

The set position was determined by the moment before the participant begins to push from the blocks. This is because of movement variability when the participant lifts their hips, and by assessing the moment just before the push off this will give more accurate results to performance contribution. The second position assessed was the toe-off, where the front foot leaves the block plate after the push-off. In line with previous research peak hip, knee and ankle extension was assessed for this phase of the start (Bezodis, Salo & Trewartha, 2014). The mid-stance was determined by the moment between flexion and extension of the athlete's hip joint. This is where the knees are parallel to each other as the rear leg begins to swing through. Finally, the toe-off for the second stride was similarly assessed to that of the push off from the blocks. This is where the hip, knee and ankle are at full extension and the foot producing the propulsion, through ground reaction forces, leaves the ground (Bezodis, Willwacher & Salo, 2019). Step length (m) was also calculated for the first two strides, with previous research supporting that adaption to this affect sprint start performance (Sandamas, Gutierrez-Farewick & Arndt, 2019).

Data files containing GRF components of the first stride touchdown to toe-off were filtered in Bioware (v5.3.0.7, Kistler Instruments Ltd) using a dual pass Butterworth low-pass filter with a cut-off frequency of 50 Hz (Nagahara et al., 2021). The contact time (seconds) was measured by determining the total time the participant was in contact with the force platform, from first touchdown to toe-off. Force results were normalised (mass x 9.81) to body weight (Bw) for accurate representations of ground reaction forces. Vertical force analysis variables during first stride contact were the impact force peak (Bws), loading rate (Bw.s^{-1}) and loading peak (Bws). Anterior posterior force was analysed to determine the braking and propulsive impulses. Figure 2 shows the breakdown of a force platform data file.

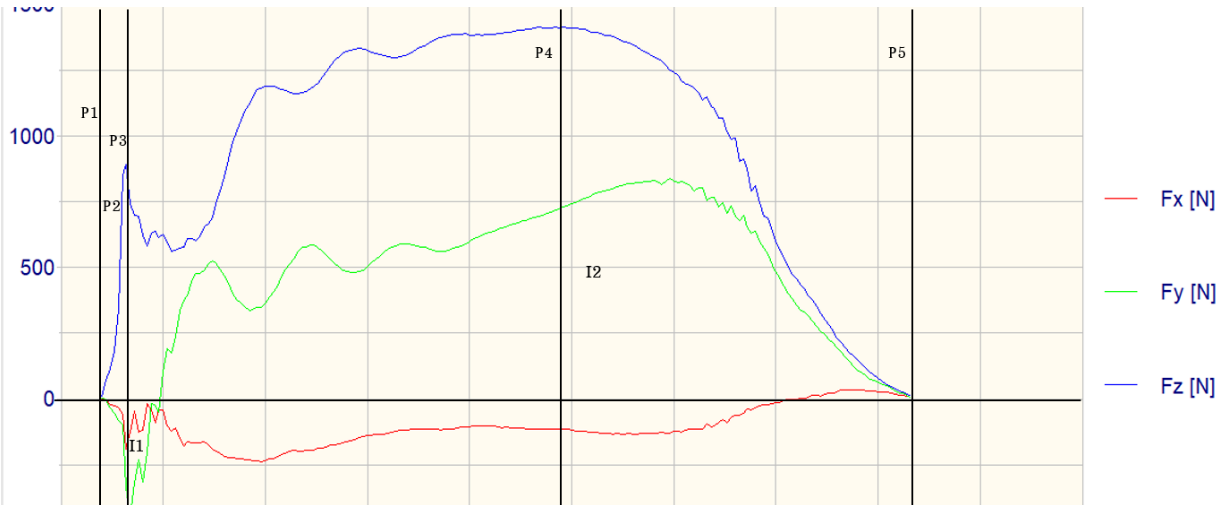

Figure 2*:* Annotated ground reaction force trace. P1- Initial contact, P2- loading rate, P3- Impact force peak, P4- Loading peak, P5- Toe-off, I1- Braking impulse, I2- Propulsive impulse. Fy = anterior posterior force; Fz = vertical force.

Timing gate data was recorded after each trial of the five-metre distance. The mean time of the trials, for pre, mid and post stages, was analysed to assess if the intervention had any effect on five-metre performance.

4.6 Statistical analysis

Results were statistically analysed using IBM SPSS statistics 23 (SPSS Inc., Chicago, IL, USA). All data was assessed for normality using the Shapiro-Wilk test. All the data for each individual athlete had a means and standard deviations generated for both preferred and non-preferred trials in each session. A mean of each variable from each session was recorded. Repeated measures ANOVA with Bonferroni post-hoc analysis was performed to compare the mean values for the five-metre sprint start performances. Significant changes (p= < 0.05) of the kinematic angles (hip, knee, ankle) and the force platform data between groups were assessed. A least significant difference (LSD) was used when the Bonferroni post-hoc was too conservative. When a significant interaction was found (p= <

0.05), a paired sample T-test analysis was implemented. Where the sphericity assumption was violated, the Greenhouse-Geisser correction was used. Effect sizes were calculated as partial eta squared (η_p^2) and small, medium, and large effects were taken as $\eta_p^2 \geq 0.01$, $\eta_p^2 \geq 0.059$, and $\eta_p^2 \geq 0.138$ respectively (Currell & Jeukendrup, 2013). Statistical significance was accepted where $P < 0.05$ was found.

Results are reported as lead and trail leg data. Lead refers to the foot on the front block in the set position, trail refers to the foot on the back block in the set position. When data is referred to in later phases as lead or trail, this still refers to the foot positioning in the set position. Therefore, lead leg and trail leg data tracks the performance of the same leg from the set position.

5.0 Results

The 5m personal best times for the intervention group were 1.19s ± 0.08s, whilst the control group had mean personal best times of 1.14s ± 0.09. All participants (n=12) completed pre, mid and post intervention stages over the eight-week period. Results in figures and tables are presented as pre, mid and post stage of intervention for the control and intervention group. Results for the hip, knee and ankle angles are presented as mean ± standard deviation for participants in the control or intervention group.

5.1 Five metre time

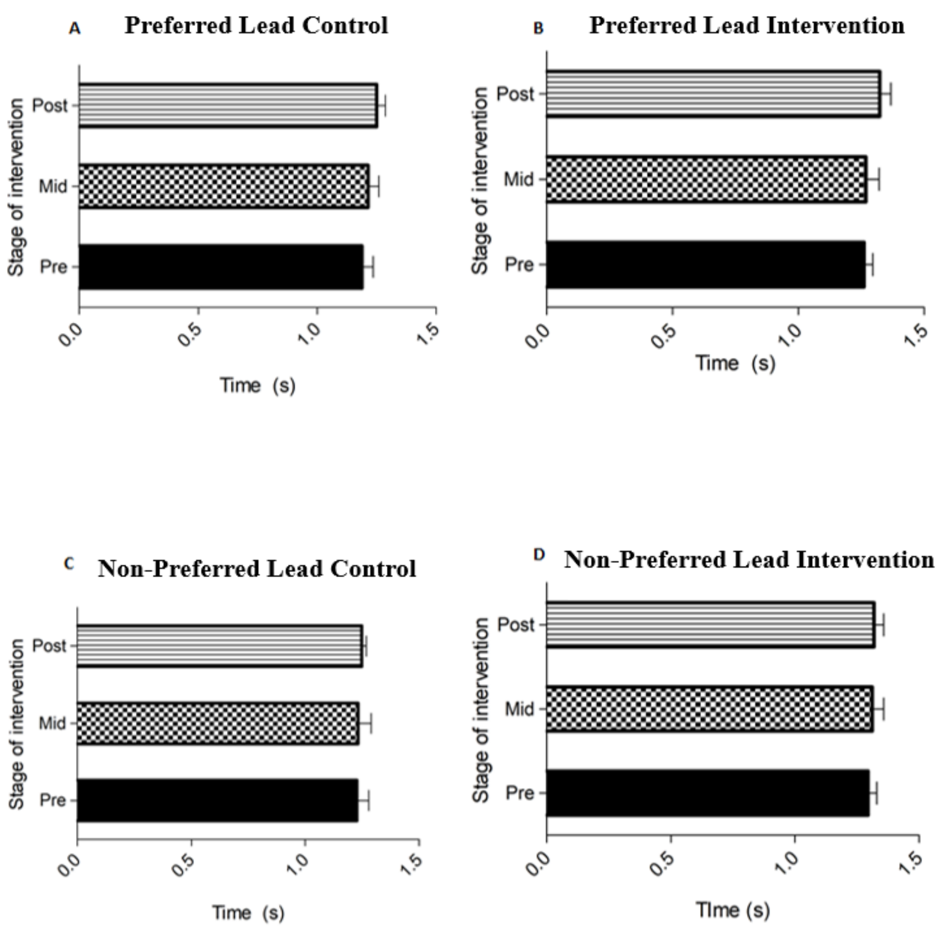

Figure 3: *Five metre time data for Preferred and Non-Preferred trials.* **A**- Control group preferred leg lead, **B**- Intervention group preferred leg lead, **C**- Control group non-preferred leg lead, **D**- Intervention group non-preferred leg lead.

Figure 3 shows 5m sprint time means across stages for both the control and intervention group. The control group when using the preferred leg presented mean times of 1.187s ± 0.112s for the pre stage, 1.215s ± 0.114s for the mid stage and 1.248s ± 0.092s for the post stage of testing. The intervention group when using the preferred leg presented 5 metre sprint mean times of 1.255s ± 0.078s for the pre stage, 1.254s ± 0.125s for the mid stage and 1.313s ± 0.103s for the post stage of testing.

When using the non-preferred leg the control group presented mean 5 metre sprint times of 1.229s ± 0.127s for the pre stage, 1.233s ± 0.142s for the mid stage and 1.250s ± 0.048s for the post stage of testing. The intervention group when using the non-preferred leg produced 5 metre sprint mean times of 1.294s ± 0.086s for the pre stage, 1.309s ± 0.114s for the mid stage and 1.316s ± 0.096s for the post stage of testing.

No significant interaction of stages was found for speed for the preferred (P = 0.136; $\eta_p{}^2$ = 0.181) or the non-preferred leg trials (P=0.716; $\eta_p{}^2$ = 0.033). There was no interaction between stages and group for the preferred (P = 0.899; $\eta_p{}^2$ = 0.011) and non-preferred leg (P= 0.974; $\eta_p{}^2$ = 0.003).

5.2 Lead leg data

Table 1 shows the average angle and standard deviation of results for both the control and intervention group. This is presented across stages with separate results for the preferred and non-preferred leg trials.

Table 1*: Lead leg side data*

		Pre-stage		Mid-stage		Post-stage	
		Control	Intervention	Control	Intervention	Control	Intervention
Set Position (°)	Hip Preferred Lead	39.05±4.75	33.53±2.69	42.10±5.21*	43.15±5.34*	42.98±4.72*	42.84±4.44*
	Hip Non-Preferred Lead	40.06±4.47	36.37±3.99	42.81±4.20*	45.08±4.51*	43.23±3.56*	43.46±4.19*
	Knee Preferred Lead	102.27±3.74	93.86±4.39	102.12±5.29	91.34±5.85	100.71±5.91	94.34±5.42
	Knee Non-Preferred Lead	106.06±4.92	91.42±5.47	106.82±6.79	94.08±5.21	103.00±5.37	93.28±4.13
	Ankle Preferred Lead	116.10±4.42	116.27±3.42	108.21±3.65*	102.10±2.91*	108.03±4.20*	102.98±3.80*
	Ankle Non-Preferred Lead	113.14±4.26	110.74±3.68	110.32±3.24*	105.16±3.03*	106.06±4.61	102.58±3.56
Toe off (°)	Hip Preferred Lead	154.16±2.93	150.69±3.76	156.09±4.56	154.09 ± 2.35	158.24±3.14*	156.41±2.67*
	Hip Non-Preferred Lead ɤ	162.46±3.92	149.87±1.38	159.41±3.90	154.60±2.52	160.30±2.82	157.47±2.10
	Knee Preferred Lead	163.68±2.32	165.93±3.09	167.88±2.26	163.48±2.90	166.16±2.01	166.62±3.16
	Knee Non-Preferred Lead	168.40±2.25	165.24±2.01	169.51±1.66	168.18±0.98	167.18±2.50	167.12±1.36
	Ankle Preferred Lead	149.38±2.25	144.52±2.86	147.34±0.84	141.58±1.31	146.52±1.54	141.90±1.26
	Ankle Non-Preferred Lead	145.37±2.61	146.20±2.15	149.92±2.31	145.28±2.38	145.78±3.35†	140.84±1.63†
Mid Stance (°)	Hip Preferred Lead	122.20±4.72	123.20±5.39	118.86±2.05	128.20±3.50	127.51±2.70	128.54±2.27
	Hip Non-Preferred Lead ɤ	125.29±3.321	118.04±4.78	124.31±3.24	126.28±2.86	125.41±2.16*	129.28±2.96*
	Knee Preferred Lead	69.08±6.04	68.73±2.60	66.94±4.95	71.19±4.93	76.57±5.44	70.78±2.70
	Knee Non-Preferred Lead	71.25±3.59	63.57±3.73	71.47±3.95	71.51±2.34	76.08±5.27*	72.25±2.11*
	Ankle Preferred Lead	130.15±4.63	122.56±4.23	121.92±4.50	125.86±3.44	121.44±3.96	122.87±2.63
	Ankle Non-Preferred Lead	128.69±4.11	122.28±5.60	127.77±2.30	124.47±3.08	122.85±4.56†	119.00±2.48†
Second stride toe-off (°)	Hip Preferred Lead	89.29±5.53	89.45±4.16	88.42±2.81	89.09±4.86	92.21±4.13	89.92±1.45
	Hip Non-Preferred Lead ɤ	90.13±3.76	81.05±4.05	90.63±3.10	89.15±3.78	90.64±3.61 *	90.96±2.11*
	Knee Preferred Lead ɤ	99.2±6.58	101.53±2.69	93.53±5.15	99.45±1.92	100.4±4.7	95.08±2.2
	Knee Non-Preferred Lead	105.43±7.25	100.39±3.41	101.77±4.69	102.21±3.74	104.38±6.01	97.75±3.85
	Ankle Preferred Lead	98.35±3.42	98.67±2.33	93.63±1.32	96.06±1.65	93.28±2.31*	92.40±1.31*
	Ankle Non-Preferred Lead	97.04±2.41	100.17±3.55	94.42±1.49*	94.50±1.52*	95.99±3.27	92.31±0.90

Note: * $P < 0.05$ Significant difference to Pre tests; † $P < 0.05$ Significant difference to Mid-stage; ɤ Denotes significant interaction between time and condition.

Set position Lead leg data

There was a significant interaction across stages for the hip angle of the preferred lead leg (*P* = 0.003; η_p^2 = 0.439). A significant increase in the hip angle was found between pre to mid stage (*P*= 0.026) and pre to post stage (*P*= 0.039), with no interaction found between stages and group (*P* = 0.206 ; η_p^2 = 0.146). There was also a significant interaction of stages for the hip angle of the non-preferred lead leg (*P*= < 0.001; η_p^2 = 0.521). A significant increase in hip angle was found between pre to mid stage (*P*=0.006) and pre to post stage (*P*=0.017), with no significant interaction found between stages and group (*P*= 0.106 ; η_p^2 = 0.201).

No significant interaction of stages was found for the preferred lead knee angle (*P*= 0.854; η_p^2 = 0.016) or the non-preferred lead knee angle (*P*= 0.586; η_p^2 = 0.04). There was no interaction between stages and group for the preferred lead (*P*= 0.659; η_p^2 = 0.041) or non-preferred lead leg (*P*=0.570; η_p^2 = 0.043) knee angle.

A significant interaction of the ankle angle data was found across stages for the preferred lead trials (*P*= < 0.001; η_p^2 = 0.549). A significant decrease in the ankle angle was found between pre to mid stage (*P*=0.001) and pre to post stage (*P*= 0.014), with no interaction between group and stages found (*P*= 0.431; η_p^2 = 0.081). There was also a significant interaction found for the ankle angle of the non-preferred leg lead (*P*= 0.024; η_p^2 = 0.311). An LSD post-hoc was used show a significant decrease in the ankle angle from pre to mid stage (*P*=0.024), with no interaction between stages and group (*P*=0.862; η_p^2 = 0.015).

<u>Toe-off Lead leg</u>

There was a significant interaction across stages for the preferred leg lead hip angle (*P*=0.012; η_p^2 = 0.359). A significant increase in hip angle was found between pre and post stage (*P*=0.011), with no interaction between stages and group found (*P*= 0.829; η_p^2 = 0.019). No significant interaction was found across stages for the non-preferred hip angle (*P*=0.106; η_p^2 = 0.201). There was a significant interaction between stages and group (*P*= 0.002; η_p^2 = 0.462). The intervention group demonstrated a greater increase in hip angle between the pre to mid stage (*P*=0.031) compared to the control group (*P*=0.175). There was also a greater increase in hip angle for the intervention group between mid and post stage (*P*=0.041) compared to the control group (*P*=0.580). There was also a greater increase in hip angle for the intervention group between pre and post stage (*P*=0.002) compared to the control group (*P*=0.458).

