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# Comparison of Stride Length and Stride Frequency Patterns of Sprint Performance in Overground vs Motorized Treadmill Sprinting.

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COMPARISON OF STRIDE LENGTH AND STRIDE FREQUENCY PATTERNS OF  
SPRINT PERFORMANCE IN OVERGROUND VS MOTORIZED TREADMILL  
SPRINTING

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SPRINT PERFORMANCE IN OVERGROUND VS MOTORIZED TREADMILL  
SPRINTING

By

FAYON KAMIEKA GONZALES, B.S.

THESIS

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## **ABSTRACT**

The purpose of this study was to investigate the relationship between different kinematic parameters when maximal effort sprints are performed overground and on a motorized treadmill by recreationally trained and collegiate level sprinters. To accomplish the goals of this study, we measured stride length, stride frequency, contact time, and flight time overground and on a motorized treadmill to determine what differences or similarities can be identified.

Anthropometric measurements such as the height, body weight, lower limb length, and lower limb circumference were also recorded. Subjects' performance of a 60 meter sprint (50 meter acceleration, 10 meter maximal velocity) was measured overground, as well as a sprint test was performed on the motorized treadmill at maximal speed (3-4 seconds). Our results showed that contact time, flight time and stride frequency were strong predictors of sprint speed overground for all subjects; while all parameters were seen as predictors for sprint speed in motorized treadmill condition. However, these result differed when analysis was done based on grouping. In conclusion, the current results show that motorized treadmill increases stride frequency dramatically when compared to overground, which could result in the motorized treadmill being used as a training tool to enhance stride frequency. However, the optimal ratio used to achieve sprint speed was altered on the motorized treadmill when compared to overground running. Therefore, while there may benefits to using such an instrument to enhance speed, it is unclear how much improvement is transferred to overground condition, which warrants more research

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## **CHAPTER 1: INTRODUCTION**

### **Introduction to Sprint Performance**

Sprinting can be described as the fastest natural form of human movement (Nesser, Latin, Berg, & Prentice, 1996). Sprint Performance (SP) can be described as the execution of rapid cyclical running movements over a short period of time at top speed. The ability to attain maximal sprinting velocity is a major factor in many athletic events. Maximal sprinting velocity can be observed from a static position as seen in track and field but this can also occur when a person is already in motion as seen in soccer, rugby, football, and other sports (Buchheit, Simpson, Peltola & Mendez-Villanueva, 2012; Vescovi & McGuigan, 200;). The 100-meter (m) sprint event of track and field has consistently been used to demonstrate extreme speed capabilities of human beings over a short distance. This sprint is determined by the ability to accelerate, the magnitude of maximal velocity and the ability to maintain velocity against the onset to fatigue (Cunha, 2005). The 100 m is the only sport that allows an all-out linear acceleration to reach maximal velocity. In a linear sprint an athlete may require 30-50 meters to accelerate to their maximal sprinting capabilities (Letzelter, 2006). This race has been the focal component of track and field, as men and women often receive the prominent title “world’s fastest athlete” for their SP.

SP is of great importance as it can determine whether an athlete transitions from High School athletics to collegiate athletics or even to the professional level (Baker & Newton, 2008). The measures of SP are often used to identify an athletes’ athletic ability, such as when the 40-yard (yd.) dash is used as a testing tool for skilled positions like running back or wide receiver. The testing of an athlete’s ability to run and jump has been shown to represent their playing potential for a sport (Garstecki, Latin, & Cuppett, 2004). Being able to rapidly move the body is

a critical factor in the realm of sports. The definition of speed goes far beyond how fast a person can run. Hall (2018) states that speed is the distance (meter) traveled per unit of time (seconds); and this tells how fast an object is actually moving. However, the term “speed” in the world of sport science transfers speed into skills useable in a particular sport. For an athlete to be successful, one must be able to use their speed during competition (Sandler, 2005). Therefore, sport speed should be broken down according to the sport’s specific movement patterns (Sandler, 2005). Sprint performance depends on many parameters which are derived from the sport’s specific movement patterns, otherwise called sprint mechanics.

### **Sprint Mechanics**

Sprinting, like walking, is a pattern of cyclical movements. A stride, which is considered a complete cycle, is when one foot comes in contact with the ground and ends when the same foot comes in contact with the ground again (Cavanagh & Kram, 1989). Half a running cycle is considered a step, as it is the foot contact from one foot contact to the next contact of the opposite foot (Cavanagh & Kram, 1989). Therefore, a stride consists of two consecutive steps. The 100 m sprint sport movement can be broken down into two specific components: stride length (SL) and stride frequency (SF) as both are a function of speed ( $\text{Speed} = \text{Stride Length} \times \text{Stride Frequency}$ ) (Ae et al., 1992; Bruggrmann et al., 1999; Charalambous, Kerwin, Irwin, Bezodis & Hailes, 2011; Delecluse et al., 1998; Ferro et al., 2001; Mann & Herman, 1985). Sprint running can be divided in to three main parts: an acceleration phase, a maximum speed phase and a deceleration phase.

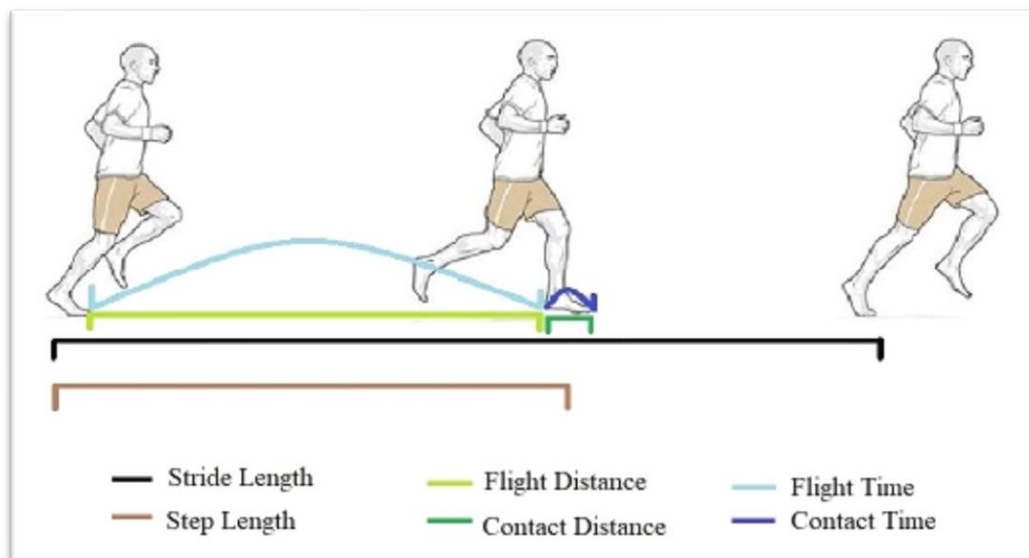


Figure 1. Running stride cycle.

From the biomechanical view, maximal sprint velocity is defined by SL and SF. SL (measured in centimeters) is considered the distance covered within a single stride (Hunter, 2004). This is ideally twice the distance of a single step with the individual achieving symmetry in the left and right side of sprint steps (Refer to Figure 1 for visual aid). SF refers to the number of times a stride is taken within a given amount of time or distance (Corn & Knudson, 2003; Weyand, Sternlight, Bellizzi, & Wright, 2000). These two factors have a negative relation towards each other, whereas an increase in one factor will result in an improvement in sprint velocity as long as the other does not undergo a proportionally similar or larger decrease (Hunter, Marshall, & McNair, 2004). These parameters are interdependent and an optimal ratio between the two allows maximal running speed (Hunter, 2004; Magness, 2010). Hunter, Marshall, and McNair (2004) divided SL and SF into subcomponents: foot contact time (CT), flight time (FT), contact distance (CD) and flight distance (CD). CT (measured in seconds) is the measurement of

the amount of time spent in contact with the ground during strides when running; whilst FT (measured in seconds) is the amount of time it took to complete one step (Hay, 1994).

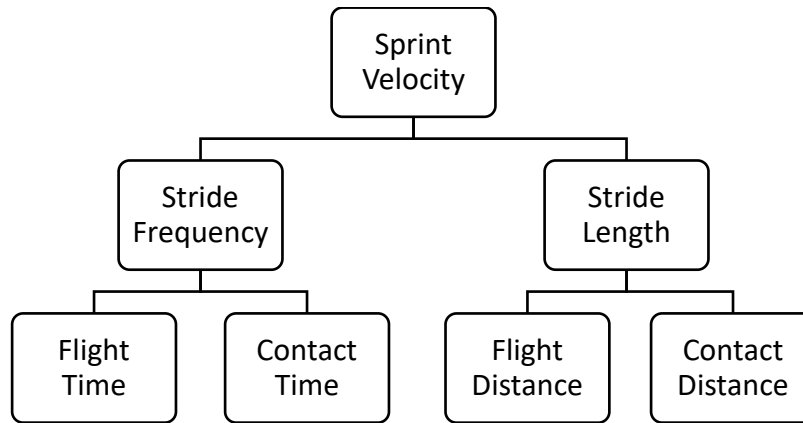


Figure 2. Determinants of sprint velocity.

Although the equation speed equals SL multiplied by SF is very straightforward, in practice, the relationship between SL and SF has an inverse relationship at maximal effort (Salo, 2010). An increase in one parameter could lead to a decrease in the other due to the negative interaction in the production of these variables (Hunter, Marshall, & McNair, 2004). These parameters are interdependent, and their optimal ratio allows for a maximum running speed (Hunter, Marshall, & McNair, 2004). There are different viewpoints regarding the importance of stride length and stride frequency when acquiring maximum speed, as well as maintaining it. As SF increases the amount of time the foot is spent in contact with the ground decreases (Hunter Marshall, & McNair, 2004). This means that contact with the ground comes from a smaller portion of the foot (toes and ball of foot) instead of the whole foot. The elimination of the whole foot touching the ground causes the heel to be pulled up immediately after ground contact for initiation of the next step. As for SL, the length of a stride affects how much distance is gained

(Hay, 1994). Improvement in distance even by an inch while maintaining frequency will improve speed, which ultimately aids sprint performance (Weyand et al., 2000). To increase from intermediate speed to maximal speed, the foot needs to come in contact with the ground and quickly reposition for the next step (Weyand et al., 2000). This quick reposition is what creates a step. The biological limit of muscles will come in effect and the body will reach the limit of how fast this turnover will occur (Weyand et al., 2000). This limit will create the maximal distance covered, SL by SF (Weyand et al., 2000). Therefore, SL and SF predetermine an athlete's sprint performance, as both are a function of speed performance.