No significant interaction across stages was found for the knee angle of the preferred leg lead (*P*= 0.665; η_p^2 = 0.040) or non-preferred lead (*P*= 0.254; η_p^2 = 0.129). There was no interaction between stages and group for the preferred (*P*= 0.167; η_p^2 = 0.164) or non-Preferred (*P*= 0.436; η_p^2 = 0.071) knee angle.

The preferred leg lead ankle angle presented no significant interaction across stages (*P*= 0.145; η_p^2 = 0.176) and between stages and group (*P*= 0.921; η_p^2 = 0.008). There was a significant interaction across stages for the non-preferred lead ankle angle (*P*= 0.032; η_p^2 = 0.291). There was a significant decrease in ankle angle between mid to post stages (*P*=0.046). No significant interaction was found between stages and group (*P*= 0.122; η_p^2 = 0.190).

<u>Mid stance Lead Leg</u>

No significant interaction of stages was found for the preferred leg lead hip angle (*P*= 0.126; η_p^2 = 0.187) or the between stages and group (*P*= 0.224; η_p^2 = 0.139). There was a significant interaction of stages found for the non-preferred lead leg hip angle (*P*= 0.044; η_p^2 = 0.268). There was a significant increase in hip angle between the pre and post stages (*P*= 0.030). A significant interaction was also found between stages and group (*P*= 0.036; η_p^2 = 0.282). The intervention group demonstrated a greater increase in hip angle between pre and mid stage (*P*=0.022) compared to the control group (*P*=0.810). There was also a greater increase in hip angle present for the intervention group between the pre and post stage (*P*=0.011) compared to the control group (*P*=0.958).

No significant interaction across stages for the knee angle for preferred leg lead trials was found (*P*= 0.115; η_p^2 = 0.194) as well as the between stages and group (*P*= 0.152; η_p^2 = 0.172). There was a significant interaction of stages found for the non-preferred lead leg knee angle (P= 0.025; η_p^2 = 0.308). There was a significant increase in knee angle from the pre to post stages (P= 0.037). No significant interaction was found between stages and group (P= 0.263; η_p^2 = 0.125).

There was no significant interaction of stages for the preferred leg ankle angle (P= 0.293; η_p^2 = 0.115) or between stages and group (P= 0.092; η_p^2 = 0.212). There was a significant interaction across stages for the non-preferred lead leg ankle angle (P= 0.042; η_p^2 = 0.272). There was a significant decrease in the ankle angle between the mid and post stage (P=0.020). No significant interaction between stages and group was found (P= 0.729; η_p^2 = 0.031).

Second stride Lead Leg

There was no significant interaction across stages for the preferred leg lead hip angle (P= 0.615; η_p^2 = 0.047) or between stages and group (P= 0.806; η_p^2 = 0.021). There was a significant interaction across stages for the non-preferred leg lead hip angle (P= 0.016; η_p^2 = 0.339). There was a significant increase in hip angle between pre and post stage (P= 0.026). A significant interaction between stages and group was also found (P= 0.032; η_p^2 = 0.292). There was a greater increase in hip angle for the intervention group between the pre and mid stage (P=0.008) compared to the control group (P=0.897). There was also a greater increase in hip angle from the pre to post stage for the intervention group (P=0.010) compared to the control group (P=0.816).

There was no significant interaction of stages found for the preferred leg lead (P=0.122; η_p^2 = 0.190) or non-preferred leg lead (P=0.551; η_p^2 = 0.058) knee angle. A significant interaction between stages and group was found for the Preferred leg lead knee angle (P= 0.018; η_p^2 = 0.329). The control group demonstrated a greater decrease in knee angle between mid and post stage (P=0.001) compared to the intervention group (P=0.217). No significant interaction between stages and group was found for the non-Preferred leg (P=0.109; η_p^2 = 0.199) for the lead knee angle.

There was a significant interaction of stages found for the preferred leg lead ankle angle (P= 0.005; η_p^2 = 0.410). There was a significant decrease in ankle angle between the pre and post stages (P= 0.008). A significant interaction was not found between stages and group (P= 0.563; η_p^2 = 0.056). A significant interaction of stages was also found for the ankle angle of the non-preferred lead leg (P= 0.016; η_p^2 = 0.339). There was a significant decrease in the ankle angle from pre to mid stages (P=0.043). A significant interaction was not found between stages and groups (P= 0.115; η_p^2 = 0.194).

5.3 Trail leg data

Table 2 shows the average angle and standard deviation of results for both the control and intervention group. This is presented across stages with separate results for the preferred and non-preferred leg trials.

Table 2: *Trail leg side data*

		Pre-stage		Mid-stage		Post-stage	
		Control	Intervention	Control	Intervention	Control	Intervention
Set Position (°)	Hip Preferred Lead	65.60±7.80	59.30±3.64	68.67±6.56	71.31±4.77	67.15±5.98	72.21±6.30
	Hip Non-Preferred Lead	62.91±7.20	60.12±3.67	67.97±7.01*	70.25±5.71*	66.99±7.06	70.71±6.32
	Knee Preferred Lead	112.08±6.03	94.99±7.81	115.85±7.69	107.34±11.52	111.74±7.67	108.48±11.23
	Knee Non-Preferred Lead	111.34±4.52	99.54±6.48	115.99±7.80	104.36±9.73	110.92±8.16	106.59±10.67
	Ankle Preferred Lead	106.84±2.13	103.87±3.13	102.58±2.81	100.04±3.28	99.34±2.63*	97.88±3.36*
	Ankle Non-Preferred Lead	108.71±3.08	100.77±3.05	104.31±2.11	97.30±3.18	101.30±2.72*	96.84±2.72*
Toe off (°)	Hip Preferred Lead	76.86±4.42	73.48±3.46	79.28±1.94*	81.76±2.70*	79.01±2.37	79.09±3.25
	Hip Non-Preferred Lead	78.22±4.14	79.17±3.32	80.10±3.78	80.82±3.04	79.92±3.17	82.87±3.76
	Knee Preferred Lead	92.87±9.34	95.96±4.74	89.60±5.23	91.47±3.12	88.90±4.39	89.96±3.55
	Knee Non-Preferred Lead	90.51±6.04	94.31±4.23	85.54±5.22*	90.77±3.18*	86.52±4.71*	88.28±2.22*
	Ankle Preferred Lead	97.30±4.86	103.33±4.69	92.65±3.07*	95.81±2.66*	92.49±3.40*	90.26±2.42*
	Ankle Non-Preferred Lead	100.12±3.96	99.18±2.56	94.73±2.91*	97.51±1.95*	94.01±3.66*	90.83±2.38*
Mid Stance (°)	Hip Preferred Lead	117.80±3.36	113.82±4.97	118.50±1.06*	121.50±3.21*	119.01±1.66	119.36±2.96
	Hip Non-Preferred Lead	117.58±4.78	118.62±4.24	117.69±2.77	120.33±3.53	121.82±1.74	119.09±2.23
	Knee Preferred Lead	120.49±2.24	128.63±3.19	120.97±4.42	126.26±3.08	118.69±3.53	124.52±3.39

	Knee Non-Preferred Lead ɣ	118.78±2.57	131.59±2.92	118.51±4.03*	124.81±2.50*	120.02±2.54	123.10±4.05
	Ankle Preferred Lead	86.81±2.88	93.52±3.07	86.95±2.57	91.15±1.90	85.04±2.86*	86.85±2.62*
	Ankle Non-Preferred Lead	92.53±2.23	90.64±2.47	90.86±2.63	90.61±1.46	90.04±3.48	87.74±1.39
Second stride toe-off (°)	Hip Preferred Lead ɣ	163.69±4.45	150.38±5.22	163.33±4.63*	162.45±2.10*	162.97±3.32	161.17±2.58
	Hip Non-Preferred Lead	162.55±4.21	155.53±4.16	162.84±3.61	157.41±2.44	161.82±2.88	160.49±2.55
	Knee Preferred Lead	156.98±2.88	152.55±3.55	156.18±3.43	156.41±1.64	155.01±3.83	158.51±2.78
	Knee Non-Preferred Lead	155.72±2.99	154.8±3.47	157.36±2.72	153.53±2.84	157.92±2.36	155.54±3.42
	Ankle Preferred Lead	140.12±3.30	141.70±2.89	143.27±3.18	138.76±3.24	138.06±3.93*	132.95±1.80*
	Ankle Non-Preferred Lead	143.31±2.93	136.49±3.75	144.03±1.35	138.58±0.57	137.77±2.99†	132.53±1.56†

Note: * P < 0.05 Significant difference to Pre tests; † P < 0.05 Significant difference to Mid-stage; ɣ Denotes significant interaction between time and condition.

<u>Set Position trail leg</u>

No significant interaction of stages was found for the preferred leg trials hip angle (P= 0.060; η_p^2 = 0.294) or the between stages and group (P= 0.155; η_p^2 = 0.170). There was a significant interaction of stages for the non-preferred leg trials hip angle (P= 0.022; η_p^2 = 0.318). There was a significant increase in the hip angle from pre to mid stage (P=0.026). No significant interaction was found between stages and group (P= 0.494; η_p^2 = 0.068).

There was no significant interaction of stages found for the Preferred leg (P=0.152; η_p^2 = 0.172) or the Non-Preferred leg (P= 0.496; η_p^2 = 0.068) trials knee angle. There was no significant interaction between stages and group for the preferred leg (P= 0.277; η_p^2 = 0.121) or non-preferred leg (P= 0.579; η_p^2 = 0.053) trials knee angle.

A significant interaction of stages was found for the preferred leg trials ankle angle (P= 0.001; η_p^2 = 0.485). There was a significant decrease in ankle angle from pre to post stage (P= <0.001). No significant interaction between stages and group was found (P= 0.885; η_p^2 = 0.012). There was also a significant interaction of stages found for the non-preferred leg trials ankle angle (P= 0.016; η_p^2 = 0.337). There was a significant decrease in ankle angle between pre and post stage (P=0.020). No significant interaction between stages and group was found (P= 0.620; η_p^2 = 0.047).

Toe off trail leg

Statistical analysis determined there was a significant interaction of the hip angle across stages for the preferred leg trials (P= 0.043; η_p^2 = 0.270). There was a significant increase in hip angle from the pre to mid stage (P= 0.042). No significant interaction between stages and groups was found (P= 0.369; η_p^2 = 0.095). No significant interaction of stages was found for the non-preferred leg trials hip angle (P= 0.329; η_p^2 = 0.105) as well as between stages and group (P= 0.792; η_p^2 = 0.023).

Preferred leg trials showed no significant interaction across stages for the knee angle (P= 0.190; η_p^2 = 0.153) or between stages and group (P= 0.934; η_p^2 = 0.007). A significant interaction of stages was found for the knee angle during non-preferred leg trials (P=0.006; η_p^2 = 0.400). There was a significant decrease in knee angle from pre to mid (P=0.012) and pre to post (P=0.019) stages. No significant interaction between stages and groups was found (P= 0.511; η_p^2 = 0.065).

The ankle angle results found a significant interaction of stages for the preferred leg trials (P= < 0.001; η_p^2 = 0.570). There was a significant decrease in ankle angle from the pre to mid (P=0.020) and pre to post (P=0.006) stages. No significant interaction was found between the stages and group (P= 0.086; η_p^2 = 0.218). A significant interaction of stages was also found for the ankle angle during non-preferred leg trials (P= < 0.001; η_p^2 = 0.562). There was a significant decrease in the ankle angle from the pre to mid (P=0.023) and pre to post (P=0.002) stages. No significant interaction was found between stages and group (P= 0.135; η_p^2 = 0.181).

Mid-Stance

A significant interaction of stages was found for the preferred leg trials hip angle (P= 0.028; η_p^2 = 0.301). There was a significant increase in the hip angle from pre to mid stage (P=0.037). No significant interaction between stages and group was found (P= 0.091; η_p^2 = 0.213). No significant interaction of stages was found for the hip angle for non-preferred trials (P= 0.651; η_p^2 = 0.042) or for the interaction of stages and group (P= 0.563; η_p^2 = 0.056).

No significant interaction of stages was found for the preferred leg trials knee angle (*P*= 0.104; η_p^2 = 0.234) or for the interaction of stages and group (*P*= 0.416; η_p^2 = 0.071). A significant interaction of stages was found for the knee angle during non-preferred leg trials (*P*= 0.048; η_p^2 = 0.262). There was a significant decrease in the knee angle from the pre to mid stage (*P*=0.031). There was also a significant interaction between stages and group (*P*= 0.016; η_p^2 = 0.338). The intervention group displayed a greater decrease in knee angle between the pre and mid stage (*P*=0.002) compared to the control group (*P*=0.891).

The ankle angle during preferred leg trials showed a significant interaction across stages (*P*= 0.016; η_p^2 =0.339). There was a significant decrease in the ankle angle from pre to post stage (*P*=0.030). No significant interaction between stages and group was found (*P*= 0.223; η_p^2 = 0.139). The non-preferred leg trials displayed no significant interaction of stages for the ankle angle (*P*= 0.175; η_p^2 = 0.160) or for the interaction between stages and group (*P*= 0.747; η_p^2 = 0.029).

<u>Second stride Toe-off</u>

A significant interaction of stages was found for the preferred leg trials hip angle (*P*= 0.008 ; η_p^2 = 0.383). There was a significant increase of the hip angle between the pre and mid stage (*P*=0.034). A significant interaction was also found for the interaction between stages and group (*P*=0.004; η_p^2 = 0.425). The intervention group demonstrated a greater increase in hip angle between the pre to mid stage *(P*=0.019) of testing compared to the control group (*P*=0.805). There was also a greater increase of hip angle for the intervention group between the pre and post stage (*P*=0.028) compared to the control group (*P*=0.712). No significant interaction of stages was found for the non-preferred leg trials hip angle (*P*= 0.479; η_p^2 = 0.058) or for the interaction between stages and group (*P*= 0.309; η_p^2 = 0.107).

No significant interaction of stages was found for the knee angle for the preferred leg (*P*=0.576; η_p^2 = 0.054) and non-preferred leg (*P*=0.604; η_p^2 = 0.049) trials. There was no significant interaction between stages and group for the preferred leg (P=0.153; η_p^2 = 0.171) and non-preferred leg (P=0.632; η_p^2 = 0.045) knee angle in trials.

There was a significant interaction of stages for the ankle angle across the preferred leg trials (P= 0.006; η_p^2 = 0.404). There was a significant decrease in the ankle angle from the pre to post (P=0.021) and mid to post (P=0.023) stages. There was no significant interaction between group and stages (P= 0.122 ; η_p^2 = 0.190). A significant interaction of stages was found for the ankle angle across non-preferred leg trials (P= 0.015; η_p^2 = 0.345). There was a significant decrease in ankle angle from the mid to post stage (P=0.011). There was no significant interaction found between stages and group (P= 0.912; η_p^2 = 0.009).

5.4 Acceleration and velocity data

All acceleration and velocity results were only collected from the right side of the body due to a technical fault with the left camera, therefore not allowing for a left side analysis of acceleration and velocity. The point of assessment was therefore changed to the shoulder assessing the acceleration and velocity from the set position to toe-off.

Table 3: *Acceleration and Velocity data*

		Pre-stage		Mid-stage		Post-stage	
	Trial	Control	Intervention	Control	Intervention	Control	Intervention
Horizontal Acceleration m/s^2	Preferred Lead	4.78±0.34†	4.97±0.28†	5.21±0.32	5.34±0.38	5.08±0.29	4.96±0.19
	Non-Preferred Lead	4.96±0.42†	5.11±0.36†	5.36±0.38	5.18±0.39	5.12±0.30	5.46±0.41
Vertical Acceleration m/s^2	Preferred Lead	-0.01±0.34	-0.38±0.18	-0.26±0.13	-0.19±0.15	-0.41±0.13	-0.07±0.21
	Non-Preferred Lead	-0.38±0.12	-0.19±0.19	-0.30±0.2	-0.10±0.30	-0.33±0.15	-0.17±0.19
Horizontal Velocity m/s	Preferred Lead	1.96±0.1	1.90±0.06	2.02±0.08	1.98±0.04	2.01±0.07	1.93±0.05
	Non-Preferred Lead	1.97±0.09	1.89±0.05	1.99±0.06	1.87±0.03	1.94±0.08	1.87±0.05
Vertical Velocity m/s	Preferred Lead	0.88±0.05	0.95±0.03	0.84±0.02	0.94±0.04	0.88±0.02	0.97±0.05
	Non-Preferred Lead	0.89±0.02	0.97±0.02	0.86±0.01	0.93±0.06	0.92±0.03	0.95±0.04

Note: * P < 0.05 Significant difference to Pre tests; † P < 0.05 Significant difference to Mid-stage; ɤ Denotes significant interaction between time and condition

Horizontal Acceleration

There was a significant interaction of stages for horizontal acceleration during the preferred leg trials (P= 0.003; η_p^2 = 0.442). There was a significant increase in horizontal acceleration from the pre to mid stage (P=0.001). No significant interaction was found between stages and group (P= 0.311; η_p^2 = 0.110). There was a significant interaction of stages found for horizontal acceleration across non-preferred lead leg trials (P=0.035; η_p^2 = 0.286). There was a significant increase in horizontal acceleration from the pre to mid stage (P=0.040). No significant interaction of stages and group were found (P=0.064; η_p^2 = 0.241).

Vertical Acceleration

No significant interaction of stages was found for vertical acceleration for the preferred leg (P=0.850; η_p^2 = 0.006) or non-preferred leg (P=0.782; η_p^2 = 0.024) trials. There was no significant interaction between stages and group for the preferred (P=0.131; η_p^2 =0.206) and non-preferred (P=0.982; η_p^2 = 0.002) leg trials.

Horizontal Velocity

No significant interaction of stages was found for the horizontal velocity during preferred leg (P=0.447; η_p^2 = 0.077) and non-preferred leg (P=0.794; η_p^2 = 0.023) trials. No significant interaction of stages and group was found for the preferred leg (P= 0.933; η_p^2 = 0.007) or non-preferred leg (P= 0.817; η_p^2 = 0.020) trials.

Vertical Velocity

There was no significant interaction of stages found for the vertical velocity across preferred (P=0.549; η_p^2 = 0.058) and non-preferred (P=0.450; η_p^2 = 0.077) trials. No significant interaction of stages and group was found for the preferred leg (P= 0.865; η_p^2 = 0.014) and non-preferred leg (P=0.662; η_p^2 = 0.040) trials.

5.5 Step length data

Table 4: *Stride length data*

		Pre-stage		Mid-stage		Post-stage	
		Control	Intervention	Control	Intervention	Control	Intervention
First Step Length (m)	Preferred Lead	0.98±0.03	0.87±0.03	0.97±0.03	0.87±0.03	1.00±0.04	0.91±0.02
	Non-Preferred Lead	1.00±0.03	0.88±0.03	0.95±0.04	0.90±0.02	0.98±0.03	0.93±0.03
Second Step Length (m)	Preferred Lead	1.10±0.04	0.97±0.05	1.07±0.04	1.04±0.03	1.11±0.04	1.01±0.02
	Non-Preferred Lead	1.11±0.01	0.95±0.05	1.07±0.02	1.00±0.03	1.11±0.03	1.01±0.03

Note: * P < 0.05 Significant difference to Pre tests; † P < 0.05 Significant difference to Mid-stage; ɤ Denotes significant interaction between time and condition

First Step

No significant interaction of stages was found for the first step length across the preferred (P=0.331; η_p^2 = 0.105) and non-preferred leg trials (P= 0.338; η_p^2 = 0.103). There was also no significant interaction of stages and group for the preferred leg (P= 0.911; η_p^2 = 0.009) and non-preferred leg (P=0.309; η_p^2 = 0.111) trials.

Second Step

No significant interaction across stages was found for the second step length across preferred leg (P= 0.765; η_p^2 = 0.026) and non-preferred leg (P= 0.600; η_p^2 = 0.050) trials. No significant interaction of stages and group was found for the preferred leg (P= 0.326; η_p^2 = 0.106) and non-preferred (P= 0.274; η_p^2 = 0.121) trials.

5.6 Force platform data

Braking Impulse

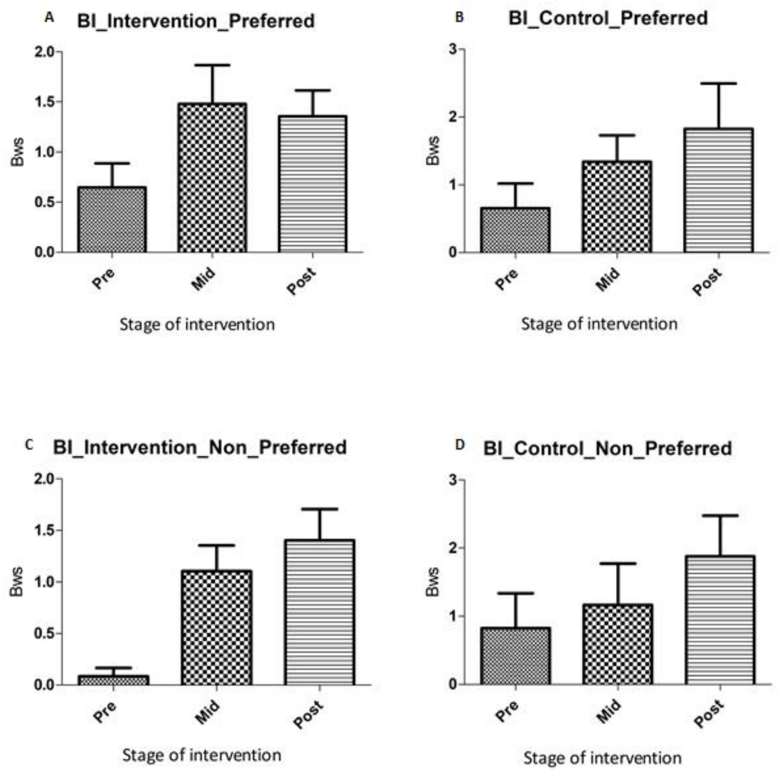

Figure 4: Force platform data graphs- **A-** Braking impulse Intervention group preferred leg trials, **B-** Braking impulse Control group preferred leg trials, **C-** Braking impulse Intervention group non-preferred leg trials, **D-** Braking impulse Control group non-preferred leg trials.

A significant interaction of stages was found for the braking impulse for the preferred leg trials (P= 0.003; η_p^2 = 0.565). There was a significant increase in braking impulse from the pre to mid (P=0.050) and pre to post (P=0.011) stage as can be seen in figure 4. There was no significant interaction between stages and group (P= 0.928; η_p^2 = 0.011). There was also a significant interaction of stages found for the braking impulse across non-preferred leg trials (P= 0.014; η_p^2 = 0.580). There was a significant increase in braking impulse from the pre to post (P=0.012) and mid to post (P=0.023) stage. No significant interaction between stages and group was found (P=0.796; η_p^2 = 0.013).

<u>Propulsive Impulse</u>

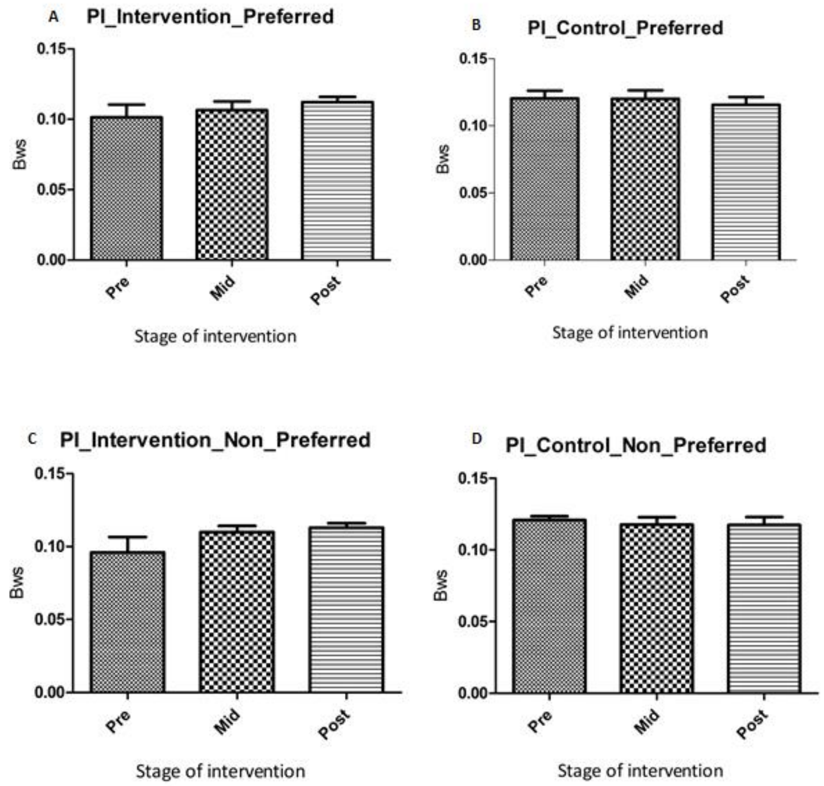

Figure 5: Force platform data graphs- **A-** Propulsive impulse Intervention group preferred leg trials, **B-** Propulsive impulse Control group preferred leg trials, **C-** Propulsive impulse Intervention group non-preferred leg trials, **D-** Propulsive impulse Control group non-preferred leg trials.

No significant interaction was found across stages for the propulsive impulse for the preferred (P= 0.517; η_p^2 = 0.065) and non-preferred (P=0.323; η_p^2 = 0.143) lead leg trials as seen in figure 5. There was no significant interaction between stages and group for the preferred (P= 0.453; η_p^2 = 0.085) and non-preferred (P=0.144; η_p^2 = 0.268) lead leg trials.

Impact force peak

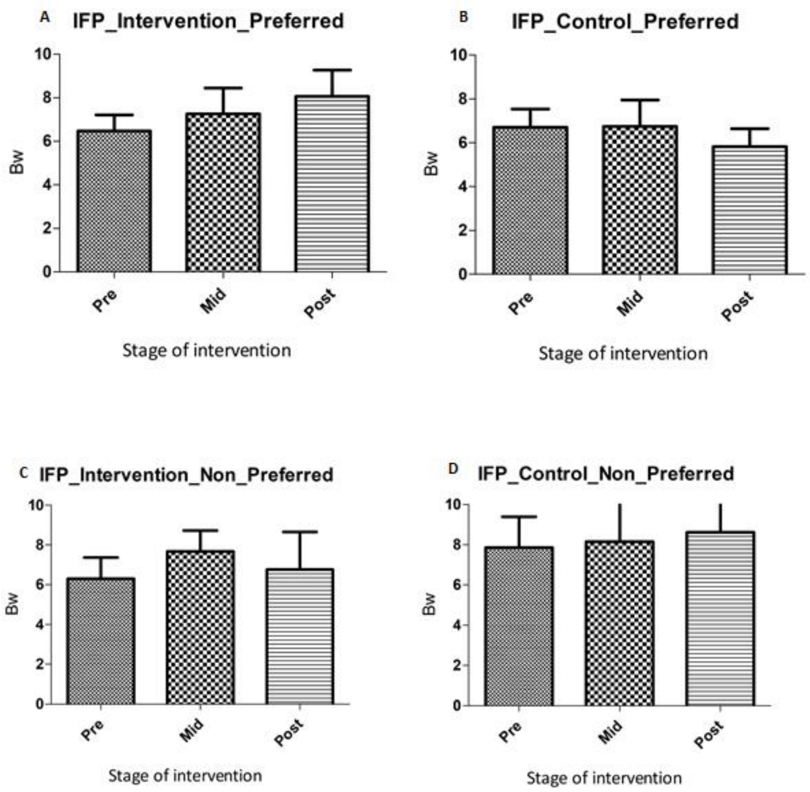

Figure 6: Force platform data graphs- **A-** Impact force peak Intervention group preferred leg trials, **B-** Impact force peak Control group preferred leg trials, **C-** Impact force peak Intervention group non-preferred leg trials, **D-** Impact force peak Control group non-preferred leg trials.

There was no significant interaction of stages for the Impact force peak across preferred (P=0.158; η_p^2 = 0.232) and non-preferred (P=0.111; η_p^2 = 0.270) leg trials as seen in figure 6. No significant interaction between stages and group was found for the preferred (P=0.939; η_p^2 = 0.009) and non-preferred (P=0.927; η_p^2 = 0.011) leg trials.

Loading peak

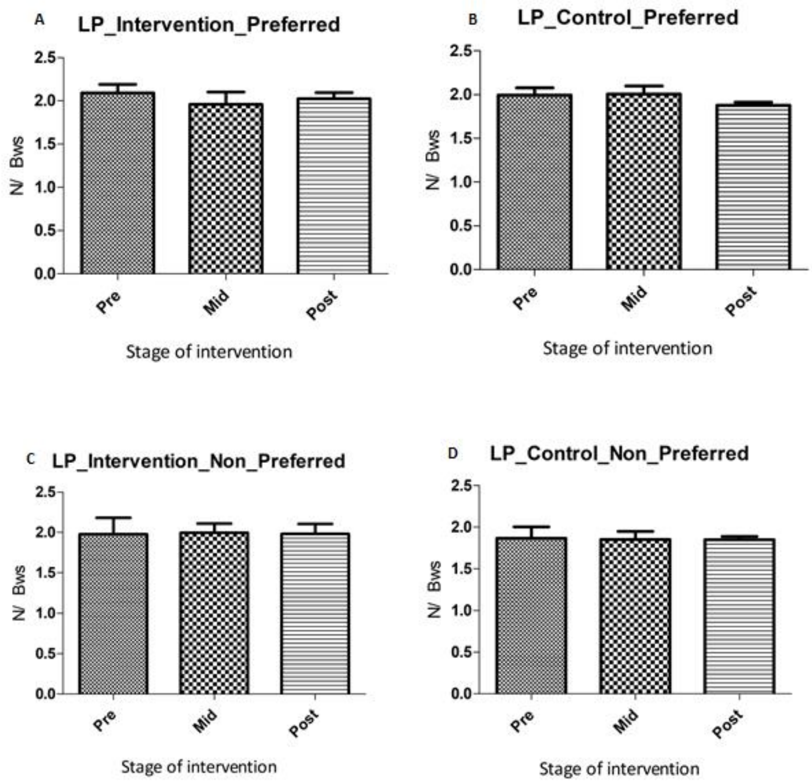

Figure 7: Force platform data graphs- **A-** Loading peak Intervention group preferred leg trials, **B-** Loading peak Control group preferred leg trials, **C-** Loading peak Intervention group non-preferred leg trials, **D-** Loading peak Control group non-preferred leg trials.

The loading peak results showed no significant interaction across stages for the preferred (P=0.360; η_p^2 = 0.136) and non-preferred (P=0.592; η_p^2 = 0.047) leg trials as seen in figure 7. No significant interaction between stages and group were found for the preferred (P= 0.592; η_p^2 = 0.072) and non-preferred (P=0.588; η_p^2 = 0.048) leg trials.

<u>Contact time</u>

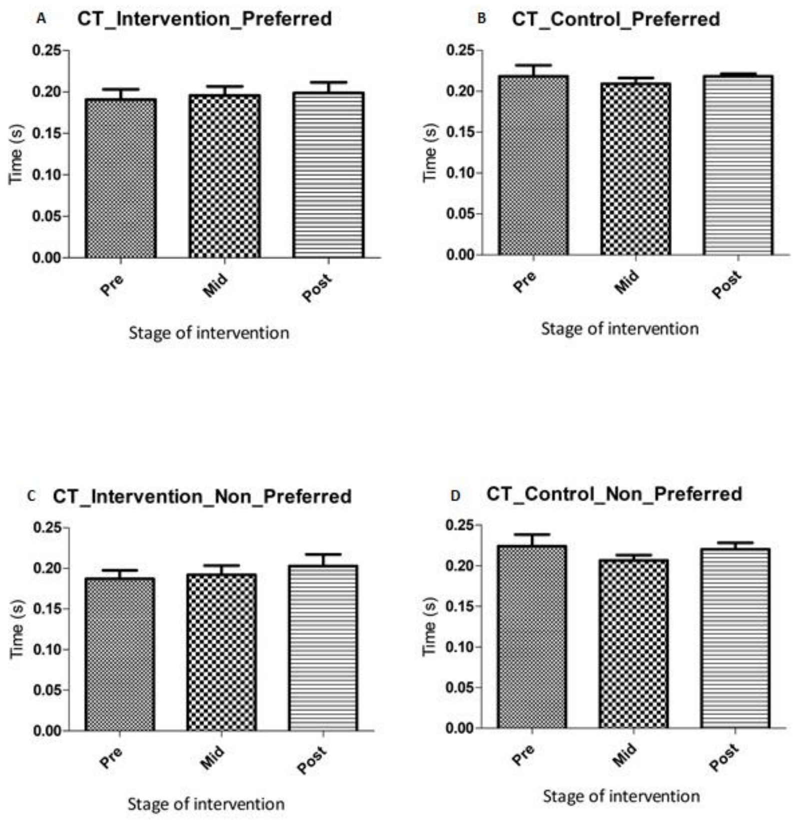

Figure 8: Force platform data graphs- **A-** Contact time Intervention group preferred leg trials, **B-** Contact time Control group preferred leg trials, **C-** Contact time Intervention group non-preferred leg trials, **D-** Contact time Control group non-preferred leg trials.