### **Sprint Modalities (Overground and Motorized Treadmill)**

Sprint training can be executed indoor and outdoor. Indoor environments have been created to facilitate almost everything that is done outdoor by using an indoor track or treadmills for running exercises. While treadmills are mostly used by recreationally trained individuals (non-athletes), it is often used by athletes as well for training purposes. High speed motorized treadmills have become a popular training tool for speed development and are capable of reaching speeds of 13.5 m/s inclines up to 40°, and a decline of 10° (Kivi, Maraj, & Gervias, 2001). These treadmills place emphasis on movement velocity and movement specificity which is critical for speed development training. It also allows the evaluation of running biomechanics under controlled conditions and the understanding of the kinematic and kinetic running on a treadmill compared to overground running (Riley et al., 2007).

Despite the high degree of specificity expected between the overground and treadmill sprinting conditions, it has been reported that there are kinematic differences between the two modalities. The kinematic studies that compared overground running to treadmill running have demonstrated a lack of consistency in the results. According to the results, at a given running



velocity overground an athlete may show no difference in SL or SF when the same velocity is completed while running on a treadmill (Frishberg, 1983). Or, the athlete may have a longer SL and lower SF (Nelson, Dillman, Lagasse, & Bickett, 1972), or exhibit the opposite which is a shorter SL and higher SF (Elliot & Blanksby, 1976; Wank, Frick, & Schmidtbleicher, 1998). Some studies also showed that athletes may have either a shorter or longer ground CT on the treadmill when compared to overground (Nelson et al., 1972; Wank et al., 1998). Disparities may have been due to individuality of running gait (Ae, Ito, & Suzuki, 1992; Frishberg, 1983; Moravec, Ruzieka, Susanka, Dostal, & Kodejs, 1988; Saito, Kobayahi, Miyashita, & Hoshikawa, 1974) which highlights the fact that each person's running mechanics are different. Also, running kinematics is highly specific with regard to the velocity used (Luhtanen & Komi, 1978; Mero et al., 1992), which means that the technique used might be dependent on the velocity used while running.

SL and SF are the most important variables when looking at speed. However, the current literature is lacking studies that investigated SL and SF differences between motorized treadmill and overground conditions at maximal sprint effort. There is still no consensus of how SL and SF are truly affected when compared on both modalities. It is still unclear why SP is different between these conditions and assumptions arise stating that differences may be due to the size of the athlete, running style (Frishberg, 1983), gender (Paruzel-Dyja, 2006), and running velocity (Elliot & Blanksby, 1976; Nelson et al., 1971). Even though treadmill-based sprint performance has been the interest of numerous studies, these studies primarily focused on the same kinematic and kinetic variables: ground reaction forces (GRF), joint angles, joint torques, and angular velocities (Caekenberghe, Segers, Aerts, Willems, & Clercq, 2013, Riley et al., 2008). When studies do focus on SL and SF, the velocity are usually constant and treadmill velocity is

matched to that of overground. SL and SF have not been studied in previous experiments at maximal effort overground and maximal effort on the treadmill. No research has focused on the relationship of SL and SF at maximal effort overground and maximal effort on the treadmill to see how the main predictors of speed overground is affected in the treadmill condition.

Therefore, the purpose of the research study was to investigate the specific changes in SL and SF, when maximal speed sprints are performed overground and on a high-speed treadmill. The primary goal of the proposed study was to: 1. examine the relationship between SL and SF between overground and motorized treadmill sprinting, 2. examine which components SL or SF was a predictor of speed overground and on the motorized treadmill. To accomplish the goals of this study, we measured sprint kinematics of SP such as SL, SF, CT, and FT overground and on a motorized treadmill to determine what differences or similarities can be identified.

## **CHAPTER 2: LITERATURE REVIEW**

Sprinting is determined by the ability to accelerate, the magnitude of maximal velocity and the ability to maintain maximal velocity against the onset of fatigue (Cunha, 2005). Sprinting speed can be calculated as a product of SL and SF and both are useful in monitoring characteristics of sprinting (Brughelli, Cronin, & Chaouachi, 2011; Debaere, Jonkers, & Delecluse, 2013; Hunter, Marshall, McNair, & 2004; Nagahara, Naito, Morin, & Zushi, 2014, Salo et al., 2011). Improving one of these components may improve the whole performance. To effectively increase speed through the components SL and SF, there is a need for the application of productive forces (such as ground reaction forces) during ground contact (Mann, 1994). This application of forces to the ground needs to be enough to make a difference in SL or SF. Schmolinsky (1992) concluded that emphasis placed on physically trying to increase SL and SF in training would result in failure of improvement. Instead, the author recommends that more emphasis should be placed on developing muscles of the lower extremity to improve explosive strength, which in turn will allow longer strides in a shorter time. Nevertheless, theoretically, improving either SL or SF will improve performance (Hunter, Marshall, McNair, & 2004; Monte, Muollo, Nardello & Zamparo, 2016).

### **Stride Length and Stride Frequency**

SL and SF generally have an inverse relationship at maximal effort (Salo, 2010). In a study of 36 athletes from sprint related sports (athletics, soccer, touch rugby), Hunter et al. (2004) found that SL at the group level was significantly related to running velocity, while SF was not. However, at the individual level, SF for subjects was higher in their fastest trial in comparison to the third fastest trial. At the individual level, SL did not reveal significant

differences (Hunter et al, 2004). A potential explanation was offered from the authors of the study stating that these differences between the individual and the group analysis could mean that SF maybe more important in the short term, while longer steps may require the development of strength and power during the long term period.

Ae et al. (1992) analyzed the final of the men's 100-m from the 1991 World championships and reported that the gold medalist exhibited a shorter SL and higher SF than the silver medalist. However, this was not consistent throughout the entire race. A similar study was done by Gajer et al. (1999) which analyzed the semifinals and the finals of the men's 100-m at the 1996 French Championships. Two groups were created from the six fastest ( $10.18 \pm 0.05$ s) and the six slowest ( $10.52 \pm 0.08$ s) athletes of the race. This study found that SL was consistently higher in the faster group and was significantly higher in seven out of ten sections. On the other hand, SF was higher in the slower group in all but the last 10-m section (one out of ten sections). Gajer et al. (1999) concluded that SL was more important than SF at the highest level.

Salo et al. (2010) analyzed SL and SF of world elite male 100-m sprinters over multiple competitions and found that some athletes were more SL reliant while one was SF reliant. Furthermore, some athletes used a combination of both and showed a reliance on neither (Salo et al., 2010). However, more recent evidence gathered from elite sprinters revealed that very high SF is attained during the early stage (10-20 m) of the 100-m event to produce their high speeds, while further increases during the race results from increased SL (Debaere, Jonkers, & Delecluse, 2013; Rabita, 2015). The results presented on elite athletes in competition provide no consensus on whether SF and SL are more important for sprint speed in competition. Furthermore, the reliance on either SF or SL to achieve and maintain high speed has been shown

to be highly individual with the well-trained sprinters (Salo, 2010). It is proposed that this reliance should be taken into consideration when creating a training regimen.

### **Factors that Affect Stride Length and Stride Frequency**

The technique of an individual can be developed to one's satisfaction; however, the physical characteristics of that individual cannot be changed for satisfaction. The biological attributes (such as body height, body mass and leg length) effect on SL and SF cannot be used for the explanation of faster running and speeds or the elements that distinguish faster sprint performances from slower ones (Mackala et al., 2015). However, the influences of biological attributes have been shown to greatly affect stride length and stride frequency independently of an athlete's physical fitness level (Frishberg, 1983; Mackala et al., 2015). An extensive study was carried out by Paruzel-Dyja et al. (2006) on a sample of 109 men and 79 women elite sprinters who competed in the 2003 World Championships in Paris. The authors found that SF was the most important parameter of sprint performance for females while SL was the important factor for male sprinters. This analysis suggested a distinction for sex specific technical training. On the contrary, studies found that SL and SF appeared to be variable among individuals and not sex, while SL is dependent on the athlete's height and leg length (Mero, Komi and Gregor, 1992; Plisk, 2000). The taller the athlete or greater the leg length, the longer stride length will be.

Sprinters with a presence of a longer lower extremity have been found to be more advantageous in achieving top sprint performance speed (Vucetic et al., 2008). Hoffman (1964) conducted an extensive study of sprint running analysis on 56 top male sprinters in the world for the 100 m race. The correlations measured from the 50 – 60m markers, between maximal SL and height and leg length were high ( $r = 0.59$ ,  $r = 0.70$  respectively). A similar relationship was later

reported by Hoffman (1967) in 23 world-class female sprinters for maximal SL and height and leg length ( $r = 0.63$ ,  $r = 0.73$ ). However, both showed that there are no differences in sex regarding SF. Paruzel-Dyja et al. (2006) found that men who are taller usually have faster times than men who are shorter; and that body height appears to have a greater impact on SL and the maintenance of speed. In addition, men have longer SL than women, which helps to explain the difference in running velocity between men and women (Mero & Komi, 1986; Mero et al., 1988; Moravec et al., 1988). Even though this relationship is found, SL cannot be defined by leg length and body height.

SF was also found to be variable among sex with large differences seen between trained and untrained individual (Mero, Komi & Gregor, 1992, Plisk, 2000). According to Plisk (2000), trained sprinters achieve a greater SF than untrained runners. Also, trained sprinters are capable of increasing SF for 25 m while untrained runners reach their maximum SF by 10-15 m from a static position. Other studies found that untrained sprinters reach maximum running speed around 30-40 m and cannot maintain speed after 40-50 m of a 100 m sprint (Coh et al., 2001; Delecluse et al., 1995). One explanation for this is the strength of the lower extremities, which has developed with several years of regular training for athletes which assist in the sprint movements (Mackala et al. 2015). Muscle power is a greater contributor during the accelerative phase of the race where it aids in the rebound of each stride (Majumdar & Robergs, 2011).

According to Donati (1995) two athletes having different SL/SF ratio can develop the same speed. For example, an athlete A may run the race in 50 strides (mean SL 2 m, mean SF 5 strides per second) while athlete B uses 45 strides (mean SL 2.2 m, mean SF 4.5 strides per second). Nevertheless, both will end with a time of 10.00 sec (Donati, 1995). This SL and SF ratio is the difference between the two athletes. SL is determined by leg length, leg strength and

running mechanics while SF is a function of leg length, genetic factors and training (Derse, Hanson, O'Rourke & Stolley, 2016). Optimal SP depends on many controllable and non-controllable factors. Aspects that are fixed are an athlete's anthropometric measurements and so it is important to understand individual performances and step characteristics rather than analyzing at the group level (Salo et al., 2010). Overall, training programs should be tailored to the needs to the individual based on their specific performance.