The contact time showed no significant interaction across stages for the preferred (P=0.337; η_p^2 = 0.137) and non-preferred (P= 0.352; η_p^2 = 0.139) leg trials as seen in figure 8. No significant interaction of stages and group was found for the preferred (P= 0.203; η_p^2 = 0.216) and non-preferred (P= 0.092; η_p^2 = 0.289) leg trials.

Loading rate

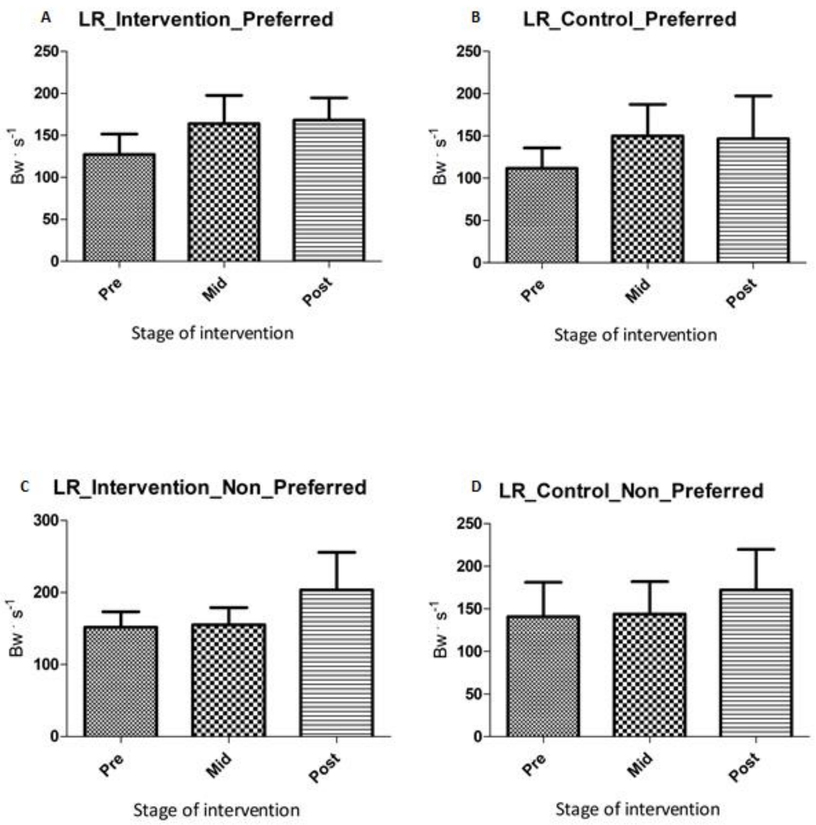

Figure 9: Force platform data graphs- **A-** Loading rate Intervention group preferred leg trials, **B-** Loading rate Control group preferred leg trials, **C-** Loading rate Intervention group non-preferred leg trials, **D-** Loading rate Control group non-preferred leg trials.

There was a significant interaction of stages for the loading rate across preferred leg trials (P=0.025; η_p^2 = 0.409). There was a significant increase in loading rate from the pre to mid (P = 0.038) and pre to post (P=0.043) stages as seen in figure 9. No significant interaction was found between group and stages (P=0.796; η_p^2 = 0.032). The non-preferred leg did not show any significant interaction across stages (P=0.107; η_p^2 = 0.274) or between stages and group (P=0.583; η_p^2 = 0.074).

6.0 Discussion

The aim of the study was to assess whether an eight-week bilateral training intervention can result in kinetic, kinematic and performance change to the sprint start. The main finding from this study was that there was no change in five metre sprint performance across the three stages (pre to mid, mid to post and pre to post) between the intervention and control group. Alongside this, no difference was observed for the interaction between stages and groups for five metre time performance. Collectively, the findings suggest that the eight-week intervention implemented in this study was insufficient to cause changes in sprint start performance over a five-metre distance for male trained sprinters. There were however changes in some of the measures of positioning and kinematic analysis, however these changes did not seem to affect start performance time over the five-metre distance.

Past literature has before implemented an eight-week bilateral training intervention on football players (Halaand and Hoff, 2003). In the study, improvements in soccer specific acceleration drills for both preferred and non-preferred leg were shown after the eight-week intervention, for the intervention group, despite the similar length of the intervention and emphasis on training the non-preferred leg. Indeed, authors attributed the differences found for both preferred and non-preferred leg in the generic improvements in football related motor skills, due to the dynamic systems approach in the training nature of football. Indeed, Halaand and Hoff (2003) implemented football-specific tests and that may have affected their findings. The current study implemented the intervention through switching the lead leg in training sessions so that each leg would spend 50% of the starts as the push off leg. Haaland and Hoff (2003) however used five different tests over the eight-week period to train and assess the effect of the bilateral intervention. In addition to accelerative assessment more interventions in foot tapping tasks were used which could be assumed to have contributed to the differing outcomes of the two studies. Notably all players assessed in the study by Haaland and Hoff (2003) were both right handed and footed, where as in the current study it was a 50% split of left and right footed athletes. To our knowledge, the current study is the first one to identify whether training different leg starts can have an effect on sprint start performance in a non-team sport, such as sprinting. Thus, it is plausible that the specificity of the task administered, the cognitive element required, as well as the previous experiences and the overall ability to perform unilateral tasks in normal training can affect the relationship between preferred, non-preferred leg and performance (Hart et al., 2014; Stockel, Weigelt, 2012).

6.1 Kinematic data

Kinematic data was collected through video cameras, that were placed on both sides for each performance trial during the pre, mid and post assessment sessions. For the five-metre sprint start analysis, only the first two strides from the blocks were analysed. Past research provides evidence that the transition of these two strides, into the next phase of acceleration, is a key parameter of sprint performance that effects the outcome of a sprint race (Coh & Tomazin, 2006). Several kinematic variables of the current paper suggested there were changes across stages for both the control and intervention group. Further, some interactions were observed between stages and groups within the kinematic data. This is consistent with motor skill research, where it is suggested that the changes seen from the intervention group are a construct of the transfer of learning. This is supported by evidence that training both the non-preferred and preferred leg has a stronger bilateral transfer of learning, than unilateral training methods (Issurin, 2013). The same paper provides evidence that within tasks, where the preferred leg is normally used, training the non-preferred side increases the cortical activation in the opposite hemisphere. Thus, evidence supports that the bilateral transfer of learning is stronger from the non-preferred to preferred leg. This is suggested by a greater change at motor neuron level for the contralateral side, when the non-preferred leg is utilised in a skill generally completed by the preferred leg (Issurin, 2013). It could therefore be suggested that the changes to intervention group mechanics in our paper is a consequence of the intervention, of training the non-preferred side for a task normally trained in by the preferred side at the front block, where force impulses are higher than the rear block (Coh et al., 1998; Bezodis, Walton & Nagahara, 2019). However, the current changes identified between intervention and control conditions have not resulted in performance time improvements; they demonstrate bilateral changes, but the impact upon performance has not been demonstrated.

A key kinematic component that both the control and intervention group altered across stages was the ankle angle, for both the preferred and non-preferred leg trials. The results demonstrated decreases in the ankle angles across all four stages (Set, Toe-off, Mid-stance and Second stride toe-off). On the other hand, no changes were found for the Mid-Stance preferred leg lead and the Mid-stance non-preferred trail leg. Research into ankle mechanics by Charalambous et al. (2012), suggested that no relationship was found between ankle stiffness and five metre sprint performance. This research could therefore support why the adaptions of the ankle angle did not affect performance over a five-metre distance. Further research of ankle mechanics should focus on the effect of ankle placement over a greater distance than five metres, with further research showing adaptions when assessing ankle angle over a greater distance (Hunter et al., 2006; Kuitunen, Komi & Kyrolainen, 2002).

Current research suggests that the change of the ankle kinematics could be exaggerated due to participants performing the trials barefoot. In a recent study, different ankle kinematics were shown when athletes trained in shoes and spikes, versus barefoot running (Hollander, Liebl & Meining, 2019). It is then plausible to hypothesize that by performing the trials barefoot, a decrease in ankle stiffness may have occurred and thus, higher degrees of dorsi flexion were achieved during the ground contacts. All participants were instructed, in lab-based tests, to perform all trials barefoot because of the effect shoes and/or spikes have on hip and knee joint torques and consequently to ground reaction forces (Kerrigan et al., 2009). In training sessions however on an outdoor track, athletes trained in spikes due to the nature of training but also from a healthy and safety perspective. It could therefore be argued that the familiarisation during training session was different to conditions experienced in lab-based studies could be due to different joint torques between barefoot and spikes (Kerrigan et al*.,* 2009).

Importantly, the angle of the ankle joint may affect performance through motor control tasks previous evidence has suggested (Kuitunen, Komi & Kyrolainen, 2002). For example, it has been suggested that reductions in the ankle angle during the toe-off may have a negative effect to initial push phase performance, a task controlled by mechanical and neural properties (Kuitunen, Komi &

Kyrolainen, 2002). Nevertheless, the changes in our angle kinematic data were not accompanied by any change in the five-metre sprint start performance. This is in line with research from Charalambous et al. (2012), where ankle stiffness showed to result in no time performance changes to five-metre performance. Further to this, evidence suggests that no correlation is found between ankle and knee stiffness and running speed, and that the increased output of hip extensor muscles is greater associated with increased speed (Kuitunen, Komi & Kyrolainen, 2002). The increased dorsi flexion across stages can be supported by the increase in braking impulse across stages for each group. Hunter et al. (2006) suggests that an increased braking impulse could negatively affect performance, however with a decrease in ankle angle stored elastic energy can be utilized for propulsion. The decrease in ankle angle during the mid-stance may therefore be a result of a higher braking impulse, and an increased horizontal net impulse. Again however, it could be considered in line with past literature that the five-metre distance in our study is not sufficient to measure changes in ankle kinematics (Charalambous et al., 2012).

A further finding from the current research was a significant increase in horizontal acceleration. Improvements of horizontal acceleration were shown from the pre to the mid stage of testing for both the preferred and non-preferred leg, for both groups. The horizontal acceleration was measured from the initial push-off from the blocks to the toe-off position, at the shoulder joint. The importance of horizontal acceleration is one of the key determinants for the success of the sprint start (Bezodis, Salo & Trewartha, 2010), meaning athletes are propelling themselves forward with greater acceleration from the starting blocks. To further our findings, future research should assess both left and right-side velocities which can then also be used to assess the velocity of the hip, knee, and ankle.

The similar pattern of changes between groups may be attributed to a learning effect for the increase in horizontal acceleration. All participants have at least two years' experience of sprint start training and therefore have some knowledge of the criteria about what is expected and required to achieve a successful sprint start. Upon arrival to the pre stage test, athletes were not familiarsed with barefoot running from the blocks or starting regularly with the non-preferred leg on the front block. The only familiarisation completed by participants, before the testing in each session, were the two familiarisation trials on each leg completed before the first of ten trials. The ability to optimisee the sprint starts mechanics is a long-term process and can only be successful when athletes understand and produce a motor pattern that leads to a greater horizontal acceleration (Coh & Zvan, 2015). Athletes therefore know what is required from the movement, which was seen as an advantage of using this sample group, leading to less fluctuation in results due to athlete experience and knowledge of the motor requirements compared to untrained sprinters (Moran et al., 2020). Our current findings however suggest that the fact the participants are barefoot may have led to an increase of the horizontal acceleration. Indeed, participants spent most of their training outside of the tests in spikes and not barefoot. Barefoot running could have triggered sprinters confidence of performing an adapted motor pattern and consequently affected the learning process (Karni et al., 1998). In particular, Karni et al. (1998) suggested that a 'fast learning' effect can take place when a new stimulus is provided to athletes. In turn, that stimuli will trigger motor performances differently, and that can take place even with limited experience and/or very short periods of exposure. Given the differences found in our data between pre and mid stages, we suggest that potentially, the barefoot running style may have influenced the results found in this study. Furthermore, the idea of 'fast learning' could also be related with the changes we observed in the control group. Participants in the control group had experience of the trials in the first pretesting stage and showed similar improvements between pre and post stages to the intervention group. Future studies need to examine this with more controlled experiments, as well as to compare differences between barefoot and spike running in training intervention designs.

To further this another key point for discussion from the results, coinciding with past papers supporting an improvement in kinematic performance of the sprint start (Bezodis, Willwacher & Salo, 2019; Brazil et al., 2018), was the increase in hip angle at toe-off for the intervention group during non-preferred leg trials. This is a key measure of performance to consider as an improvement to the kinematics of block performance, with a greater range of extension at the hip is thought to be positively associated with greater block power (Bezodis, Willwacher & Salo, 2019; Brazil et al., 2018). In the current study, block impulses were not assessed, future research should further examine the relationship after a bilateral training intervention between hip extension and block impulse data to confirm our findings.

Research of start kinematics can help provide evidence for why we think this to be a key effect of the intervention to performance. For the front leg kinematics this is key, with the front leg producing 66-76% of the total horizontal impulse during the push off from the blocks, and more than 60% of the total joint work by that leg during the push-off. To assess the change, velocity of the hip angle needs to be interpreted to confirm the change to hip velocity (Bezodis, Trewartha & Salo, 2008; Bezodis, Willwacher & Salo 2019). In the current study however, this was the original aim, to assess velocity and acceleration of the hip joint. However, velocities and accelerations were assessed from the shoulder, due to disruption to the footage of one of the cameras used for recording. Future research therefore should look to assess the acceleration and velocity at the hip, to further support the effect of the intervention and the outcome of the current studies results.

A transfer of learning can happen from left to right or right to left leg, therefore changes often seen in bilateral interventions can occur regardless of footedness and hemispherical utilisation (Stockel & Wang, 2011). The control and intervention group in the current paper were a mixture of preferred left and preferred right leg lead athletes. This is however is thought not to affect the outcome of results, where similar motor transfer patterns are seen for both preferred left and preferred right participants (Issurin, 2013). The same findings suggest that for our current study, the transfer of learning may have caused a significant interaction in non-preferred hip angle results at toe-off. This is supported by evidence suggesting that the transfer of learning a skill is greater following practice or experience of the preferred limb (Tousi, Emami & Hoeseini, 2017). In the current study all sprinters had experience of training the preferred leg from the front block pre intervention, and the sprint start was a part of their training schedules. Therefore, it could be suggested that training the non-preferred leg on the front block has led to a transfer of learning taking place, which is easier to acquire when the preferred side has experience of the motor sequence. This can be furthered by research supporting that this learning is far more likely to happen when practicing the skill through a variety of sport specific training methods (Tousi, Emami & Hoeseini, 2017). Stockel and Wang (2011) suggest that for a leg extension, where there this a measure of high force impulse, it is very beneficial to the transfer of learning to have prior experience of the preferred leg. This is further examined by the fact that a greater learning effect is likely to occur in these conditions when performers are focused on the outcome goal, rather than paying attention solely to the kinematics of their own movement. This is supported by Ille et al. (2013), who found in their research that having the external focus of attention in a sprint start can lead to a greater performance from the athlete thus influencing performance. Within the current study a five-metre sprint distance was used, with athletes focused on performing a maximal sprint past this point. Literature supports results for the improvement in non-preferred side hip performance, where the rotation of the leg on the front block increases hemispherical co-ordination, and thus leads to kinematic changes of performance (Pan & van Gemmert, 2013).

The above is further supported by motor performance research suggesting that when a transfer of learning, takes place the athletes access the motor skill from the relevant cerebellum. This is where motor skill sequences are stored within the long-term memory, and that by athletes accessing cerebellum this sets motor co-ordinates for athletes to use to achieve the motor task (Hikosaka et al., 2002). This is supported by the idea of the hemispheres specialising in different tasks, with the dominant hemisphere greater at trajectory control and the non-dominant at positioning (Pan & Van Gemmert, 2013). This therefore suggests that the opposing hemisphere, to that which the skill is practiced with, has still acquired knowledge of movement of the skill, indirectly from the well-practiced hemisphere (Sainburg, 2002). This once again suggests for the above research that the interaction may have only been seen in the non-preferred hip due to the acquisition of a skill already well practiced by the preferred side and that has the motor sequence within the cerebellum. To achieve this, it is suggested that the intracortical connection from the associated cortices transpires into the motor-cortices associated with the non-preferred limb performance. Research by Hikosaka et al. (2002) suggests that this may develop motor coordinates for the performance of the skill, and this is strongly associated with joint angular specific tasks combined with muscular force. This allows for the transfer of learning where the non-preferred limb uses pre-composed motor co-ordinate information from the preferred limb to produce the motor sequence.

Overall, our ankle and hip kinematic findings may suggest positive implications to performance. It is important however to once again note that no performance change in five metre time occurred. However, due to the lack of evidence for horizontal and vertical forces at different phases of each sprint trial, it is unknown whether the kinematic changes we observed had a positive impact on other biomechanical factors after the first two strides. Research suggests this due to there being different transitions during the acceleration, where one transitions success has a significant impact to performance of the next part of the acceleration (Nagahara et al., 2014). The study declares there to be two transitions of the sprint start, with the first two strides accounting for what is defined by Nagahara et al. (2014) as the first and second breakpoint. This first phase consists of the rapid hip extension from the blocks for athletes to propel forward. Implications to the current study therefore suggest that five metre distance only assesses part of the accelerative performance, therefore it cannot be generalised to represent sprint acceleration as a whole sequence. Future research should look at determining the effect of intervention over a greater distance, where all transition phases of the sprint start can be assessed and examined.

Notably there was a main effect found across stages for the preferred leg lead and trail for both groups. Both the lead and trail leg trials suggested an increase in the hip angle across stages during the toe-off from blocks. This is thought to be a key kinematic enhancement as the extension of both hips can lead to increasing the horizontal force production (Bezodis, Willwacher & Salo, 2019). The same study supports that a greater sprint start performance is strongly associated with greater hip extensor range at the rear hip during the push off. Further to this the enhancement of both hip extensors during push off is thought to improve the hamstring motor recruitment, thus improve propulsion from both front and rear blocks (Morin et al., 2015). This could further be supported by the research of Haaland and Hoff (2003) suggesting that when there Is an improvement in the non-preferred leg you could also possibly see an improvement in preferred leg performance. Evidence from past literature (Teixeira, 2000) can further provide support for this explaining how interhemispheric activity and cause adaptions to performance. The activation of a group of control units, towards performing the motor task from the contralateral limb, leads to activation of homologous units within the opposite hemisphere.

A further finding across stages was that the second stride toe-off demonstrated the greatest number of differences between groups, suggesting that the intervention had led to kinematic differences in trials. During non-preferred trials, where the lead leg from the blocks suggested that the intervention group demonstrated a greater increase in hip angle from the pre to mid stage of testing during second stride toe-off. Also, a further interaction of the hip was found for the preferred lead leg trials, where the trail leg from the blocks also demonstrated a greater increase in hip angle from pre to mid stages for the intervention group. However, it is ultimately hard to assess the implications of these kinematic changes to performance, with the second stride ground reaction forces not assessed. The only measure therefore to the effect of these interaction is five-metre speed performance, of which there was no change. Future research should aim to do a full kinematic assessment of the second stride post bilateral intervention, to assess the effects of the kinematic changes found in our study.

6.2 Force platform data

Force platform data was collected during the first step of the acceleration phase. There were no changes between stages and groups for any of the platform data, therefore the intervention did not affect first stride touchdown ground reaction forces. Similarly, to the timing gate data, no difference was observed for contact time of the foot during the first stride touchdown. This suggests again that the eight-week intervention did not affect the five-metre start performance. There is evidence that longer ground reaction times may be strongly associated with decrements in performance. (Coh & Tomazin, 2006; Bezodis, Willwacher & Salo, 2019).

Braking impulse data suggested that there was an increase of the impulse for both preferred and non-preferred leg trials from pre to post stages of assessment. An increase of the braking impulse could lead to a negative effect on sprint performance (Nagahara et al., 2018). However, our increased braking impulses did not seem to have an effect on five-metre sprint start performance, for both groups and across stages. Nonetheless, current evidence suggests that an increase in the horizontal net impulse, or the braking and propulsive forces, can be strongly associated with faster sprint performance (Morin et al., 2015). Findings from Morin and et al. (2015) acknowledge that faster sprinters produce higher propulsive impulses, when compared to slower sprinters. Importantly, authors suggest that these higher propulsive impulses do not necessarily result in the sprinters reducing the braking impulse, especially over the first twenty metres of a sprint acceleration. In the current paper there were no changes in propulsive forces across stages for either the control or intervention group. However, the increase in braking impulses may be related to the higher horizontal net impulse we observed. We suggest that further research should examine the relationship between braking impulses and propulsive impulses within distances varying from zero to twenty metres to further understand ground reaction force requirements.

Results of the current paper could still be justified however, as to why there was no change to performance even with the increased horizontal net impulse. Research suggests that during the sprint acceleration the propulsive impulse greater determines the success outcome than the braking impulse. In a study for sprint acceleration (Hunter et al.,2005) showed that during the acceleration phase, the propulsive impulse accounted for 57% of variances in sprint velocity and the braking impulse only accounted for 7% of the ground force variances. It was also concluded that a lower magnitude of the relative braking impulse was also associated with a faster sprint performance. Hunter et al. (2005) findings are in contrast to Moran et al. (2015), suggesting a loss of horizontal acceleration when there are greater braking impulses. Hunter et al. (2005) did support however that a higher magnitude of horizontal ground impulse is beneficial to performance, but that the main enhancements often come from higher propulsion. The paper also expressed that it could not be ruled out that higher braking impulses could still lead to performance benefits, specifically through the storage of elastic energy to be utilised during the propulsive phase. Both studies (Moran et al., 2015); Hunter et al., 2005) assessed participants over a greater distance than five metres. It is concluded that barefoot performances played a factor in results, and that five metres was not a great enough distance to assess the impact of an increased braking impulse to performance.

6.3 Limitations and directions for future research

A limitation to the current study is the distance in which athletes' times and kinematics were assessed. In the current study a five-metre distance was used, due to the lab size and a safe deceleration period after the final timing gate. Past papers generally use a fifteen to twenty metre distance to assess start success and acceleration, with this distance thought to represent the overall acceleration phase of a sprinter (Aerenhouts et al., 2012). Studies that assessed the changes to the set position also use similar distances to assess start success and the effect on performance (Nagahara, Gleadhill & Ohshima, 2020). This therefore could have influenced the results with the distance possibly being too short to determine any changes to speed performance. Another limitation of the study is the phase of the sprint in which data were collected. In our research, we assessed the first step and the transition towards to the second step. Previous work that focuses on adaptions to the set position has demonstrated significant differences when assessing both the first two strides (Coh & Zvan, 2015). Previous studies show that eight weeks is a sufficient amount of time for a bilateral transfer of learning to take place (Haaland & Hoff, 2003). We found that the inability to control variables such as training speed and duration, during the bilateral training intervention, could have played a role towards our results.

7.0 Conclusion

Overall, our findings indicated that the eight-week bilateral training intervention did not change the five-metre sprint start time performance. Nevertheless, some key kinematic data changed through the intervention. Based on previous findings (Brazil et al., 2018) these changes have been found to have previously played a role towards improved performances. In particular, our results demonstrated an increase in the hip angle at toe-off position for the intervention group across stages, for the non-preferred leg trials. Across trials both groups demonstrated an increase in braking impulse, accompanied by a decrease in ankle angle during the mid-stance phase. Despite these changes in the kinematic and platform data, no changes were found for the five-metre performance. However, literature suggests this could be due to the learning effect of completing trials barefoot, where athletes experience different joint torques to shoe and spike running (Kerrigan et al., 2009). Conclusively, we suggest that future research may further examine the implications of a bilateral sprint start training intervention, with attention given towards well-controlled experiments, using a greater testing distance, and aligning data collected from kinematic and mechanical variables.

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9.0 Appendix

Appendix 1- Ethics Approval

Canterbury Christ Church University

20th February 2019 Ref: 18/SAS/35C

Charles Shingleton
c/o School of Human and Life Sciences
Faculty of Social & Applied Sciences

Dear Charles,

Confirmation of ethics compliance for your study – ***'The effect of bilateral sprint start training on sprint start performance on both the dominant and non-dominant side of the body.'***

The Faculty Ethics Chair has reviewed your Ethics Review Checklist application and appropriate supporting documentation for the above project. The Chair has confirmed that your application complies fully with the requirements for proportionate ethical review, as set out in this University's Research Ethics and Governance Procedures.

In confirming compliance for your study, you are reminded that it is your responsibility to follow, as appropriate, the policies and procedures set out in the *Research Governance Framework* (http://www.canterbury.ac.uk/research-and-consultancy/governance-and-ethics/governance-and-ethics.aspx) and any relevant academic or professional guidelines. This includes providing, if appropriate, information sheets and consent forms, and ensuring confidentiality in the storage and use of data.

Any significant change in the question, design or conduct of the study over its course should be notified via email to red.resgov@canterbury.ac.uk and may require a new application for ethics approval.

It is a condition of compliance that you **must** inform red.resgov@canterbury.ac.uk once your research has completed.

Wishing you every success with your research.

Yours sincerely,

Penny

Penny Keogh
Research Integrity & Development Officer
Email: red.resgov@canterbury.ac.uk

CC Dr Mathew Brown, Supervisor

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Professor Rama Thirunamachandran, Vice Chancellor and Principal

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Appendix 2- Informed Consent

Canterbury Christ Church University

CONSENT FORM

Title of Project: The effect of bilateral sprint start training on sprint start performance on both the preferred and non-preferred side of the body

Name of Researcher: Charles Michael Shingleton

Contact details:

Address: Section of Sport and Exercise Sciences, School of Human and Life Sciences, Faculty of Social and Applied Sciences, Canterbury Christ Church University, North Holmes Road, Canterbury, Kent, CT1 1QU.

Tel: Supervisor Mathew Brown- (0)1227 923168

Email: c.m.shingleton774@canterbury.ac.uk

Please initial box

1. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions.
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.
3. I understand that any personal information that I provide to the researchers will be kept strictly confidential
4. I agree to take part in the above study.
5. I agree that I am happy to have my image captured on video

Name of Participant:	Date:	Signature:
Name of person taking consent *(if different from researcher)*	Date:	Signature:
Researcher:	Date:	Signature:
Charles Shingleton		

Copies: 1 for participant
1 for researcher

Canterbury Christ Church University

The effect of bilateral sprint start training on sprint start performance on both the preferred and non-preferred side of the body

PARTICIPANT INFORMATION SHEET

A research study is being conducted at Canterbury Christ Church University (CCCU) by Charles Shingleton supervised by Mathew Brown and Jon Swain.

Background

In past research Bilateral training has been shown to improve the power of a performer. Yet there is minimal research into sprinting and bilateral training especially when focused around the block start. During the drive phase performers must accelerate and try to hit their top speed as quickly and efficiently as possible. Even though the initial step is using the lead leg to push from the block and the trail to move through, the sprint is a continuous cycle of this just with different phases thus different biomechanical factors.

The aim of this research is to assess whether a bilateral training programme for block starts improves performance of both the preferred and non-preferred leg when leading during the initial push off from the blocks. If the results have a significant difference this can be used as a coaching tool to improve athlete performance.

What will you be required to do?

Participants in this study will be required to undertake a 8-week intervention where a slight change in block start training may be required. As well as this participant's will be required to attend three lab-based sessions over a period of Ten weeks.

Within these sessions' participants will be asked to perform Ten sprint starts over a 5m distance. Prior to performing the sprints participants will undertake a set warm up to reduce the risk of injury. Three starts with the left leg lead and three starts with the right leg lead. The sprint will be in a straight line where measurements will be taken by 3D cameras, Force platform and timing gates.

To participate in this research you must:

- Be A Male athlete
- Be undertaking sprint training

Procedures

You will be asked to follow the procedure set by the researcher if given the intervention where you will be asked to train block starts bilaterally rather than unilaterally for a period of 8 weeks. The researcher will supervise these sessions. The intervention will consist of a slight adaption to training block starts within sessions. Instead of training just the preferred and preferred leg, participants will be asked to switch legs and also train the non-preferred leg as the lead leg in training. The process will be done in a random order to avoid the influence of fatigue.

For lab sessions participants will be required to fill out a PAR-Q and sign this form to make sure safety of the participant and consent is assessed. A short warm up set by the researcher is also required as well as the measurement of both height and weight.

Participants will then have markers positioned on to key anatomical reference points to allow analysis through the 2D camera system. Once this is completed a short briefing on what is required will be conducted. Participants will be asked to set up the blocks in a random order decided by the researcher for both legs. Once this is completed participants will be asked to complete ten sprints. Five with left leg push off and Five with right leg push off.

Feedback

After the session is completed participants can ask for feedback from timing data. Further feedback can be given to everyone on their own performance once analysis of data is complete.

Confidentiality and Data Protection

On the legal basis of consent all data and personal information will be stored securely within CCCU premises in accordance with the General Data Protection Regulation (GDPR) and the University's own data protection policies. The following categories of personal data will be processed. Name, Age, Height and Weight. Personal data will be used to accuracy of results and help measurements. Data can only be accessed by Charles Shingleton, Mathew Brown and Jon Swain.

After completion of the study, all data will be made anonymous (i.e. all personal information associated with the data will be removed) and held for a period of 5 years.

Dissemination of results

Published to the Canterbury Christ Church University Library.

Deciding whether to participate

If you have any questions or concerns about the nature, procedures or requirements for participation do not hesitate to contact me. Should you decide to participate, you will be free to (i) withdraw consent at any time without having to give a reason, (ii) request to see all your personal data held in association with this project, (iii) request that the processing of your personal data is restricted, (iv) request that your personal data is erased and no longer used for processing.

Process for withdrawing consent

You are free to withdraw consent at any time without having to give a reason. To do this please email Charles Shingleton (c.m.shingleton774@canterbury.ac.uk).

Any questions?

Please contact Charles Shingleton on c.m.shingleton774@canterbury.ac.uk. Mathew Brown on mathewbrown@canterbury.ac.uk , Section of Sport and Exercise Sciences, School of Human and Life Sciences, Faculty of Social and Applied Sciences, Canterbury Christ Church University, North Holmes Road, Canterbury, Kent, CT1 1QU. Tel: (0)1227 923168

Appendix 3- RPE Scale

RPE Scale

rating of perceived exertion

rating	description
6	NO EXERTION AT ALL
7	
	EXTREMELY LIGHT
8	
9	VERY LIGHT
10	
11	LIGHT
12	
13	SOMEWHAT HARD
14	
15	HARD (HEAVY)
16	
17	VERY HARD
18	
19	EXTREMELY HARD
20	MAXIMAL EXERTION

Appendix 4- Quintic

Image 1: Set Position

Image 2: Toe-off

Image 3: Mid-Stance

Image 4: Second Toe-off

Appendix 5- Results table and figures data

Figure 1 Data

	Participant	Pre	Mid	Post
1	1.00	1.09	1.13	1.31
2	1.00	1.34	1.16	1.21
3	1.00	1.31	1.44	1.38
4	1.00	1.11	1.20	1.25
5	1.00	1.20	1.17	1.24
6	1.00	1.08	1.18	1.11
7	2.00	1.23	1.19	1.17
8	2.00	1.30	1.23	1.34
9	2.00	1.37	1.48	1.45
10	2.00	1.15	1.28	1.21
11	2.00	1.32	1.33	1.38
12	2.00	1.20	1.10	1.39

Preferred leg five metre time

	Participant	Pre	Mid	Post
1	1.00	1.09	1.20	1.23
2	1.00	1.43	1.33	1.25
3	1.00	1.32	1.45	1.32
4	1.00	1.17	1.04	1.23
5	1.00	1.22	1.20	1.28
6	1.00	1.13	1.17	1.18
7	2.00	1.24	1.18	1.18
8	2.00	1.36	1.27	1.36
9	2.00	1.40	1.52	1.44
10	2.00	1.16	1.27	1.23
11	2.00	1.29	1.30	1.32
12	2.00	1.32	1.33	1.38

Non-preferred leg five metre time

<u>Lead leg data</u>

<u>Set Position</u>

	Participant	Pre	Mid	Post
1	1.00	43.38	42.93	45.03
2	1.00	29.02	29.26	26.96
3	1.00	38.07	42.65	40.29
4	1.00	37.70	47.97	52.80
5	1.00	59.27	62.24	58.30
6	1.00	26.88	27.60	34.54
7	2.00	36.69	53.56	51.23
8	2.00	35.78	43.78	39.55
9	2.00	25.01	29.72	29.12
10	2.00	43.79	58.38	51.02
11	2.00	29.99	48.03	54.37
12	2.00	29.96	25.47	31.75

Preferred lead hip angle

	Participant	Pre	Mid	Post
1	1.00	47.84	43.65	44.71
2	1.00	35.33	32.18	34.82
3	1.00	36.36	45.14	44.34
4	1.00	34.11	44.55	42.78
5	1.00	58.33	59.71	58.35
6	1.00	28.41	31.68	34.42
7	2.00	50.29	61.58	52.02
8	2.00	33.05	41.80	38.57
9	2.00	23.52	34.59	31.07
10	2.00	44.82	53.75	52.91
11	2.00	36.31	45.60	52.78
12	2.00	30.23	33.17	33.45

Non-preferred lead hip angle

	Participant	Pre	Mid	Post
1	1.00	114.76	114.57	114.06
2	1.00	104.99	91.14	86.07
3	1.00	88.81	86.60	81.58
4	1.00	94.58	93.70	100.26
5	1.00	105.25	113.31	105.23
6	1.00	105.22	113.42	117.12
7	2.00	105.36	100.25	113.93
8	2.00	85.81	86.87	88.38
9	2.00	79.52	68.88	84.34
10	2.00	94.39	103.02	98.94
11	2.00	91.23	82.98	77.84
12	2.00	106.90	106.05	102.64