### Phases of Sprinting

To analyze speed, we must take into account the three phases of a sprint: Acceleration, Maximum Speed and Speed Endurance/Deceleration (Ae et al., 1992; Brüggemann & Glad, 1990; Shen, 2000). When analyzing these components to a linear 100 m sprint we are able to apply these phases as shown in the figure below (Figure 3.). The dispersion of these phases is based on the level of sprint abilities and may vary among different population (Mackala et al., 2015). The first phase acceleration (10 m to 40 m) allows the ability to reach maximum speed. The second phase maximum speed (40 m to 60 m) is where the maximum velocity is achieved by a person. Lastly, the third phase speed endurance (60 m to 100 m) is the ability to maintain speed with minimal deceleration. The top-leveled sprinters have been shown to reach a maximum speed between 50 and 70 m.

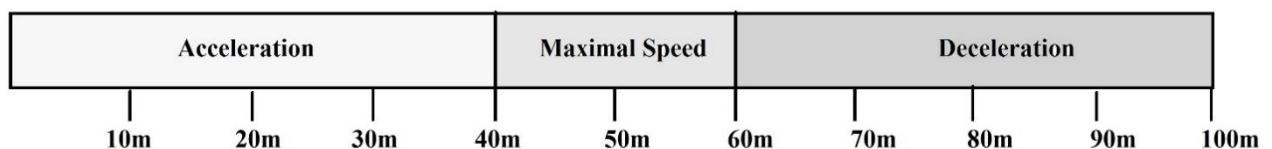


Figure 3. Components of a 100 m sprint: acceleration, maximum speed and speed endurance.

## Acceleration

Acceleration is the ability to reach maximum speed in the least amount of time starting from a static position. Earlier studies found that the length of the acceleration phase is 30 to 50 m long in top sprinters during a 100 m race (Moravec et al., 1988; Volkov & Lapin, 1979). A later study found that the first phase (acceleration) may be broken down into sub phases: initial/starting acceleration and main acceleration (Mackala et al., 2015). The initial/starting acceleration is characterized as a constant increase of SL from 0 -12 m, while the main acceleration is 12 -35 m. A third transition may be seen but only in elite athletes, which last up until maximum running 35-60 m (Mackala, Frostiak & Kowalski, 2015). A sprinter is generally able to accelerate at full effort for about six seconds (Derse, Hanson, O'Rourke & Stolley, 2016). At that point, the sprinter has reached acquired speed and the decreased efficiency of muscular contractions stop the runner from accelerating further (Derse, Hanson, O'Rourke & Stolley, 2016).

According to Frye (2000), the initial acceleration phase is achieved by pushing with the drive leg, which requires a forward body-lean from the ground up. The first few strides of the acceleration phase also cause the body's center of gravity (COG) to change because of initial ground contact (Mackala et al., 2015). Technique during the acceleration phase is very critical as it determines the efficiency of SL and SF for a sprinter. According to Hoffman (2002), as SF increases, the amount of time spent on the ground decreases, while the time spent in flight phase increases. Furthermore, if SF increases and the SL remains constant, running speed will increase. Similarly, if SF remains constant but SL increases, then running speed will also increase (Hoffman, 2002). The contribution of both SL and SF to sprint speed changes at different running velocities.



Hoffman (2002) found that the initial changes in speed are the result of an increase in the runner's stride and that as running velocity continues to increase there is an increase in both SL and SF which contributes to the higher velocities. According to Mero, Komi and Gregor (1992), there is a linear increase in both stride length and frequency up until  $7 \text{ m}\cdot\text{s}^{-1}$  during the acceleration phase. After which as speed is increased even further, there is a slight decrease in SL while a sustained increase can be seen in SF (Hoffman, 2002; Mero, Komi, & Gregor, 1992). This SF appears to be more important than SL in determining the runner's maximum velocity (Mero, Komi, & Gregor, 1992). Nevertheless, the accelerative phase shows a decrease in CT and an increase in SL, SF, and FT to values that approach those reported for maximum speed (Moravec et al., 1988). When the acceleration phase is of sufficient length, the athlete shifts into optimum value running speed which is the maximal velocity phase.

### **Maximal speed**

Maximal speed is the maximal velocity an individual can attain during a sprint. The maximum velocity phase is usually achieved after four-to-five seconds of utmost effort and often last for as short as two to three seconds (Derse, Hanson, O'Rourke & Stolley, 2016). It is favorable for the body of the athlete to have a slight forward lean as it optimizes the striking angle of the foot during the contact phase (Delecluse, 1997; Majumdar & Robergs, 2011). This enables a greater chance of having a forefoot strike (commonly known termed as the ball of the foot) which translate to a quicker toe-off in the initiation of the next stride (Ross et al., 2001). Schweigert and Beil (n.d.) stated that while the body is in this near vertical position, the foot contact will adjust from a push action to a pull action that cause contact to be slightly ahead of their center of gravity. Also, throughout this phase horizontal forces will be at their peak and the maintenance of maximal velocity becomes top priority. During maximal velocity sprinting, there

is also an attempt to minimize braking forces and increase vertical propulsive forces (Schweigert & Beil, n.d.). The braking phase begins as the lead foot touches the ground, causing a momentary braking or slowing. Minimizing this braking force will allow the maintenance of speed. More vertical propulsive force generation cause more time to be spent in the air, which allows the repositioning of limbs for the next ground contact (Weyand et al., 2000). The maintenance of maximal velocity is highly dependent on the forward propulsion created by the hip and ankle extensors (Markovic, Jukic, Milanovic & Metikos, 2007; Weyand et al., 2000). Therefore, the maximal momentum that was developed during the acceleration phase tends to maintain a forward movement at the same speed if the internal and external forces acting on the body are balanced.

At maximal speed, there is no more acceleration and the biomechanics of the sprinting action changes (Delecuse, 1997). The body during maximal sprinting biomechanically favor a slight forward lean to optimize foot contact with the ground (Majumdar & Robergs, 2011). The maintenance of maximal velocity can be submaximal, maximal or supramaximal (Mero, Komi, & Gregor, 1992). Submaximal speed is running at a constant velocity, which is below maximal velocity (Barnes, & Kilding, 2015). According to Barnes and Kilding (2015), running at constant velocity enables the athlete to run at a self-selected pace causing SL to be lengthened or shortened based on the desire of the athlete. Furthermore, with running characteristics freely chosen over running time it tends to be more varied than the characteristics of maximal velocity or supramaximal velocity.

The maximum velocity phase of the sprint race is characterized by the highest SF and the most optimal SL. At higher speeds there is a smaller incremental increase in SL and a greater incremental increase in SF (Mero, Komi, & Gregor, 1992). This means that sprinters increase

their velocity by increasing SF to a relatively greater extent than SL at higher speeds. During the maximal sprint phase for male sprinters, it is suggested that SF has a more decisive role than SL (Mero et al., 1981), with highest values of SF reported being above 5 steps per second while SL ranged from approximately 2 to 2.6 m (Mann & Herman, 1985; Mero et al., 1982; Moravec et al., 1988). Also, elite sprinters tend to have SF of 5 steps per second (Mann, 2005; Mero, Komi and Gregor, 1992). In maximal sprinting flight times were found to range from 0.120 to 0.140, while contact times are very short and range from 0.080 to 0.100 second (Kunz & Kaufmann, 1981, Mero et al., 1982; Moravec et al., 1988). Increasing SL by over-striding reduces speed because it increases the time of the braking phase (Derse, Hanson, O'Rourke & Stolley, 2016). Conversely, overly short strides, or under-striding, may increase SF but still reduce speed because of the decrease in SL (Derse, Hanson, O'Rourke & Stolley, 2016). Therefore, an optimal ratio of SL and SF is required to achieve maximum velocity.

The supramaximal velocity is when running velocity is greater than what the athlete can attain on his or her own (Mero & Komi, 1986). Mero and Komi (1985) examined supramaximal running by a horizontal towing system, which showed velocity was 8.4%, SF 6.9% and SL 1.5% greater than maximal running. However, when towing was done both horizontally and vertically, SF remained unchanged and changes were only seen for SL (Mero et al., 1987). This means longer strides were taken using the same SF. Supramaximal running is usually associated with more braking and the angle of the ground knee was greater due to the inclination of the ground shank at the beginning of eccentric phase (Mero & Komi, 1985). Overall, supramaximal running compared to the maximal running showed that the contact phase was shorter while the flight phase was longer resulting in athletes running at a higher SF than in maximal running (Mero & Komi, 1985).

## **Deceleration**

Deceleration also considered as speed endurance is the ability to maintain speed beyond the maximal speed phase with minimal deceleration. Deceleration occurs after maximal speed has been maintained for several meters and the onset of fatigue takes over reducing the velocity (Mero, Komi, & Gregor, 1992). Velocity tends to decrease on a scale of 0.9% to 7% for athletes from their peak velocity during the maximal sprint phase (Moravec et al., 1988) and is caused by central and peripheral fatigue. This phase is usually seen after 60 m in a 100 m sprint race. While SF decreases, SL slightly increases during deceleration (Moravec et al., 1988; Mero & Peltola, 1989). As for CT and FT, there is an increase in the end of the race due to the vertical decent of the body's COG and increase in horizontal braking forces (Mero et al., 1992).

## **Modality Options for Sprinting**

### **Overground Sprinting**

Overground sprinting consists of several sections, which includes accelerating, maintaining constant speed and then decelerating. When running overground, the starting position can begin from a crouch position in starting block formation (Mero, Komi & Gregor, 1992). In this set position, the height of center of gravity varies from 0.61 to 0.66 m (Baumann, 1976; Mero et al., 1983). After taking off from the blocks, the runner accelerates by increasing both SL and SF and at higher speeds velocity is increased by SF at greater extent than SL (Mero, Komi & Gregor, 1992). When moving from accelerating phase to maximal speed phase, ground contact phases become shorter due to the anterior trunk tilt achieved as the race progress (McKenna & Riches, 2007). During these phases, speed constantly changes due to the amount of force that is being applied to the ground. This is usually an important factor when comparing overground running to that on a treadmill (Morin & Seve, 2011).