Preferred lead Knee angle

	Participant	Pre	Mid	Post
1	1.00	121.23	125.13	115.37
2	1.00	100.82	96.20	97.06
3	1.00	86.14	86.29	80.99
4	1.00	106.23	94.18	103.95
5	1.00	114.49	115.64	103.86
6	1.00	107.46	123.50	116.83
7	2.00	102.15	108.73	105.50
8	2.00	77.89	95.83	89.71
9	2.00	81.66	77.21	81.88
10	2.00	86.43	104.49	97.82
11	2.00	87.38	80.31	82.46
12	2.00	113.02	97.96	102.33

Non-preferred lead knee angle

	Participant	Pre	Mid	Post
1	1.00	113.51	115.72	103.02
2	1.00	132.92	115.96	125.49
3	1.00	99.54	92.76	95.83
4	1.00	119.91	113.37	110.01
5	1.00	117.29	107.65	111.68
6	1.00	113.49	103.86	102.19
7	2.00	112.06	104.65	107.19
8	2.00	114.89	98.48	108.04
9	2.00	115.87	103.73	115.40
10	2.00	116.35	111.81	103.00
11	2.00	106.70	90.41	92.47
12	2.00	131.80	103.58	91.77

Preferred lead ankle angle

	Participant	Pre	Mid	Post
1	1.00	105.71	114.25	99.10
2	1.00	116.24	118.34	116.77
3	1.00	96.30	96.27	86.93
4	1.00	122.50	106.11	113.10
5	1.00	123.57	113.70	113.86
6	1.00	114.56	113.30	106.64
7	2.00	104.89	97.66	103.87
8	2.00	111.04	109.23	100.70
9	2.00	104.94	106.30	117.17
10	2.00	113.23	112.23	104.66
11	2.00	103.03	94.39	90.62
12	2.00	127.31	111.17	98.50

Non-preferred lead ankle angle

<u>Toe-off</u>

	Participant	Pre	Mid	Post
1	1.00	145.91	153.66	153.89
2	1.00	146.62	141.25	147.21
3	1.00	156.98	152.00	160.08
4	1.00	163.24	171.52	169.61
5	1.00	160.29	167.04	162.61
6	1.00	151.97	151.13	156.07
7	2.00	144.52	151.15	156.76
8	2.00	147.66	152.61	153.26
9	2.00	146.28	149.06	158.79
10	2.00	157.83	162.48	161.08
11	2.00	141.98	149.18	145.12
12	2.00	165.92	160.06	163.47

Preferred lead hip angle

	Participant	Pre	Mid	Post
1	1.00	156.25	159.24	162.69
2	1.00	145.93	142.96	148.80
3	1.00	164.50	159.38	162.45
4	1.00	170.67	172.80	169.72
5	1.00	169.01	162.25	160.73
6	1.00	168.43	159.88	157.47
7	2.00	148.47	150.32	156.46
8	2.00	147.74	149.02	154.03
9	2.00	154.11	162.82	166.21
10	2.00	152.84	162.11	161.07
11	2.00	145.05	151.64	153.73
12	2.00	151.01	151.73	153.32

Non-preferred hip angle

	Participant	Pre	Mid	Post
1	1.00	155.22	161.62	165.75
2	1.00	161.80	161.78	161.21
3	1.00	166.85	172.86	167.54
4	1.00	160.78	168.48	161.51
5	1.00	165.72	167.45	166.25
6	1.00	171.71	175.14	174.72
7	2.00	159.20	151.82	162.79
8	2.00	159.86	169.19	170.69
9	2.00	175.36	160.14	172.37
10	2.00	172.39	166.78	171.99
11	2.00	170.32	171.20	169.40
12	2.00	158.47	161.77	152.49

Preferred lead knee angle

	Participant	Pre	Mid	Post
1	1.00	162.25	170.23	171.88
2	1.00	160.93	163.74	159.00
3	1.00	169.10	166.43	166.56
4	1.00	172.78	168.86	160.66
5	1.00	173.71	174.33	172.59
6	1.00	171.66	173.52	172.43
7	2.00	156.54	164.20	161.56
8	2.00	163.44	170.86	169.52
9	2.00	169.15	167.10	166.72
10	2.00	168.23	168.99	171.39
11	2.00	164.63	167.73	167.39
12	2.00	169.51	170.25	166.18

Non-preferred lead knee angle

	Participant	Pre	Mid	Post
1	1.00	154.24	147.65	141.50
2	1.00	154.32	148.39	151.86
3	1.00	145.60	149.71	143.22
4	1.00	141.48	143.72	147.12
5	1.00	146.75	146.40	146.36
6	1.00	153.92	148.19	149.09
7	2.00	139.77	141.98	141.99
8	2.00	143.33	140.73	137.74
9	2.00	154.42	145.60	144.47
10	2.00	149.69	144.18	144.99
11	2.00	145.31	136.35	143.72
12	2.00	134.64	140.69	138.50

Preferred lead ankle angle

	Participant	Pre	Mid	Post
1	1.00	141.28	146.62	133.61
2	1.00	144.94	144.82	140.80
3	1.00	144.87	146.91	141.98
4	1.00	136.12	147.35	151.11
5	1.00	152.83	159.22	153.91
6	1.00	152.24	154.60	153.31
7	2.00	138.98	137.69	139.94
8	2.00	143.97	143.83	135.99
9	2.00	146.23	143.48	143.94
10	2.00	154.37	155.43	146.56
11	2.00	144.15	147.11	141.39
12	2.00	149.52	144.15	137.24

Non-preferred lead ankle angle

<u>*Mid-stance*</u>

	Participant	Pre	Mid	Post
1	1.00	114.61	121.55	122.29
2	1.00	108.75	117.34	129.43
3	1.00	140.33	123.20	134.03
4	1.00	128.22	122.01	136.20
5	1.00	115.13	109.51	121.78
6	1.00	126.17	119.57	121.36
7	2.00	125.55	119.95	119.09
8	2.00	118.72	133.31	131.24
9	2.00	126.65	120.98	130.57
10	2.00	114.99	126.70	127.03
11	2.00	107.36	125.52	127.62
12	2.00	145.93	142.78	135.74

Preferred lead hip angle

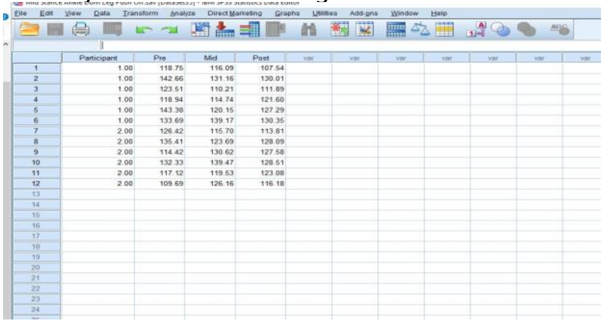
	Participant	Pre	Mid	Post
1	1.00	116.52	125.99	120.18
2	1.00	115.35	114.14	123.23
3	1.00	133.17	127.23	134.27
4	1.00	124.71	136.34	120.72
5	1.00	127.32	116.88	125.79
6	1.00	134.71	125.29	128.29
7	2.00	104.13	117.74	116.77
8	2.00	116.69	123.76	131.11
9	2.00	122.68	126.57	135.80
10	2.00	128.27	129.25	130.05
11	2.00	104.76	122.19	125.80
12	2.00	131.76	138.19	136.19

Non-preferred lead hip angle

	Participant	Pre	Mid	Post
1	1.00	66.27	65.68	77.40
2	1.00	65.05	63.74	80.67
3	1.00	64.99	62.17	74.09
4	1.00	52.49	50.99	52.11
5	1.00	97.02	87.62	91.19
6	1.00	68.67	71.45	83.99
7	2.00	72.23	70.06	73.48
8	2.00	64.87	51.16	65.57
9	2.00	74.88	71.27	60.15
10	2.00	73.91	88.86	78.24
11	2.00	68.31	75.07	73.36
12	2.00	58.19	70.77	73.93

	Participant	Pre	Mid	Post
1	1.00	67.52	74.70	73.64
2	1.00	81.96	73.02	83.80
3	1.00	73.63	68.30	88.20
4	1.00	57.09	53.73	55.03
5	1.00	78.22	79.46	87.21
6	1.00	69.08	79.63	68.61
7	2.00	65.30	72.56	75.00
8	2.00	68.01	67.46	70.43
9	2.00	64.90	71.79	64.94
10	2.00	74.70	81.57	80.40
11	2.00	61.25	64.76	70.52
12	2.00	47.27	70.96	72.26

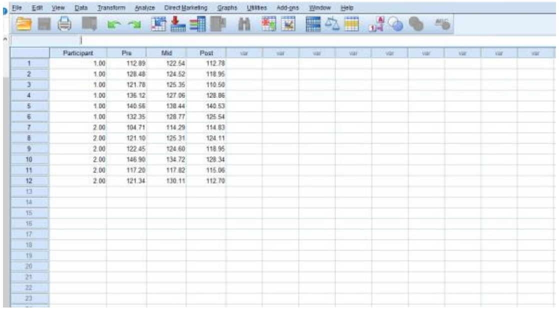
Preferred lead knee angle



	Participant	Pre	Mid	Post
1	1.00	118.75	116.09	107.54
2	1.00	142.66	131.16	130.01
3	1.00	123.51	110.21	111.89
4	1.00	118.94	114.74	121.60
5	1.00	143.38	120.15	127.29
6	1.00	133.69	139.17	130.35
7	2.00	126.42	115.70	113.81
8	2.00	135.41	123.69	128.09
9	2.00	114.42	130.62	127.58
10	2.00	132.33	139.47	128.51
11	2.00	117.12	119.53	123.08
12	2.00	109.69	126.16	116.18

Preferred lead ankle angle

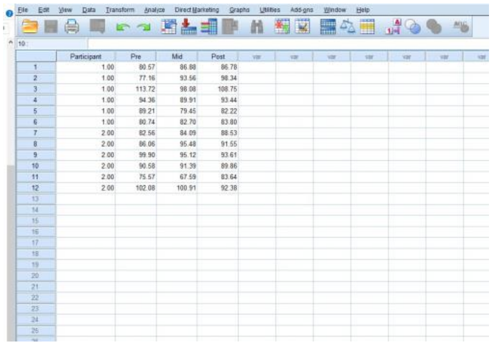
Non-preferred lead knee angle



	Participant	Pre	Mid	Post
1	1.00	112.89	122.54	112.78
2	1.00	128.48	124.52	118.95
3	1.00	121.78	125.35	110.50
4	1.00	136.12	127.06	128.86
5	1.00	140.56	138.44	140.53
6	1.00	132.35	128.77	125.54
7	2.00	104.71	114.29	114.83
8	2.00	121.10	125.31	124.11
9	2.00	122.45	124.60	118.95
10	2.00	146.90	134.72	128.34
11	2.00	117.20	117.82	115.06
12	2.00	121.34	130.11	112.70

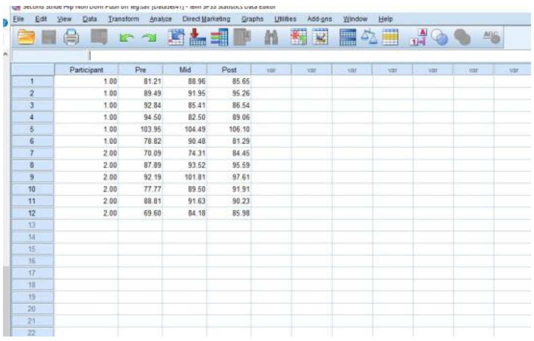
Non-preferred lead ankle angle

Second stride toe-off



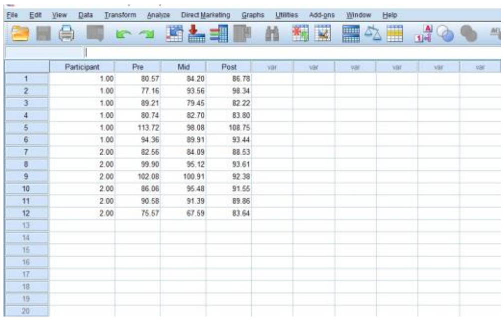
	Participant	Pre	Mid	Post
1	1.00	80.57	86.88	86.78
2	1.00	77.16	93.56	98.34
3	1.00	113.72	98.08	108.75
4	1.00	94.36	89.91	93.44
5	1.00	89.21	79.45	82.22
6	1.00	80.74	82.70	83.80
7	2.00	82.56	84.09	88.53
8	2.00	86.06	95.48	91.55
9	2.00	99.90	95.12	93.61
10	2.00	90.58	91.39	89.86
11	2.00	75.57	67.59	83.64
12	2.00	102.08	100.91	92.38

Preferred lead hip angle



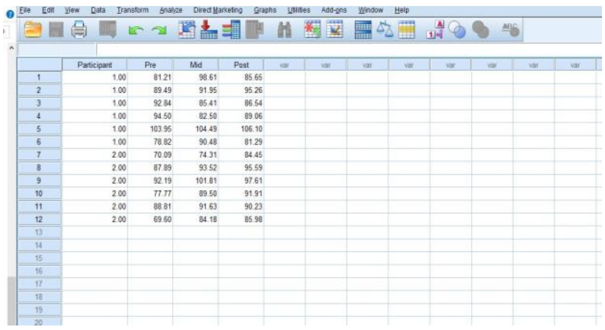
	Participant	Pre	Mid	Post
1	1.00	81.21	88.96	85.65
2	1.00	89.49	91.95	95.26
3	1.00	92.84	85.41	86.54
4	1.00	94.50	82.50	89.06
5	1.00	103.95	104.49	106.10
6	1.00	78.82	90.48	81.29
7	2.00	70.09	74.31	84.45
8	2.00	87.89	93.52	95.59
9	2.00	92.19	101.81	97.61
10	2.00	77.77	89.50	91.91
11	2.00	88.81	91.63	90.23
12	2.00	69.60	84.18	85.98

Non-preferred lead hip angle



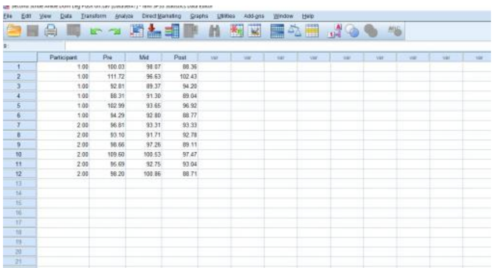
	Participant	Pre	Mid	Post
1	1.00	80.57	84.20	86.78
2	1.00	77.16	93.56	98.34
3	1.00	89.21	79.45	82.22
4	1.00	80.74	82.70	83.80
5	1.00	113.72	98.08	108.75
6	1.00	94.36	89.91	93.44
7	2.00	82.56	84.09	88.53
8	2.00	99.90	95.12	93.61
9	2.00	102.08	100.91	92.38
10	2.00	86.06	95.48	91.55
11	2.00	90.58	91.39	89.86
12	2.00	75.57	67.59	83.64

Preferred lead knee angle

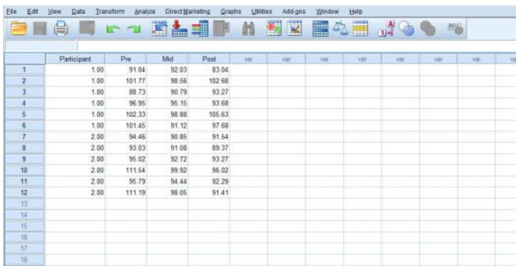


	Participant	Pre	Mid	Post
1	1.00	81.21	98.61	85.65
2	1.00	89.49	91.95	95.26
3	1.00	92.84	85.41	86.54
4	1.00	94.50	82.50	89.06
5	1.00	103.95	104.49	106.10
6	1.00	78.82	90.48	81.29
7	2.00	70.09	74.31	84.45
8	2.00	87.89	93.52	95.59
9	2.00	92.19	101.81	97.61
10	2.00	77.77	89.50	91.91
11	2.00	88.81	91.63	90.23
12	2.00	69.60	84.18	85.98

Non-preferred lead knee angle



	Participant	Pre	Mid	Post
1	1.00	100.03	98.07	88.36
2	1.00	111.72	96.63	102.43
3	1.00	92.81	89.37	94.20
4	1.00	88.31	91.30	89.04
5	1.00	102.99	93.65	96.92
6	1.00	94.29	92.80	88.77
7	2.00	96.81	93.31	93.33
8	2.00	93.10	91.71	92.78
9	2.00	98.66	97.26	89.11
10	2.00	109.60	100.53	97.47
11	2.00	95.69	92.75	93.04
12	2.00	98.20	100.86	88.71