## **Motorized Treadmill Sprinting**

A motor-driven treadmill can ensure that an athlete attains the same velocity as overground sprinting during the constant velocity phase (Frishberg, 1983); however, the result may be from different sprinting kinematics. When an athlete is on a treadmill, the treadmill will pull the foot underneath the body causing only a push action. This push action supports the body but also minimize the amount of force being placed on the treadmill (Schache et al., 2001). The speed at which the foot is being pulled underneath the body is dependent on the speed selected on the treadmill. The moving treadmill belt reduces energy requirements that would have used to propel the body forward; this contributes to the greater angular motion of the leg and reduced angular motion of the thigh resulting in reduced workload (Frishberg, 1983). An environment is presented where variables such as velocity and gradient can be standardized and reproduced consistently (Schache et al., 2001) facilitating a more repeatable pattern of movement in comparison with the short discontinuous trials associated with overground analyses (Fellin, Manal & Davis, 2010). Treadmills powered by a torque allow some control over the belt's velocity, and aid in reaching maximum velocity. Alternatively, the use of a non-motorized treadmill enables the control of the belt's velocity; however, the athlete only attains 80% of maximum over-ground velocity (Lakomy, 1987).

High-speed treadmills have become a popular training tool for speed development. This is because the treadmill is capable of reaching speeds of 12-14 meters per second (m/s), inclines up to 40 degrees, and declines of 10 degrees with controlled training under a wide range of conditions. A runner's pace can be controlled on the treadmill, which leads to training possibilities at submaximal, maximal and supramaximal running speeds (Frishberg, 1983). These treadmills place an emphasis on the movement velocity and movement specificity, which must

be considered during training for speed development. Furthermore, increasing the incline during treadmill sprinting places a greater mechanical load on the hamstrings and produces increases in joint angular velocities and lower extremity muscle activation. When training on the treadmill at maximal velocity, the time spent on the treadmill at maximal speed is usually 2-4 seconds since neural fatigue will not allow one to have further gains past that time (Seagrave, 1989). Also, some sprinting protocols utilize repetition of six bouts of 30 seconds all-out effort with a recovery time of four minutes (Koral, Oranchuk, Herrera & Millet, 2018), which can be done on the treadmill.

Studies considering the effect of different treadmills are rare. Treadmill belt speed variations can be assumed to depend on the power of the treadmill engine, the system controlling the belt speed, the speed of locomotion and the mass of the subject (Savelberg, Vortenbosch, Kamman, van de Weijer & Schambardt, 1998). In a study done by Nigg et al. (1995), the effect of different treadmills on kinematic parameters. They were not able to attribute the kinematic differences to differences between treadmills. However, the treadmills used were selected for differences in running areas and not for differences in engine powering. Furthermore, the study did not consider differences in the belt speed variation.

### **Overground Sprinting vs Motorized Treadmill Sprinting**

High speed treadmills have become popular training tools for speed development as they allow closely controlled training under a wide range of conditions. Treadmills capable of ensuring that an athlete reaches the same velocity as overground during the constant velocity phase (submaximal, maximal and supramaximal). Nevertheless, questions arise on whether the results from a treadmill can be directly applied to overground running. Nelson et al. (1972)

reported his personal conversation with recognized physiologist (Åstrand, Balke and Magaria), who indicated that the fundamental mechanics of running on a treadmill states no difference would be seen between moving overground or the ground (treadmill's belt) moving beneath. This statement was supported by Van Ingen Schenau (1980) who used a theoretical mathematical approach and showed that the mechanics of overground running and treadmill running are basically the same if the speed of the treadmill belt is constant. Therefore, the underlying assumption was that locomotion on a treadmill is similar to overground.

Frishberg (1983) analyzed overground and treadmill sprinting and found no difference between the running conditions. Frishberg's (1983) study focused on maximum velocity sprinting ( $9.21 \pm 0.11$  m/s) collected from five college sprinters overground and matched the treadmill velocity to that of overground. Data was analyzed using a Pathe (16mm) camera to operate at 75 fps. Frishberg (1983) found major biomechanical differences during the support phase and the supporting leg suggested that the moving belt reduces the energy requirements of the runner by bringing the supporting leg back under the body during the support phase of sprinting. Nevertheless, it was concluded that statistical analysis of SL and SF showed no significant differences between the two modes of running.

Riley et al. (2008) also found similar results when looking at kinematic and kinetic parameters of overground and treadmill running. The results were on 10 males and 10 females with data collected from motion capture systems using whole body markers. The authors found that treadmill running mechanics can be generalized to overground running mechanics and that parameters measured (SL CT, SF) were very similar. Dal Monte et al. (1973) studied the biomechanical aspect of running on a treadmill and compared it to overground using three middle distance athletes who had extensive experiences running on the treadmill. The results of

their study showed differences where less vertical movement of center of mass, decreased period of nonsupport and decreased stride length was found during treadmill running. The authors concluded that the treadmill could be used as a specific simulator for middle distance running even though there were differences.

Although the kinematics of treadmill and overground running has been reported to be similar or slightly different, some studies believe that they are fundamentally different. While a conventional motor-driven treadmill may allow an athlete to attain the same velocity as overground sprinting during the constant velocity phase (McKenna & Riches, 2007), it does not provide free sprinting as compared to overground (Morin & Seve, 2011). Nelson et al. (1971) examined the biomechanics of overground running and treadmill running using cinematography. The results of their study included 16 competitive male running at three speeds (3.35, 4.88, 6.40  $\text{m}\cdot\text{s}^{-1}$ ) on three different slopes (level, uphill, downhill) over both modalities. Results revealed only slight differences between overground and treadmill for SL and SF. The authors found that subjects ran with longer SL and slower SF at the highest velocity and concluded that performances on the treadmill produce significant changes in the biomechanics of running.

The opposite was found for Elliot and Blanksby (1976) and Wank et al. (1998) studies where SL decreased, and SF increased with the period of non-support significantly less when running on treadmill compared to overground. Elliot and Blanksby (1976) used cinematography to biomechanically compare individually selected overground jogging and running velocities with equated treadmill jogging and running velocities. The results included 24 experienced male and female treadmill runners with slow jogging speeds (3.3-4.8  $\text{m}\cdot\text{s}^{-1}$ ) and running speed from (4.82-6.2  $\text{m}\cdot\text{s}^{-1}$ ). The author concluded that both male's and female's SL decreased, SF increased and the period of non-support was also significantly less when running on a treadmill when



compared to overground. Kivi, Maraj and Gervais (2002) study also looked at a kinematic analysis of high-speed treadmill springing over a range of velocities by using six power/speed athletes. Trials were performed at 70%, 80%, 90% and 95% of their individual maximum velocity and view using a video data collected from the sagittal view at 60 Hz. The authors found that SF increased, and ground CT decreased with increasing velocity on the treadmill. Furthermore, when an athlete trains near maximal velocity on a treadmill, an increase is seen in hip extension angular velocity (Kivi, Maraj & Gervais, 2002). The authors concluded that sprinting at 95% of maximal speed causes the mechanical form to deteriorate.

Frishberg (1983) found that treadmill sprinting was not as physiologically demanding as overground sprinting. Furthermore, it would not result in the same physiological adaptations that could be acquired with overground sprinting. Sprinting overground usually requires more muscle activation than treadmill because of the ground reaction forces needed in the accelerating phase and maximal speed phase. Bowtell, Tan and Wilson (2009) found that overground sprinting had an increased rate of fatigue when compared to treadmill sprinting. The reason for this fatigue is believed to be from wind resistance and aerodynamics drag that has shown to not only increase fatigue but to cause a decrease in power as well (Weyand et al., 2000). Naturally, performing several bouts of overground sprint will increase the level of fatigue due to an increase in metabolic demand, which is often less in the treadmill condition (Bowtell et al., 2009). A lesser metabolic demand is found in treadmill sprinting due to the action of running, which requires the treadmill belt to place the foot further in front of the center of gravity and return it underneath the body by the moving belt. Bowtell et al. (2009) found that the mean kinetic energy of the center of mass remained around zero, resulting in the reduced fatigue as no net mechanical work is needed during the acceleration phase on the treadmill. However, this less fatigue and decrease of

metabolic demand has caused athletes to attain greater speeds on the treadmill, and speeds they have never experienced overground (Bowtell et al., 2009). In addition, treadmill sprinting does not show a noticeable decrease in speed as the treadmill will not stop; this causes the athlete to either partake in a maximal or supramaximal sprint which maintains power output levels (Brown, 2002).

## **Treadmill Training**

Assisted sprinting is a training method that can be done using the treadmill and thought to increase maximal velocity through the maintenance of SL while increasing SF (Faccioni, 1994). Treadmill running, and other forms of assisted training methods are thought to mediate SF increases through achieving supramaximal speeds beyond the athletes unassisted capability, resulting in neuromuscular and stretch-shortening cycle adaptations with prolonged training (Cissik, 2005; Faccioni, 1994; Majdell & Alexander, 1991, Mero & Komi, 1985). Running mechanics can change or may be difficult to control when running at supramaximal speeds. Therefore, supramaximal running attained by an athlete being pulled via elastic tubing or other towing methods is recommended to be at speeds no greater than 106-110% of maximum speed (Cissik, 2005; Faccioni, 1994; Majdell & Alexander, 1991, Mero & Komi, 1985). As for supramaximal speed achieved by adjusting the treadmill to a speed greater than the athlete can achieve on their own, there are currently no training guidelines proposed within the literature. However, due to similarities in theoretical adaptations to assisted towing, the recommended guide above could be potentially used with repetitions lasting between 3-6 seconds according to the maintenance of mechanics (Behrens & Simonson, 2011; Cissik, 2005; Faccioni, 1994; Majdell & Alexander, 1991, Myer et al., 2007; Plisk, 2000; Swanson & Caldwell, 2000; Mero & Komi, 1985). Treadmill training can create the optimal learning environment with benefits from

manipulating the grade and speed, also eliminating the reduction in speed when an athlete becomes fatigued as seen overground. While treadmill based training, programs claim to develop speed using this instrument, the rise to popularity has come with no justification through scientific and peer reviewed research.

### **Optimal Ratio of Stride Length and Stride Frequency at Maximal Speed**

Running speed is the product of two sprint parameters: SL and SF. The achievement of maximal running speed depends on a specific length/frequency ratio, where a different ratio would produce a lower speed (Donati, 1995). However, this is not true when focusing on sprint performance as an athlete's physical condition, power, elasticity and technique can change the biomechanical rule of length/frequency ratio. With continuous training over a long period of time, these features may be influenced, improved or impaired leading to variations in the length/frequency ratio (Donati, 1995). It is difficult to give a clear statement about the relationship between training and each parameter of running speed, because the parameters are independent yet related.

Running at maximal speed has a strong involvement of the sprint parameters SL and SF, however, distinguishing the role of each parameter is difficult. Analyzing the relation between SL and SF at maximal speed provides a better understanding of SP. It also provides a distinct goal for sprint speed training: the development of SL or the development of SF (Donati, 1995). This significantly enriches training methodology depending on the athlete's choice of optimal ratio. Although running on a treadmill is mechanically similar to running overground, kinematic differences have been reported (Dillman, 1975, Frishberg, 1983, Nelson et al., 1972, Nigg et al., 1995). However, they did not compare these parameters (SL and SF) between overground and motorized treadmill modalities at maximal speed. Maximal effort speed overground has only

been compared to a computed matching speed on the treadmill as seen in Frishberg's (1983) study. However, Frishberg's (1983) study focused on running technique in both overground and treadmill conditions. Maximal effort on the motorized treadmill will be in a state of supramaximal speed however, peak SL and SF can be distinguished which highlights optimal capacity. Focusing on maximal speed overground and maximal speed of the treadmill allows the analysis of optimal ratio at maximal effort in both modality.

### **Summary of Literature Review**

Whatever the level of running speed was for both running conditions, the comparisons did not reach a consensus on overground and treadmill running mechanics. In some studies five or fewer subjects were used (Dal Monte et al., 1973; Frishberg, 1983), and the applicability of these results is questionable. Speed of running may also be a factor in the variations between overground and treadmill running. When significant differences occurred, they were for speeds greater than 5 m/s (Dal Monte et al., 1973; Elliot & Blanksby, 1976, Nelson et al., 1972), with a few exceptions of isolated measures of lower speeds (Dal Monte et al., 1973; Nelson et al., 1972). The only study that focused on maximal overground sprinting matched the same speed on the treadmill (Frishberg, 1983). Matching the speed on the treadmill provides the same velocity in both condition but free sprinting overground is not translated in the treadmill setting. Therefore, no study has looked at maximal speed in both sprint modalities. Furthermore, the data was collected by video analysis with the use of whole-body markers. Therefore, the current literature is lacking studies that investigate the SL and SF differences between treadmill and overground conditions during the maximal velocity phase. Current technology can be used to investigate the specific changes in running kinematics to fill this gap in the literature.

## **Hypothesis**

Based on the review of the literature, we hypothesize that SL and SF would increase on a motorized treadmill compared to overground conditions. Also, SF would increase significantly to enable faster running speed. In addition to our hypothesis, the exploratory purpose of this study is to explore gender differences, as well as, trained (TRACK) and untrained (CONTROL) subject differences in various kinematic variables during overground and treadmill sprinting.

## **CHAPTER 3: METHODS**

### **Approach to the Problem**

Collegiate level sprinters and recreationally active men and women that regularly engage in running were recruited for this study. Total subject pool included 40 subjects: 20 were recruited from the student population of the University of Texas at El Paso (CONTROL group); and 20 collegiate sprinters were recruited from the university's track and field team (TRACK group). The study used a one-day testing session design to complete the anthropometric measures, as well as the overground and motorized treadmill sprint testing. Both groups continued their normal lifestyle and exercise routine prior to the testing session. All subjects performed testing in the order of sprinting overground and then sprinting on the motorized treadmill with an hour rest in between the testing conditions. Maximal sprints were done overground on a NCAA certified track and treadmill testing was performed on a high-speed motorized treadmill indoor the UTEP Exercise Physiology Laboratory. Data collected from both groups were compared on the basis of maximal sprint speed, SL, SF, CT, FT and anthropometric variables.

### **Subject Selection**

Forty college age males and females were recruited for this study. Twenty recreationally trained, physically active college aged males and females, along with 20 trained male and female sprinters from the track and field team of the University of Texas at El Paso were used in this study. Accordingly, subjects were assigned to two groups: a) college aged recreationally active males and females (CONTROL), and b) collegiate level male and female sprinters (TRACK). College recreationally trained sprinters used were students who exercised on a regular basis.

Collegiate level sprinters were student-athletes who competed at the Division 1 level at the NCAA level with a range of 1-4 years of competition experience. Both groups attended both overground and treadmill testing. All recruited subjects were informed of the risks and then asked to sign an informed consent form and complete a background questionnaire on their exercise history. Subjects unable to sprint 60 m (65 yd), or those with any injury preventing them from activity were excluded from the study.

Inclusion criteria for the subjects included: 1) no underlining medical health conditions (spine deformities, impaired gait, restricted range of motion, heart conditions, musculoskeletal deformations, etc.); 2) must not have attained a serious injury within the past year (injured ankle, leg, foot, back, head injury, or chronic condition); 3) must be recreationally active, at least 2-3 times a week with no physical disability and 4) must be between the ages of 17 and 30 years of age. The recreationally trained subjects engaged in activities that are representative of a running motion. Activities such as recreational sports (soccer, basketball, baseball, softball, handball, and racket-ball) or training (running, plyometrics, cone drills, or high intensity interval training) that involved similar movement patterns to sprinting were acceptable weekly activities for study participation. The collegiate level sprinters engaged in events that are representative of a running motion. Events such as 100-m, 200-m, 400 m, 4 x 100 m, 100 m hurdles, 110 hurdles and long jump that involved a forward running motion were acceptable for study participation.

Exclusion criteria for the subjects in each group included: 1) Chronic medical condition or has been recently diagnosed with medical condition (spine deformities, impaired gait, restricted range of motion, heart conditions, musculoskeletal deformations, etc.); 2) Injury within the past two years (broken bones, surgery, injured ankle, leg, foot, back, head injury, or chronic condition, etc.); 3) not recreationally active for at least 2-3 days a week (does not engage in

recreational sports such as basketball, soccer, softball, or regular training to include resistance training, swimming, running, cycling, etc.), and 4) is not within the 17-30 year age range.

Athletes in track and field events that do not require forward linear sprint were not used for study participation.

### **Preparation for Recruitment**

The researcher obtained an IRB approval from the University of Texas at El Paso (IRB #: 808481-7) before subject recruitment and data collection. After attainment of IRB approval, the researcher met with the Kinesiology Department professors to help aid in informing and making students aware of the proposed study. Upon agreement with professors, the researcher spoke to the classroom of students to recruit participants. An informed consent form outlining the purpose and details of the proposed study was provided to students interested in participating. The researcher also met with the coaches of the track and field team prior to recruitment. A copy of the IRB was presented to the head coach along with an informed consent form outlining the purpose and details of the proposed study. Upon agreement with the coaches, the researcher was able to identify sprinters who would be qualified for the study. Qualified sprinters were identified as individuals whose events include: 100 m, 200 m, 400 m, 4 x 100 m, 100 m hurdles, 110 hurdles and long jump. The researcher was able to meet with qualified sprinters and an informed consent form outlining the purpose and details of the proposed study was provided to athletes interested in participating.

### **Procedures**

#### **History of Physical Activity**

Previous physical activity of the subjects was assessed in the form of a questionnaire. Subjects with no previous history of being physically active were considered to be a part of the



exclusion criterion and were not accepted in the study. The questionnaire was in a checklist format that asked subjects to provide a check mark for the number of times a week they engage in physical activity (Appendix 4). Subjects received a questionnaire to fill out their activity level (preferably 2-3 days a week performing multiple activities) (Appendix 5). Subjects were considered active if they performed some type of training (weight training, swimming, running, cycling, etc.) or are active in recreational activities (basketball, volleyball, softball, etc.).

### **Anthropometric Measurements**

Anthropometric measurements included height, weight, thigh circumference and leg length of each participant. The collection of the subject's height, weight, and thigh circumference measurement allowed further analysis of SL and SF based on the characteristics of the individual. Anthropometric variables were recorded on each subject's data sheet (Appendix 6).

#### *Height and Weight*

Body weight of each participant was assessed using a medical weight scale (Tanita WB-110A class III, Tanita Corporation, Tokyo, Japan) and recorded in kilograms (kg). Height was assessed and recorded in centimeters (cm) using a stadiometer (Seca 213, Seca GmbH, Germany).

#### *Thigh Circumference*

Thigh circumference was assessed with a metric tape measure (Gulick, M-22 CII, Michigan, USA) and recorded in centimeters (cm). The subject was asked to stand with the right leg just in front of the left leg and the weight shifted back to the left leg. This instruction was demonstrated by the examiner. The lower portion of the gluteal furrow was used as point of

measurement for the upper portion of the thigh. The tape measure was placed below this landmark and wrapped securely around the subject's thigh. The tape rested firmly on the skin without compression on the skin. The examiner checked to make sure the tape was positioned correctly. The thigh circumference was measured to the nearest 0.1 cm.

### *Leg Length*

Leg length was assessed with a metric tape measure (Gulick, M-22 CII, Michigan, USA) and recorded in centimeters (cm). The subject was asked to stand erect with feet flat on the floor. Length as measured from the lateral malleolus to the greater trochanter. The examiner palpated the hip by firmly pushing the tissue to locate the top of the greater trochanter. The tape measure was placed on both landmarks ensuring the tape measure ran along the body smoothly. The examiner checked to make sure the tape was positioned correctly. The leg length was measured to the nearest 0.1 cm.

### **Tool: OptoJump Next Measuring System**

The OptoJump Next (Microgate, S.r.l., Bolzano, Italy) is an optical measuring system consisting of a transmitting and receiving bar used to assess one's performance. This device acquires the fundamental parameters that characterize the level of an individual performance and physical condition. The sensors on the transmitting bar communicate continuously with those on the receiving bar detecting any interruptions in communication. Also, it calculates the duration of disruptions, which makes measuring FT, CT, SL and SF possible during performances from running or walking. The accuracy of this device is of 1/1000 of a second. The OptoJump Next can be used on the flat surface as well on a treadmill. Blažević, Novak and Petrić (2014) used the

OptoJump Next system to examine the relations between kinematic parameters of sprinter's running and specific motor abilities.

## **Data Collection**

### **Overground Test Set-up**

Sprint testing was conducted over a 60 m distance with the first 50 m used for acceleration and the last 10 m for maximal sprinting. A Motion Start Timing System (TC-System, Brower Timing Systems, Draper, UT, USA) with two timing gates was used to capture maximal sprint speed for the 10 m. The first timing gate was placed at 50-m and the second timing gate was placed at 60-m which marked the finish line (Appendix 8). Ten 1 m panels of the OptoJump Next optical measuring system were used in this study (5 transmitting and 5 receiving panels). The five 1 m transmitting panels of the OptoJump Next system were joined creating a total of 5 m combined; same was done with the receiving bars. The panels were placed within the 10 m testing zone, 2.5 m after the first timing gate and 2.5 m before the second timing gate. The panels were placed on the outside of the track lane marked by the white line in a parallel position. This created a width of 1.22 m (IAAF standard). The OptoJump panels were elevated on the overground surface to match a 1.5 cm difference in height found in the motorized treadmill condition. The distances used for the timing gates were verified prior to each testing session using a 100-m measuring tape.