	Participant	Pre	Mid	Post
1	1.00	91.04	92.03	83.04
2	1.00	101.77	98.56	102.68
3	1.00	88.73	90.79	93.27
4	1.00	96.95	95.15	93.68
5	1.00	102.33	98.88	105.63
6	1.00	101.45	91.12	97.68
7	2.00	94.46	90.85	91.54
8	2.00	93.03	91.08	89.37
9	2.00	95.02	92.72	93.27
10	2.00	111.54	99.92	96.02
11	2.00	95.79	94.44	92.29
12	2.00	111.19	98.05	91.41

Preferred lead ankle angle

Non-preferred lead ankle angle

<u>Trail leg data</u>

<u>Set position</u>

Set Hip Dom Trail Leg.sav [DataSet4] - IBM SPSS Statistics Data Editor

	Participant	Pre	Mid	Post
1	1.00	67.90	62.71	65.62
2	1.00	53.51	53.28	49.99
3	1.00	64.58	64.15	63.92
4	1.00	55.83	71.71	72.14
5	1.00	102.04	99.18	92.92
6	1.00	49.79	61.02	58.32
7	2.00	68.31	76.73	85.49
8	2.00	67.67	73.90	66.61
9	2.00	51.48	54.75	52.22
10	2.00	65.51	79.86	78.46
11	2.00	48.05	83.60	91.52
12	2.00	54.79	59.04	59.00

Set Hip Non Dom Trail Leg.sav [DataSet6] - IBM SPSS Statistics Data Editor

	Participant	Pre	Mid	Post
1	1.00	62.49	65.85	69.47
2	1.00	53.65	44.68	42.42
3	1.00	55.14	63.05	60.08
4	1.00	59.17	72.52	75.99
5	1.00	97.74	97.51	93.70
6	1.00	49.32	64.26	60.33
7	2.00	67.21	72.83	84.90
8	2.00	69.76	77.52	65.48
9	2.00	47.47	47.87	49.63
10	2.00	66.59	79.85	79.66
11	2.00	53.47	84.42	87.20
12	2.00	56.25	59.04	57.44

Preferred trail hip angle

Non-preferred trail hip angle

Set Knee Dom from push off trail leg.sav [DataSet8] - IBM SPSS Statistics Data Editor

	Participant	Pre	Mid	Post
1	1.00	123.09	132.28	126.16
2	1.00	112.61	90.44	85.76
3	1.00	133.48	129.51	116.28
4	1.00	96.24	99.75	106.34
5	1.00	95.91	108.32	98.52
6	1.00	111.19	134.83	137.44
7	2.00	119.76	119.00	140.19
8	2.00	80.20	90.82	85.53
9	2.00	67.20	70.10	81.29
10	2.00	103.19	126.76	110.11
11	2.00	92.28	90.81	90.75
12	2.00	107.32	146.59	143.07

	Participant	Pre	Mid	Post
1	1.00	127.30	130.12	128.76
2	1.00	106.32	83.50	78.42
3	1.00	120.04	122.79	107.39
4	1.00	96.57	106.14	111.42
5	1.00	105.15	116.65	104.69
6	1.00	112.71	136.73	134.86
7	2.00	116.17	120.63	142.23
8	2.00	77.46	89.28	87.93
9	2.00	84.61	71.20	77.31
10	2.00	105.26	127.70	109.34
11	2.00	98.72	90.36	90.26
12	2.00	115.05	127.02	132.52

Preferred trail knee angle

Non-preferred trail knee angle

	Participant	Pre	Mid	Post
1	1.00	102.43	100.71	92.78
2	1.00	112.52	101.24	105.59
3	1.00	99.58	95.79	89.85
4	1.00	108.96	95.91	103.54
5	1.00	105.64	109.72	100.96
6	1.00	111.97	112.13	103.36
7	2.00	109.07	99.48	107.84
8	2.00	91.52	90.12	88.03
9	2.00	103.43	92.83	92.28
10	2.00	104.27	106.54	100.70
11	2.00	100.86	99.78	92.15
12	2.00	114.12	111.49	106.30

	Participant	Pre	Mid	Post
1	1.00	113.11	98.16	96.30
2	1.00	109.76	112.26	110.47
3	1.00	97.43	99.81	92.39
4	1.00	116.45	106.68	104.32
5	1.00	101.61	102.63	98.69
6	1.00	113.94	106.35	105.66
7	2.00	100.93	103.02	107.11
8	2.00	92.84	92.48	89.10
9	2.00	99.31	88.70	92.63
10	2.00	98.52	105.95	100.81
11	2.00	98.04	89.82	92.49
12	2.00	114.99	103.86	98.94

Preferred trail ankle angle

Non-preferred trail ankle angle

<u>Toe-off</u>

	Participant	Pre	Mid	Post
1	1.00	63.47	70.80	69.19
2	1.00	69.47	82.72	80.75
3	1.00	94.24	81.09	81.51
4	1.00	74.01	84.27	77.85
5	1.00	83.34	78.83	86.82
6	1.00	76.64	78.02	77.98
7	2.00	69.05	81.68	74.83
8	2.00	63.66	77.08	83.20
9	2.00	75.71	78.77	76.40
10	2.00	85.70	86.73	84.81
11	2.00	66.68	74.21	66.76
12	2.00	80.11	92.11	88.58

Preferred trail hip angle

	Participant	Pre	Mid	Post
1	1.00	71.09	77.98	71.93
2	1.00	66.38	74.40	74.42
3	1.00	92.49	85.02	85.20
4	1.00	88.30	95.03	92.21
5	1.00	74.04	68.03	74.62
6	1.00	77.08	80.18	81.18
7	2.00	80.29	73.91	73.08
8	2.00	77.09	80.26	93.00
9	2.00	79.98	79.35	83.33
10	2.00	85.38	93.84	91.44
11	2.00	64.56	73.81	70.78
12	2.00	87.73	83.75	85.64

Non-preferred trail hip angle

	Participant	Pre	Mid	Post
1	1.00	84.13	94.40	86.69
2	1.00	110.57	101.87	98.14
3	1.00	76.89	79.92	86.50
4	1.00	72.47	71.77	79.78
5	1.00	130.89	104.39	105.13
6	1.00	82.30	85.28	77.19
7	2.00	79.14	86.51	78.01
8	2.00	86.08	88.56	92.88
9	2.00	107.45	104.63	102.43
10	2.00	103.11	94.09	90.17
11	2.00	93.71	82.56	82.41
12	2.00	106.28	92.47	93.89

Preferred trail knee angle

	Participant	Pre	Mid	Post
1	1.00	93.70	89.05	87.66
2	1.00	102.92	94.84	98.33
3	1.00	75.00	78.04	76.37
4	1.00	78.06	68.92	75.39
5	1.00	111.85	103.95	102.16
6	1.00	81.54	78.45	79.22
7	2.00	79.55	83.68	88.02
8	2.00	95.41	85.28	82.99
9	2.00	107.68	99.77	97.70
10	2.00	93.05	92.23	86.69
11	2.00	86.85	83.51	83.54
12	2.00	103.37	100.19	90.77

Non-preferred trail knee angle

	Participant	Pre	Mid	Post
1	1.00	91.74	91.55	82.51
2	1.00	104.80	101.86	99.48
3	1.00	87.74	87.54	87.10
4	1.00	92.48	84.68	90.97
5	1.00	118.22	102.07	105.12
6	1.00	88.86	88.22	89.75
7	2.00	99.93	94.26	91.00
8	2.00	85.44	85.42	84.83
9	2.00	103.84	98.43	90.01
10	2.00	117.56	105.45	101.48
11	2.00	99.37	94.34	88.07
12	2.00	113.86	97.00	86.21

Preferred trail ankle angle

	Participant	Pre	Mid	Post
1	1.00	104.51	101.33	87.47
2	1.00	114.14	103.88	109.92
3	1.00	89.12	88.11	87.85
4	1.00	94.08	86.70	91.31
5	1.00	106.42	97.27	99.27
6	1.00	92.49	91.13	88.25
7	2.00	93.13	96.21	90.06
8	2.00	92.61	89.85	84.86
9	2.00	106.67	101.42	92.49
10	2.00	106.83	103.13	100.71
11	2.00	98.25	95.39	91.85
12	2.00	97.63	99.11	85.05

Non-preferred trail ankle angle

Mid-stance

	Participant	Pre	Mid	Post
1	1.00	112.49	115.44	113.32
2	1.00	104.07	117.22	118.48
3	1.00	126.74	118.48	125.13
4	1.00	121.75	122.21	120.22
5	1.00	118.85	116.71	116.12
6	1.00	122.91	120.98	120.80
7	2.00	95.55	110.33	110.08
8	2.00	109.60	117.97	114.71
9	2.00	120.61	124.01	126.11
10	2.00	126.03	128.87	123.90
11	2.00	105.86	116.79	114.10
12	2.00	125.30	131.02	127.28

	Participant	Pre	Mid	Post
1	1.00	110.78	119.46	115.25
2	1.00	104.20	113.13	121.23
3	1.00	136.93	127.06	127.83
4	1.00	114.34	122.81	122.66
5	1.00	113.76	108.28	119.62
6	1.00	125.50	115.44	124.37
7	2.00	105.58	110.76	110.38
8	2.00	111.42	110.59	121.19
9	2.00	125.46	127.27	125.32
10	2.00	125.42	120.93	123.17
11	2.00	111.87	132.20	115.34
12	2.00	132.01	120.28	119.18

Preferred trail hip angle *Non-preferred trail hip angle*

	Participant	Pre	Mid	Post
1	1.00	118.13	123.12	119.70
2	1.00	124.43	131.11	129.24
3	1.00	116.21	112.48	109.36
4	1.00	115.28	114.92	112.52
5	1.00	129.63	130.27	128.71
6	1.00	119.29	113.97	112.63
7	2.00	118.96	115.89	110.87
8	2.00	121.64	126.52	125.92
9	2.00	135.95	138.12	134.73
10	2.00	137.88	130.54	131.06
11	2.00	125.22	123.91	122.81
12	2.00	132.13	122.62	121.78

	Participant	Pre	Mid	Post
1	1.00	119.07	114.13	113.01
2	1.00	121.86	122.98	123.29
3	1.00	111.53	108.56	116.37
4	1.00	112.12	112.88	115.26
5	1.00	128.38	136.23	129.57
6	1.00	119.77	116.30	122.62
7	2.00	121.49	114.91	107.92
8	2.00	125.70	122.36	126.78
9	2.00	140.96	131.22	130.54
10	2.00	135.47	131.34	133.90
11	2.00	130.44	124.14	125.04
12	2.00	135.50	124.91	114.46

Preferred trail knee angle *Non-preferred trail knee angle*

	Participant	Pre	Mid	Post
1	1.00	82.05	81.24	73.61
2	1.00	90.78	91.92	88.38
3	1.00	78.86	83.76	80.82
4	1.00	83.18	80.82	87.81
5	1.00	98.37	96.61	93.89
6	1.00	87.62	87.39	85.77
7	2.00	90.62	88.84	91.00
8	2.00	84.19	85.92	80.68
9	2.00	92.81	88.36	83.23
10	2.00	104.54	98.63	97.50
11	2.00	88.85	90.55	86.88
12	2.00	100.12	94.63	81.85

	Participant	Pre	Mid	Post
1	1.00	96.84	92.98	82.58
2	1.00	96.36	95.98	101.84
3	1.00	87.44	82.71	85.40
4	1.00	88.19	90.07	86.48
5	1.00	99.12	99.09	99.99
6	1.00	87.24	84.37	83.97
7	2.00	89.87	93.16	89.64
8	2.00	89.32	85.43	84.69
9	2.00	90.29	90.65	88.56
10	2.00	102.37	94.43	92.16
11	2.00	86.66	87.24	88.66
12	2.00	85.33	92.78	82.77

Preferred trail ankle angle *Non-preferred trail ankle angle*

__Second stride toe-off__

Second Stride Hip Dom trail leg.sav [DataSet40] - IBM SPSS Statistics Data Editor

	Participant	Pre	Mid	Post
1	1.00	169.36	161.28	161.08
2	1.00	143.68	143.65	147.50
3	1.00	171.00	171.34	168.68
4	1.00	169.17	164.05	165.67
5	1.00	165.91	162.68	169.40
6	1.00	173.05	177.04	165.54
7	2.00	139.78	155.49	151.27
8	2.00	161.08	166.14	166.13
9	2.00	150.97	161.73	166.88
10	2.00	148.92	160.61	160.17
11	2.00	167.93	170.40	166.00
12	2.00	133.60	160.37	156.61

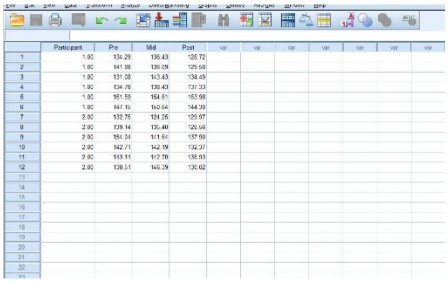
	Participant	Pre	Mid	Post
1	1.00	146.37	163.59	153.24
2	1.00	154.32	149.72	154.09
3	1.00	169.32	159.54	160.61
4	1.00	163.06	161.35	165.92
5	1.00	173.50	166.03	166.70
6	1.00	168.77	176.82	170.40
7	2.00	141.98	148.36	152.81
8	2.00	160.28	158.93	162.79
9	2.00	165.71	158.28	166.74
10	2.00	157.38	155.96	158.34
11	2.00	163.99	166.90	167.71
12	2.00	143.84	156.05	154.56

Preferred trail hip angle *Non-preferred trail hip angle*

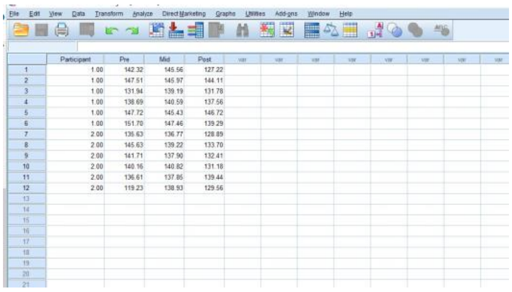
	Participant	Pre	Mid	Post
1	1.00	159.36	157.26	161.08
2	1.00	143.68	143.65	147.50
3	1.00	171.00	171.34	168.68
4	1.00	169.17	164.05	165.67
5	1.00	165.91	162.68	169.40
6	1.00	173.05	177.04	165.54
7	2.00	139.78	155.49	151.27
8	2.00	161.08	166.14	166.13
9	2.00	150.97	161.73	166.88
10	2.00	148.92	160.61	160.17
11	2.00	167.93	170.40	166.00
12	2.00	133.60	160.37	156.61

	Participant	Pre	Mid	Post
1	1.00	146.37	153.51	153.24
2	1.00	154.32	149.72	154.09
3	1.00	169.32	159.54	160.61
4	1.00	163.06	161.35	165.92
5	1.00	173.50	166.03	166.70
6	1.00	168.77	176.82	170.40
7	2.00	141.98	148.36	152.81
8	2.00	160.28	158.93	162.79
9	2.00	165.71	158.28	166.74
10	2.00	157.38	155.96	158.34
11	2.00	163.99	166.90	167.71
12	2.00	143.84	156.05	154.56

Preferred trail knee angle *Non-preferred trail knee angle*



	Participant	Pre	Mid	Post
1	1.00	134.29	136.43	128.72
2	1.00	141.88	136.09	129.58
3	1.00	131.08	143.43	134.49
4	1.00	134.78	138.43	137.33
5	1.00	151.59	154.61	153.98
6	1.00	147.15	150.64	144.30
7	2.00	132.75	124.26	129.97
8	2.00	139.14	135.40	128.56
9	2.00	154.04	141.64	137.90
10	2.00	142.71	142.19	132.37
11	2.00	143.11	142.70	138.93
12	2.00	138.51	146.39	130.02

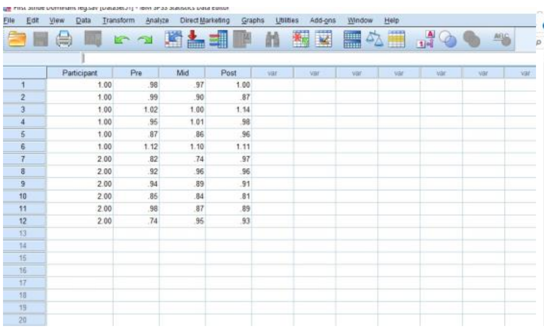


	Participant	Pre	Mid	Post
1	1.00	142.32	145.56	127.22
2	1.00	147.51	145.97	144.11
3	1.00	131.94	139.19	131.78
4	1.00	138.69	140.59	137.56
5	1.00	147.72	145.43	146.72
6	1.00	151.70	147.46	139.29
7	2.00	135.63	136.77	128.89
8	2.00	145.63	139.22	133.70
9	2.00	141.71	137.90	132.41
10	2.00	140.16	140.82	131.18
11	2.00	136.61	137.86	139.44
12	2.00	119.23	138.93	129.56