### **Overground Maximal Sprint Test**

The overground testing condition was conducted at the UTEP track and field stadium where a 400m outdoor track was present with a 100 m runway. Testing was carried out only on non-rainy days that had low wind speed averaging less than 3m/s. Prior to testing subjects were

asked to wear athletic clothes with tennis shoes and reserved 3 hours for testing. The total runway of 60-m was chosen to ensure subjects would reach their maximal speed prior to entering the first timing gate. All subjects were instructed to use the 50-m prior to the testing zone for acceleration. The 50-m acceleration zone allowed subjects to have enough distance to accelerate into maximal speed while recreationally trained subjects could accelerate at their own pace to reach maximal speed during the testing zone. When recreationally trained subjects accelerated at their own pace, the distance was not too long for subjects to experience a deceleration prior to the testing zone.

Subjects performed a general warm up of running two 400-m laps, followed by static and dynamic stretching for 12 minutes (Appendix 7). Five minutes was given to subjects for additional stretches if they desired. Subjects were then instructed to perform two practice sprints at approximately 50% and 80% maximal effort. The second practice sprint was performed while using the timing system to become familiar with the sounds from the systems and the testing procedure. Subjects were given five minutes rest before each practice run to allow recovery. All tests were supervised by the same researcher. Each subject lined up by the start line and only approached the start line when their name was called. Subjects were then instructed to complete the 60-m sprint and to ensure that they were at maximal effort prior to entering the first timing gate. The testing trial began with the subject in a standing position with the lead foot behind the line. Subjects were instructed to start at their own will. Throughout each test, subjects were verbally encouraged to attain top speed when they came within 10-m of the first timing gate and maintain speed throughout the 10-m testing zone. Once subjects crossed the finish line at the 60-m mark, the times collected from the first timing gate and the second timing gate were recorded from the handheld display of the timing system. Recorded speeds were shared with the subjects

as a motivation for better performance. Subjects completed two maximal sprints through the timing system.

### **Motorized Treadmill Sprint Set-up**

A motorized Track Master Treadmill (Full Vision, Inc., Newton, KS, USA) was utilized for treadmill sprint testing. This treadmill has a maximum speed of 13.5 m/s which far exceeds any subject's anticipated maximum sprint speed. Four 1 m panels (two transmitting and two receiving panels) of the OptoJump Next optical measuring system were used for treadmill testing. Two panels were placed on each side of the treadmill's straddle area. The straddle area was 1.5 cm above the belt of the motorized treadmill. For each treadmill sprint, subjects wore a safety harness which was attached to a supporting cable that suspended from a steel frame. The safety harness prevented subjects from falling or being forcefully thrown off the treadmill because of the high belt speed. The safety harness also prevented subjects from being fearful when required to execute maximal effort. A step was created at each side of the treadmill to create a new straddle area for the subjects. Subjects were asked to stand on these steps that were on the sides of the treadmill to be in a straddled position. While in this position, subjects were instructed to hold on the rails and keep away from the moving belt. The accuracy of the belt speed was assessed by a Model DT-107A Handheld Contact LED Digital Tachometer (NIDEC-SHIMPO, American Corp, Itasca, IL, USA) which was placed directly onto the moving belt.

### **Motorized Treadmill Maximal Sprint Test**

The treadmill testing was conducted in the UTEP Exercise Physiology Laboratory. Subjects performed several stretches prior to the treadmill testing (Appendix 7). Subjects performed two practice sprints on the high-speed motorized treadmill, followed by 2-5 minutes

rest in between. The first practice run started from an estimated 50% and increased to 80% maximal effort of the subject. The second practice run began at an estimated 70% until the subject could not keep up with the speed of the treadmill.. The treadmill belt was accelerated to a speed that was 0.45 m/s below their maximal practice speed. When the target belt speed was attained and verified, subjects were instructed to gradually transfer their weight on to the moving belt while they continued to hold the handrails. Once they were in an upright position and adjusted to the running speed, they released their arms from the handrails. As soon as the subject removed their hands from the rail and achieved normal running motion with arms swinging at the side, the speed of the belt was increased to 0.22 m/s above their maximal practice run. Acceleration of the belt from 0 mph (0 m/s) to 22 mph (9.83 m/s) was examined in an unloaded (without subject) and loaded (with subject) state (Figure 4). No significant changes were observed over time in both conditions.

Subjects were verbally encouraged to run until failure while the belt of the treadmill accelerated. Once the belt reached the maximal set speed, subjects were asked to stay on the treadmill for 3-4 seconds while running at maximum intensity. Each session was supervised, and subjects performed two maximum speed sprints for 3-4 seconds with a 5-minutes rest time in between attempts. More time was given but not more than 6-minutes. This work-to-rest ratio has been shown to prevent fatigue when investigating maximum running speed measurements on treadmills (Bowtell et al., 2009; Brughelli, Cronin & Chaouachi, 2011). The speed that was attained by the subject was recorded as their maximal effort. Recorded speeds were shared with the subjects as a motivation for better performance.

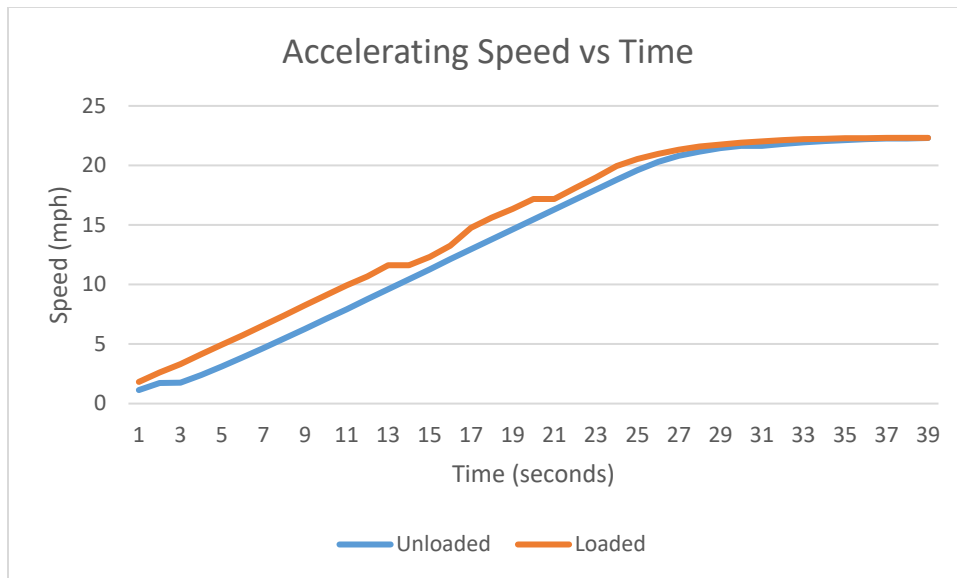


Figure 4. Acceleration of the motorized treadmill to a speed of 22 mph over time. During the loaded condition (with subject) subject maximal speed was recorded up to 18.09 mph while the motorized treadmill continued to accelerate afterwards.

### Statistical and Data Analysis

Data was exported from the OptoJump Next system to Excel 2010 where the faster trial of the two trials for each subject was chosen. The maximum recorded data point for each parameter (SL, SF, CT, FT) was used for each subject and a new datasheet was formed from this data. This data sheet was then exported to SPSS Software for Windows (version 24.0; SPSS, Inc., Chicago, IL, USA) for statistical analysis. Similar data extraction method was used in a study done by Debaere, Jonkers and Delecluse (2013). Data are presented as means and standard deviation (SD). A normality test was conducted to determine the use of parametric or non-parametric statistical tests; data was considered to be normally distributed if skewness levels were  $<-1$  or  $>1$  and/or if kurtosis levels were  $<-3$  or  $>3$ . To determine differences across conditions, a Pearson correlation test was performed when appropriate. To determine differences

in sex and differences in groups across sprint parameters during overground or motorized treadmill, an independent-t test was conducted. To determine differences across sprint parameters in both overground and motorized treadmill conditions a Paired Sample T-Test was conducted. Finally, multiple linear regressions were conducted to determine predictors of sprint speed during overground and motorized treadmill for all subjects, and then as groups (TRACK and CONTROL). Effect sizes were reported, and interpreted as: 0.1 to 0.3 as small, 0.3 to 0.5 as medium, and, 0.5 to 1.0 as large. Significance was set at an alpha level of 0.05 for all analyses.

### **Power Analysis**

Power analyzes for all tests were performed on G\*Power 3.1.9.2. Analysis for Pearson's test to have a large power of 0.95 (Figure 5). In addition, the analysis for independent sample t-test showed a large power of 0.89 (Figure 6). Finally, the linear regression also showed to have a large power of 0.89 (Figure 7).



## CHAPTER 4: RESULTS

Descriptive statistics are shown in Table 1 for all subjects and subgroups. Data analysis of all subjects showed age:  $21.3 \pm 1.92$  years, weight:  $70.24 \pm 10.61$  kg, height:  $169.01 \pm 8.60$  cm, leg length  $90.44 \pm 5.14$  cm and thigh circumference:  $56.64 \pm 4.64$  cm. Comparisons between CONTROL and TRACK groups revealed no significant difference for height ( $p = 0.11$ ) and weight ( $p = 0.14$ ) while a significance difference was seen for age ( $p = 0.02$ ), leg length ( $p = 0.004$ ) and thigh circumference ( $p = 0.004$ ) (Table 1).

### **All Subjects (CONTROL and TRACK combined, n = 40).**

The correlation analyses of overground and motorized treadmill sprint performances for all subjects ( $n = 40$ ) are presented in Table 2. We observed that among 40 subjects, there is a strong positive correlation for speed, CT, and SF performed during overground modality and speed, CT and SF performed on the motorized treadmill (Pearson,  $R = 0.94$ ;  $R = 0.68$ ; and  $R = 0.65$ , respectively). Also, no correlation was seen for SL or FT in overground and motorized treadmill modalities (Pearson,  $R = 0.22$ ;  $R = -0.06$ , respectively). Further analysis was done to compare sprint performance variables performed overground and on a motorized treadmill for all subjects (Table 12). Among the 40 subjects, we observed a significant difference ( $p = 0.000$ ) between OG-speed & TM speed (mean diff =  $-0.214$ , SD diff =  $0.384$ ), OG-CT & TM-CT (mean diff =  $-0.010$ , SD diff =  $0.020$ ), and OG-SF & TM-SF (mean diff =  $-0.471$ , SD diff =  $0.311$ ). No significance difference was observed between OG-FT & TM-FT (mean diff =  $-0.101$ , SD diff =  $0.248$ ) and OG-SL & TM-SL (mean diff =  $-65.325$ , SD diff =  $95.750$ ). Nevertheless, all variables were found to be lower OG when compared to TM, but only speed, CT and SF were of a statistically significant difference.

A linear regression analysis was done to observe the relationship between sprint speed and the variables collected from the sprint performance overground (Table 15). Among 40 subjects, CT, FT, and SF were found to be predictors of sprint speed in the overground modality ( $p = 0.000$ ) while SL was not a predictor of sprint speed in this modality. CT was the strongest predictor ( $b = -1.369$ ) with an  $R^2$  of 0.79, which means that this model explains 79% of the variance. The linear regression for motorized treadmill conditions in 40 subjects showed that CT, FT, SL and SF are all predictors of sprint speed ( $p < 0.05$ ). CT was the strongest predictor of sprint speed ( $b = -0.454$ ) with a  $R^2$  of 0.63, meaning that this model explains 63% of the variance (Table 16). The plots expressing each variables relationship to sprint speed is presented in Figures 8-15.

### **CONTROL Group.**

The correlation analyses of overground and motorized treadmill sprint performances for CONTROL subjects ( $n = 20$ ) are presented in Table 3. We observed that for the CONTROL subjects, there is a correlation for speed, CT, and SF performed during overground modality and speed, CT and SF performed on the motorized treadmill (Pearson,  $R = 0.91$ ;  $R = 0.46$ ; and  $R = 0.56$ , respectively). Also, no correlation was seen for SL or FT in overground and motorized treadmill modalities (Pearson,  $R = -0.03$ ;  $R = -0.11$ , respectively). A linear regression analysis was done to observe the relationship between sprint speed and the variables collected from the sprint performance overground (Table 17). Among 20 CONTROL subjects, CT was the only variable found to be a predictor of sprint speed in the overground modality ( $p = 0.002$ ). FT was trending toward significance ( $p = 0.053$ ), however, SL and SF were not a predictor of sprint speed in this modality. CT had a  $b$  of  $-1.369$  with an  $R^2$  of 0.74, which means that this model explains 74% of the variance. The linear regression for motorized treadmill conditions in 20

CONTROL subjects showed that CT, FT, SL and SF were not predictors of sprint speed ( $p > 0.05$ ) (Table 18).

### **TRACK group**

The correlation analyses of overground and motorized treadmill sprint performances for TRACK subjects ( $n = 20$ ) are presented in Table 4. We observed that among 20 TRACK subjects, there is a correlation for speed, CT, and SF performed during overground modality and speed, CT and SF performed on the motorized treadmill (Pearson,  $R = 0.93$ ;  $R = 0.50$ ; and  $R = 0.62$ , respectively). Also, no correlation was seen for SL or FT in overground and motorized treadmill modalities (Pearson,  $R = 0.33$ ;  $R = -0.10$ , respectively). A linear regression analysis was done to observe the relationship between sprint speed and the variables collected from the sprint performance overground (Table 19). Among 20 TRACK subjects, CT, FT, SL and SF were all found to be predictors of sprint speed in the overground modality ( $p < 0.05$ ). CT was the strongest predictor ( $b = -2.056$ ) with an  $R^2$  of 0.69, which means that this model explains 69% of the variance. The linear regression for motorized treadmill conditions in 20 TRACK subjects showed that FT and SL are predictors of sprint speed ( $p < 0.05$ ). SL was the strongest predictor of sprint speed ( $b = 0.920$ ) with a  $R^2$  of 0.78, meaning that this model explains 63% of the variance (Table 20). CT and SF were not predictors of sprint speed in the motorized treadmill modality for the TRACK group.

### **CONTROL group vs TRACK group.**

An Independent Samples t-test was done to compare the CONTROL and TRACK groups in order to determine whether the means of sprint performances variables during overground and motorized treadmill modalities are significantly different (Table 11). The variance of OG-speed

and TM-speed of CONTROL group were found to be significantly different than that of TRACK group ( $p < 0.05$ ). The mean overground speed for CONTROL group was 1.481 m/s slower than the mean overground speed for TRACK group. The same was found for motorized treadmill speed, where the mean speed for the CONTROL group was slower (1.575 m/s) than the speed of the TRACK group. The variance of OG-CT and TM-CT of CONTROL group were also found to be significantly different than that of TRACK group ( $p < 0.05$ ). The mean OG-CT for CONTROL group was 0.032 s longer than the mean OG-CT for TRACK group. The same was found for motorized treadmill speed, where the mean TM-CT for the CONTROL group was longer ( 0.030 s) than the TM-CT of the TRACK group. Lastly, the variance of OG-SF and TM-SF of CONTROL group were found to be significantly different than that of TRACK group ( $p < 0.05$ ). The mean OG-SF for CONTROL group was 0.284 step/s slower than the mean OG-SF for TRACK group. The same was found for motorized treadmill modality where SF mean for the CONTROL group was slower (0.359 step/s) than the SF of the TRACK group. There were no significant difference in the mean OG-FT, TM-FT, OG-SL and TM-SL between CONTROL group and TRACK group ( $p > 0.05$ ).

### **Sex Grouping.**

*All Males.* The correlation analyses of overground and motorized treadmill sprint performances for all male subjects ( $n = 20$ ) are presented in Table 5. We observed that among 20 male subjects, there is a correlation between the speed performed overground and the speed performed on the treadmill (Pearson  $R = 0.92$ ). In addition, CT performed overground was also found to be correlated to CT on the motorized treadmill ( Pearson  $R = 0.67$ ). No correlation was seen between the variables FT, SL or SF overground and FT (Pearson,  $R = 0.00$ ), SL (Pearson  $R = -0.42$ ) or SF ( Pearson  $R = 0.37$ ) in motorized treadmill modality.

*CONTROL males and TRACK males.* The correlation analyses of overground and motorized treadmill sprint performances for CONTROL male subjects ( $n = 10$ ) are presented in Table 6. We observed that among the 10 CONTROL male subjects, there is no correlation between the sprint performance parameter (Speed, CT, FT, SL, SF) overground and the sprint performance parameter on the motorized treadmill ( $p > 0.05$ ). The correlation analyses of overground and motorized treadmill sprint performances for TRACK male subjects ( $n = 10$ ) are presented in Table 7. We observed that among the 10 TRACK male subjects, the only parameter found to have a correlation between overground and motorized treadmill condition was speed (Pearson  $R = 0.16$ ). The other sprint parameters (CT, FT, SL or SF) were found to have no correlation between overground and motorized treadmill modality ( $p > 0.05$ ).

*All Females.* The correlation analyses of overground and motorized treadmill sprint performances for all female subjects ( $n = 20$ ) are presented in Table 8. We observed that among 20 female subjects, there is a correlation between the speed performed overground and the speed performed on the treadmill (Pearson  $R = 0.51$ ). In addition, CT performed overground was also found to be correlated to CT on the motorized treadmill (Pearson  $R = 0.74$ ) and SF performed overground was also found to be correlated to SF on the motorized treadmill (Pearson  $R = 0.78$ ). No correlation was seen between FT overground and FT on the motorized treadmill (Pearson,  $R = 0.27$ ) or SL overground and SL on the motorized treadmill (Pearson  $R = 0.12$ ).

*CONTROL females and TRACK females.* The correlation analyses of overground and motorized treadmill sprint performances for CONTROL female subjects ( $n = 10$ ) are presented in Table 9. We observed that among the 10 CONTROL female subjects, there is a correlation between the speed performed overground and the speed performed on the treadmill (Pearson  $R = 0.91$ ). In addition, CT performed overground was also found to be correlated to CT on the

motorized treadmill ( Pearson  $R = 0.66$ ). No correlation was observed between FT, SL or SF overground and FT, SL or SF on the motorized treadmill (  $p > 0.05$ ). The correlation analyses of overground and motorized treadmill sprint performances for TRACK female subjects ( $n = 10$ ) are presented in Table 10. We observed that among the 10 TRACK female subjects, there was a correlation between speed overground and speed on the treadmill (Pearson  $R = 0.91$ ); also, a correlation was observed between SF overground and SF on the motorized treadmill ( Pearson  $R = 0.70$ ). The other sprint parameters CT, FT and SL were found to have no correlation between overground and motorized treadmill modality ( $p > 0.05$ ).

### **Sex Differences Overground and Motorized Treadmill.**

An Independent Samples t-test was done to compare the mean of the sprint performance variables observed overground for males and female subjects (Table 13). A significance difference was seen for mean speed, CT and SF between males and females. Males mean speed was 1.271 m/s faster than female's mean speeds. Mean CT for males was 0.015 s shorter than the mean CT for females and mean SF for males was 0.238 s faster in males than for females. Mean FT and mean SL did not have a significant difference between sex. An Independent Samples t-test was also done to compare the mean of the sprint performance variables observed on the motorized treadmill for males and female subjects (Table 14). Only mean speed and mean CT were seen to have a significant difference between males and females. Mean FT, SL and SF showed no difference between males and females in the motorized treadmill condition.

## **CHAPTER 5: DISCUSSION**

The purpose of this research study was to: examine the differences in key variables SL and SF between two modalities (overground and motorized treadmill) across different groups at maximal speed. We hypothesized that SL and SF would increase on a motorized treadmill compared to overground modality. However, only SF would increase significantly to enable faster running speed on the motorized treadmill. To our knowledge, the present study was the first to investigate/compare sprint performance parameters at maximal sprint speed overground and maximal sprint speed on a motorized treadmill. Therefore, we hoped that the methodology of the study would allow us to explore SL and SF along with additional kinematic variables such as CT and FT, differences between trained (TRACK) and recreationally trained (CONTROL) groups, as well as males and females during overground and motorized treadmill modalities. The main result of this study is that maximal speed sprint performances variables were different between overground and motorized treadmill modality. These differences were characterized from the greater sprint speed performances on the motorized treadmill compared to overground modality.

### **Overground Modality**

It is imperative to first determine the degree of success with which maximal effort was recorded during overground conditions and whether there is a relation to previous research. The main finding from the linear regression analysis of performance overground showed that CT, FT and SF were predictors of sprint speed in all our subjects while SL was unrelated. This finding indicates that at maximal speed and thereafter, the speed is increased by an increasing SF. CT and FT are subsets of SF and so having CT being the strongest influencer followed by FT is not

astonishing. This does not mean that SF is more important than SL in regards to sprint speed. Instead, we can infer that from these results, for all subjects tested, a greater SF had a prominent and positive effect on sprint speed. Several studies have indicated that both SL and SF are increased with running velocity, however, SL is often used to get to 90% of maximal speed while SF is used to get to maximal effort (Luhtanen & Komi, 1978; Mero and Komi, 1986; Weyand et al., 2000). Therefore, other studies were able to identify SF to be of interest as it stands out when looking at maximal velocity.