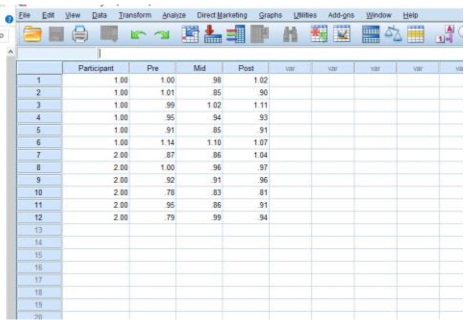
Preferred trail ankle angle

Non-preferred trail ankle angle

Stride length



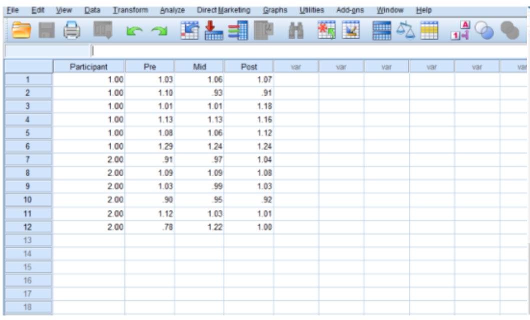
	Participant	Pre	Mid	Post
1	1.00	.98	.97	1.00
2	1.00	.99	.90	.87
3	1.00	1.02	1.00	1.14
4	1.00	.95	1.01	.98
5	1.00	.87	.86	.96
6	1.00	1.12	1.10	1.11
7	2.00	.82	.74	.97
8	2.00	.92	.96	.96
9	2.00	.94	.89	.91
10	2.00	.85	.84	.81
11	2.00	.98	.87	.89
12	2.00	.74	.95	.93



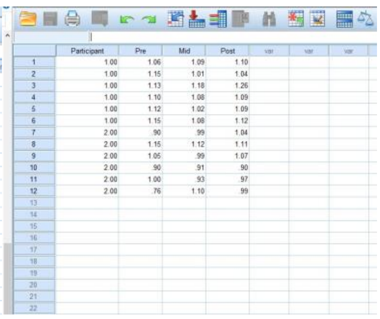
	Participant	Pre	Mid	Post
1	1.00	1.00	.98	1.02
2	1.00	1.01	.85	.90
3	1.00	.99	1.02	1.11
4	1.00	.95	.94	.93
5	1.00	.91	.85	.91
6	1.00	1.14	1.10	1.07
7	2.00	.87	.86	1.04
8	2.00	1.00	.96	.97
9	2.00	.92	.91	.96
10	2.00	.78	.83	.81
11	2.00	.95	.86	.91
12	2.00	.79	.99	.94

First step preferred leg

First step non-preferred leg



	Participant	Pre	Mid	Post
1	1.00	1.03	1.06	1.07
2	1.00	1.10	.93	.91
3	1.00	1.01	1.01	1.18
4	1.00	1.13	1.13	1.16
5	1.00	1.08	1.06	1.12
6	1.00	1.29	1.24	1.24
7	2.00	.91	.97	1.04
8	2.00	1.09	1.09	1.08
9	2.00	1.03	.99	1.03
10	2.00	.90	.95	.92
11	2.00	1.12	1.03	1.01
12	2.00	.78	1.22	1.00



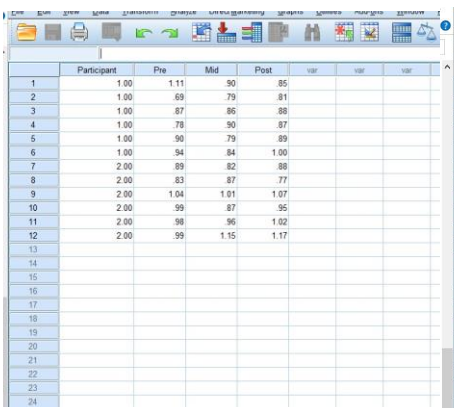
	Participant	Pre	Mid	Post
1	1.00	1.06	1.09	1.10
2	1.00	1.15	1.01	1.04
3	1.00	1.13	1.18	1.26
4	1.00	1.10	1.08	1.09
5	1.00	1.12	1.02	1.09
6	1.00	1.15	1.08	1.12
7	2.00	.90	.99	1.04
8	2.00	1.15	1.12	1.11
9	2.00	1.05	.99	1.07
10	2.00	.90	.91	.90
11	2.00	1.00	.93	.97
12	2.00	.76	1.10	.99

Second step preferred leg

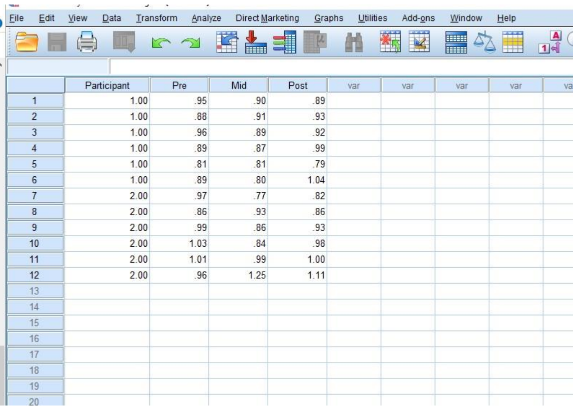
Second step Non-preferred leg

Velocity and acceleration

Vertical velocity



	Participant	Pre	Mid	Post
1	1.00	1.11	.90	.85
2	1.00	.69	.79	.81
3	1.00	.87	.86	.88
4	1.00	.78	.90	.87
5	1.00	.90	.79	.89
6	1.00	.94	.84	1.00
7	2.00	.89	.82	.88
8	2.00	.83	.87	.77
9	2.00	1.04	1.01	1.07
10	2.00	.99	.87	.95
11	2.00	.98	.96	1.02
12	2.00	.99	1.15	1.17



	Participant	Pre	Mid	Post
1	1.00	.95	.90	.89
2	1.00	.88	.91	.93
3	1.00	.96	.89	.92
4	1.00	.89	.87	.99
5	1.00	.81	.81	.79
6	1.00	.89	.80	1.04
7	2.00	.97	.77	.82
8	2.00	.86	.93	.86
9	2.00	.99	.86	.93
10	2.00	1.03	.84	.98
11	2.00	1.01	.99	1.00
12	2.00	.96	1.25	1.11

Preferred lead

Non-preferred lead

Horizontal Velocity

	Participant	Pre	Mid	Post
1	1.00	1.48	1.93	2.03
2	1.00	1.88	1.98	1.82
3	1.00	2.13	1.94	2.09
4	1.00	2.38	2.37	2.21
5	1.00	1.65	1.78	1.79
6	1.00	2.30	2.15	2.17
7	2.00	2.05	1.98	2.12
8	2.00	1.87	1.95	1.93
9	2.00	1.69	1.78	1.76
10	2.00	1.93	2.12	1.87
11	2.00	2.11	2.01	2.08
12	2.00	1.80	2.06	1.88

Preferred lead

	Participant	Pre	Mid	Post
1	1.00	1.96	1.99	2.14
2	1.00	1.79	1.86	1.70
3	1.00	2.13	2.04	2.22
4	1.00	2.15	2.12	1.91
5	1.00	1.61	1.79	1.77
6	1.00	2.18	2.20	1.94
7	2.00	2.09	1.92	1.92
8	2.00	1.84	1.84	1.88
9	2.00	1.86	1.84	1.90
10	2.00	1.76	2.01	1.81
11	2.00	2.04	1.91	2.06
12	2.00	1.75	1.73	1.67

Non-preferred lead

Vertical acceleration

	Participant	Pre	Mid	Post
1	1.00	1.42	-.54	-.65
2	1.00	-1.01	-.70	-.71
3	1.00	.35	-.20	-.44
4	1.00	-.53	-.29	-.63
5	1.00	-.20	-.09	.01
6	1.00	-.13	.23	-.04
7	2.00	-.51	-.26	.16
8	2.00	-.86	-.83	-.52
9	2.00	-.29	-.17	-.08
10	2.00	.47	-.25	.13
11	2.00	-.49	.02	-.27
12	2.00	-.64	.30	1.03

Preferred lead

	Participant	Pre	Mid	Post
1	1.00	.04	.06	-.18
2	1.00	-.40	-.23	-.08
3	1.00	-.27	.09	-.26
4	1.00	-.60	-.99	-.77
5	1.00	-.24	.13	.11
6	1.00	-.88	-.87	-.82
7	2.00	.53	.40	-.35
8	2.00	-.66	-.95	-.45
9	2.00	.20	.89	.75
10	2.00	-.08	.31	-.63
11	2.00	-.60	-.58	-.08
12	2.00	-.53	-.70	-.29

Non-preferred lead

Horizontal acceleration

	Participant	Pre	Mid	Post
1	1.00	4.96	5.74	5.93
2	1.00	4.01	4.59	4.37
3	1.00	6.29	6.53	5.96
4	1.00	4.85	5.05	5.06
5	1.00	4.03	4.33	4.34
6	1.00	4.58	5.07	4.83
7	2.00	6.28	7.13	5.78
8	2.00	4.59	4.55	4.53
9	2.00	4.34	4.64	4.54
10	2.00	4.72	5.25	5.17
11	2.00	4.81	5.24	4.93
12	2.00	5.08	5.24	4.82

Preferred lead

	Participant	Pre	Mid	Post
1	1.00	5.43	5.63	5.15
2	1.00	3.44	4.00	4.24
3	1.00	5.46	5.90	5.09
4	1.00	5.55	5.90	6.00
5	1.00	3.86	4.40	4.35
6	1.00	6.02	6.37	5.94
7	2.00	6.27	6.16	6.92
8	2.00	3.87	3.49	4.12
9	2.00	4.37	4.77	4.50
10	2.00	5.12	5.27	5.57
11	2.00	5.88	5.69	5.84
12	2.00	5.15	5.76	5.85

Non-preferred lead

Force platform data

Contact time

	Participant	Pre	Mid	Post
1	1.00	.21	.20	.21
2	1.00	.28	.23	.22
3	1.00	.19	.	.22
4	1.00	.19	.19	.
5	1.00	.25	.23	.24
6	1.00	.22	.21	.21
7	2.00	.18	.18	.
8	2.00	.23	.25	.24
9	2.00	.22	.20	.22
10	2.00	.17	.17	.16
11	2.00	.19	.18	.18
12	2.00	.15	.18	.20

	Participant	Pre	Mid	Post
1	1.00	.22	.22	.22
2	1.00	.28	.22	.23
3	1.00	.20	.	.22
4	1.00	.19	.19	.
5	1.00	.22	.21	.23
6	1.00	.21	.20	.19
7	2.00	.17	.20	.
8	2.00	.23	.24	.23
9	2.00	.20	.20	.21
10	2.00	.16	.17	.16
11	2.00	.17	.17	.18
12	2.00	.18	.18	.22

Preferred lead *Non-preferred lead*

__Braking impulse__

Preferred lead

	Participant	Pre	Mid	Post
1	1.00	.00	-.77	-.96
2	1.00	.00	-1.33	-.45
3	1.00	.00	.	-2.93
4	1.00	-1.72	-1.42	.
5	1.00	-.36	-.55	-.89
6	1.00	-1.85	-2.79	-3.88
7	2.00	.00	-2.00	.
8	2.00	.00	-1.08	-.97
9	2.00	.00	-.33	-.61
10	2.00	.00	-1.12	-1.69
11	2.00	-.49	-2.97	-1.90
12	2.00	-.68	-.42	-.75

Non-preferred lead

	Participant	Pre	Mid	Post
1	1.00	-.65	-1.44	-1.77
2	1.00	-1.07	-.33	-1.43
3	1.00	-3.22	.	-3.43
4	1.00	.00	-.89	.
5	1.00	.00	-.31	-.85
6	1.00	.00	-4.01	-3.78
7	2.00	-1.74	-1.52	.
8	2.00	-.50	-1.44	-1.94
9	2.00	-.43	-.76	-1.12
10	2.00	.00	-1.12	-1.69
11	2.00	.00	-1.21	-1.86
12	2.00	.00	-.53	-1.80

Preferred lead *Non-preferred lead*

__Propulsive impulse__

Preferred lead

	Participant	Pre	Mid	Post
1	1.00	89.89	93.26	92.71
2	1.00	78.99	80.51	80.79
3	1.00	90.76	.	86.74
4	1.00	89.79	85.08	.
5	1.00	69.03	69.84	65.69
6	1.00	102.16	99.94	94.56
7	2.00	80.23	81.35	.
8	2.00	87.79	88.98	85.06
9	2.00	84.79	80.95	83.81
10	2.00	62.84	70.66	69.91
11	2.00	89.30	79.40	80.85
12	2.00	44.86	75.20	71.14

Non-preferred lead

	Participant	Pre	Mid	Post
1	1.00	86.61	91.99	89.98
2	1.00	89.28	83.73	80.49
3	1.00	95.61	.	94.72
4	1.00	85.03	86.52	.
5	1.00	72.40	66.06	67.78
6	1.00	94.65	92.59	93.98
7	2.00	69.94	62.07	.
8	2.00	84.10	82.35	84.64
9	2.00	82.57	81.27	84.01
10	2.00	55.87	77.51	72.77
11	2.00	72.69	82.15	80.20
12	2.00	32.39	58.41	71.56

Preferred lead *Non-preferred lead*

__Impact force peak__

Preferred lead

	Participant	Pre	Mid	Post
1	1.00	398.80	503.55	427.81
2	1.00	478.26	497.76	358.33
3	1.00	651.82	.	461.46
4	1.00	572.68	490.36	.
5	1.00	226.60	251.61	229.79
6	1.00	613.99	781.38	883.68
7	2.00	453.57	516.12	.
8	2.00	516.61	572.80	520.23
9	2.00	240.05	270.81	289.63
10	2.00	646.54	779.31	834.65
11	2.00	376.73	814.43	548.76
12	2.00	555.65	454.24	485.16

Non-preferred lead

	Participant	Pre	Mid	Post
1	1.00	439.08	617.60	529.76
2	1.00	556.93	492.14	560.60
3	1.00	873.36	.	654.52
4	1.00	434.06	554.72	.
5	1.00	253.03	216.83	267.60
6	1.00	946.35	1090.00	1207.50
7	2.00	504.70	412.99	.
8	2.00	511.50	472.70	488.44
9	2.00	268.86	276.72	328.07
10	2.00	721.94	842.13	1024.27
11	2.00	608.49	520.75	565.77
12	2.00	250.39	677.50	595.15

Preferred lead *Non-preferred lead*

__Loading peak__

Preferred lead

	Participant	Pre	Mid	Post
1	1.00	1333.54	1360.94	1407.92
2	1.00	1398.20	1609.02	1543.22
3	1.00	1598.44	.	1467.54
4	1.00	1604.80	1640.60	.
5	1.00	1162.46	1052.31	1131.76
6	1.00	1465.72	1399.07	1278.11
7	2.00	1543.56	1261.49	.
8	2.00	1094.39	1220.14	1146.64
9	2.00	1301.55	1562.42	1581.49
10	2.00	1694.63	1579.20	1592.22
11	2.00	1505.38	1311.54	1379.32
12	2.00	1294.66	1301.36	1158.98

Non-preferred lead

	Participant	Pre	Mid	Post
1	1.00	969.47	1173.40	1258.38
2	1.00	1403.54	1490.54	1453.08
3	1.00	1461.72	.	1437.84
4	1.00	1660.86	1518.30	.
5	1.00	1224.38	1170.44	1143.66
6	1.00	1405.58	1396.76	1445.18
7	2.00	1425.76	1050.94	.
8	2.00	1294.16	1329.92	1364.58
9	2.00	1678.46	1734.94	1575.21
10	2.00	1580.28	1623.40	1547.00
11	2.00	1925.28	1515.60	1495.72
12	2.00	972.78	1279.92	1140.50

Preferred lead *Non-preferred lead*

<u>Loading rate</u>

	Participant	Pre	Mid	Post
1	1.00	162.90	150.74	184.85
2	1.00	43.09	124.59	63.19
3	1.00	120.84	.	83.05
4	1.00	152.58	126.79	.
5	1.00	32.67	60.33	72.54
6	1.00	157.44	286.93	329.01
7	2.00	129.31	176.87	.
8	2.00	195.05	246.50	295.36
9	2.00	81.72	89.41	59.44
10	2.00	169.00	296.45	248.03
11	2.00	66.86	176.21	106.56
12	2.00	209.27	180.32	205.85

Participant	Pre	Mid	Post
1.00	158.06	233.96	189.05
1.00	92.19	99.03	162.15
1.00	131.80	.	134.59
1.00	62.91	98.23	.
1.00	70.35	52.28	41.71
1.00	328.61	236.08	333.93
2.00	93.97	98.84	.
2.00	156.38	175.21	159.52
2.00	68.12	57.21	122.52
2.00	216.14	156.31	325.74
2.00	112.38	92.40	106.05
2.00	83.45	169.09	231.75

Preferred lead *Non-preferred lead*