The relationship at maximal effort is classified as the optimal ratio used by the athlete to achieve one's best sprinting times. Therefore, one can assume that recreationally trained individuals may have less experience in using optimal ratio of SL and SF to achieve speed. The most noticeable difference about these groups is the greater speeds attained overground by TRACK group than the CONTROL group. This was expected as the athletic population training is based on speed development. The results of the linear analysis for the TRACK group showed that all variables CT, FT, SL and SF were significant in predicting sprint speed in the overground modality. SF was a stronger influencer over SL for sprint speed. This trend agrees with earlier research which showed that as sprint speed increases from near-maximal to maximal, SF increases whereas SL remains the same or slightly decreases (Hay, 2002, Luhtanen & Komi, 1977). Both SL and SF are working together to achieve optimal ratio, however, SF is often used to increase speed. Hoffman (1971) also noted that an athlete in their season tends to achieve best performances with higher SF.

The same results could not be garnered from the CONTROL group's data, where neither FT, SL or SF was an influencer of sprint speed overground (Table 15). Only CT was an influencer of sprint speed in the overground condition for the CONTROL group. This difference



could be due to a lack of power as the regression was limited to the group. Athletes in the TRACK group could have had the difference observed because athletes train with the aim to optimize their SL and SF ratio while the recreationally trained individuals in the CONTROL group never focuses on technique but rather staying fit and being healthy. It is also safe to assume that there may be a wide range of SL and SF combination used by the CONTROL group to attain speed. Other studies found similar results and stated that SF was found to be largely different between trained and untrained individuals (Mero, Komi & Gregor, 1992; Plisk, 2000). If this large difference is seen for SF, the same could be said for SL among trained and untrained, due to lack of muscle power that aids in the rebound of each stride (Majumdar & Robergs, 2011). Therefore, lack of speed development training could be a possible explanations as to why untrained individuals are not SL or SF reliant. When we separate based on sex, we were able to see the difference between males and females in the mean speed, CT and SF. The males in our study had greater average speeds which could have been from the difference observed in CT and SF. It was expected for males to have a greater speed over women, as the body type and hormones differ between the two.

### **Motorized Treadmill Modality.**

In the motorized treadmill modality, linear regression analyses showed that all variables (CT, FT, SL and SF) were influencers of sprint speed for all subjects (Table 16). When separated into TRACK and CONTROL the results differed where none the variables were found to be influencers of sprint speed for the CONTROL group, while FT and SL were the only influencers of sprint speed for TRACK. One could have assumed that both groups would have had similar responses in the motorized treadmill condition because of the regulated the speed caused by the belt. Frishberg (1983) found that subjects had individual adaptation to treadmill

running and stated this could be due different running style. Furthermore, he found that runners with faster SF overground usually decrease their SF for treadmill running, while those with lower SF were able to increase their SF. However, this result was found when sprint speed on the treadmill matched the maximal sprint speed produced overground. What our result show is that running at maximal velocity on a motorized treadmill is substantially different from running at maximal velocity overground with regards to the variables that are found to be predictors of sprint speed. Our hypothesis to explain this difference in performance is that the characteristics of the treadmill, friction between the belt and supporting frame during the contact of the feet and overall inertia of the belt system limiting speed production are not fully overcome by the effort to produce maximal speed.

### **Overground and Motorized Treadmill Modality**

In the overground condition CT, FT, and SF were found to be influencers of sprint speed while in the motorized treadmill condition the predictors of speed are now seen in all variables. With all subjects the power of the analysis is greater than when the subjects are separated into groups (TRACK and CONTROL). Future research is required for these groups using larger population sample sizes. While TRACK group had all variables being a predictor of sprint speed in overground conditions, only FT and SL were predictors of sprint speed in the motorized treadmill condition ( Table 20). SL was considered the strongest predictor in the motorized treadmill conditions which means that athletes were relying on the length of their stride to achieve their speed, regardless of the significant increase noted for SF. The reason for this dependence on SL could be due to the fact that when running on a treadmill, the subject is never really pushing off from the ground but instead, the moving belt is what gives the subject a running motion. Running at maximal effort might be less of free running and more of a task to

keep up with the belt speed for as long as their lower extremity allows. This may require a pattern of reaching with the legs in front of the body and picking up of the leg for stride initiation at a faster rate. So instead of creating a maximal speed, subjects are trying to keep up with the increasing speed being set by the motorized treadmill. In this study, failure to keep up resulted in the subject falling and the harness catching them. This failure was used to identify maximal speed. In addition, the mechanical difference often created by running in a motorized treadmill modality might further explain this change in the variables .

Among all the subjects tested, we consistently observed that the speed (m/s) exhibited on the motorized treadmill was significantly different from the speed (m/s) recorded in overground testing modality (Table 12). The maximal sprint speed performed on the motorized treadmill were significantly greater than the maximal sprint speed performed overground. Having subjects run on a motorized treadmill at maximal speed did create an environment for supramaximal running. This type of running was not based on a given velocity but rather a reflection of their maximal sprinting effort and capabilities on the motorized treadmill. According to several studies, running at supramaximal speed on a motorized treadmill enables greater speeds to be achieved than that of overground sprinting (Faccioni, 1994; Myer et al., 2007; Swanson & Cadwell, 2000). The significant difference observed in speed could be due to the significant difference observed in CT and SF between both modalities. Furthermore, correlation analyses revealed that among our subjects and groups of 20 subjects, there was a large correlation observed for speed, CT and SF in both modalities (Table 2). However, when subsets were made from those groups only males of the CONTROL group (n=10) failed to show a correlation between the speed of overground and speed of motorized treadmill modality. This lack of significance could have been due to the loss of power due to the small group size. Nevertheless,

when the group has a size of 40 subjects the observed relationship between speed overground and on the motorized treadmill agrees with previous findings about treadmills yielding greater performances which makes it a tool for supramaximal sprinting. Earlier research support this finding where SF increased at higher speeds (Elliot & Blanksby, 1987; Kivi, Maraj & Gervias, 2002; Mero, Komi & Gregor, 1992) and is said to be due to a decrease in the non-support phase (Elliot & Blanksby, 1987). As for SL, Mero et al. (1992) found that at higher speeds there is only a small incremental increase in SL while a greater incremental increase is seen in SF. Our results indicated that in a group of all subjects and groups of CONTROL and TRACK, greater speeds on the treadmill were primarily done through increasing the SF variable to a significant difference and only increasing SL by a non-significant difference. Treadmill sprint performance is not equal to that observed in overground conditions, but correlates significantly with it ( Morin & Seve, 2011).

All our subjects were recruited based on having some experience with treadmill running and could accommodate to treadmill running for several minutes prior to testing. While the TRACK group appeared to be less experienced than the CONTROL group at the onset of each trial, they adapted to the condition once they were comfortable. The only noticeable difference between the two groups is the difference in the speeds as the TRACK group had a greater speed in both testing conditions. If both speeds are given at maximal effort this should eliminate the differences seen for predictors in the motorized condition but this was not the case. This results further agrees with Frishberg (1983) conclusion that subjects had individual adaptation to treadmill running. Therefore, even at maximal effort, each person will still have a different mechanical adaptation regardless of the structured and controlled environment created by the motorized treadmill.

Visual fields during treadmill running leads to a conflict between the visual sense of speed, the sensation of the legs and feet (Dingwell, Cusumano, Cavanaugh, & Sternard, 2001; Srinivasan, 2009). Frenkel-Toledo et al. (2005) found that a treadmill may act as a simple external cue to direct attention to the task of completing sprint locomotion; which would be an additional cognitive task to the locomotion task (total of two task to focus on) leading to the alterations seen in gait characteristics (Beauchet, Dubost, Hermann, & Kressing, 2005). Lindsay et al. (2014) found that stride timing during treadmill running had more regular dynamics than overground running. Studies have shown that many constraints can be found for treadmill running due to tightly regulated speed, limited physical dimensions in terms of degrees of freedom (Terrier & Deriaz, 2011) and less freedom for gait regulation (Malatesta, Simar, Dauvilliers, Candau, Borrani, Prefaut, et al., 2003). Therefore, overground running is considered to use more of a random dynamic form while motorized treadmill running does not. The treadmill is not an everyday locomotion tool and always demands voluntary control, therefore, there may be underlying things affecting the subject's performance that we could not control.

The mechanism by which training interventions might increase running speeds most effectively has not been fully evaluated in the context of gait mechanic when using a motorized treadmill. Our result and quantitative parameters of maximal running speed in both modalities show a natural form of running overground. Sprints were done using free motion to achieve maximal velocity overground while the belt of the treadmill was used a marker for subjects to keep up with. Nevertheless, a correlation was observed for SF when completed overground and in motorized treadmill conditions (Figure 6). A significant increase is observed in SF which allows greater speeds on the motorized treadmill, and SF on the motorized treadmill is shown to be correlated to overground. This correlation could be the reason why treadmills have been used

for training. However, Weyand et al. (2000) theorized that top running speeds are attained by limbs that are capable of applying greater forces to the ground. Sprinting on a motorized treadmill might have limited the muscular force production in bouncing gaits due to the speed set by the belt. Therefore, this limits full training to be performed in an environment such as the motorized treadmill.

## **Limitations**

There are a few relevant limitations to the study. The surface of the synthetic track and the surface of the treadmill belt are not the same, and different running modalities can affect the dynamic stability for mechanical uniformity (Chang, Sejdic, Wright, & Chau, 2010). The motorized treadmill belt is consistently subjected to fluctuating forces as the subject's foot comes in contact with the belt. In this situation the belt may not maintain a perfectly constant speed which may affect CT (Savelberg et al., 1998). The stiffness in the motorized treadmill belt's surface may result in another limitation, because as body weight is acting downwards it generates an equal and opposite upward ground reaction. A shear force that acts anteriorly on the ground causes an equal and opposite posterior reaction. Morin and Seve (2011) found that on average there was a 20% difference in the sprint parameters due to a difference in force production in both modalities. The surface of the treadmill belt is therefore producing less ground reaction forces compared to overground condition which may have affected CT and FT.

Subjects were not trained to use the treadmill but were recruited on the basis that they have some experience using the treadmill prior to testing. With subjects not being assessed on experience, those who were more skilled at treadmill running may be better overcoming the mismatch between physical effort, visual stimuli and the different skill requirement (Lindsey et al., 2014). We noticed that CONTROL group found it easier to transition from a static position to

a running position when the belt was at their near-maximal speed. The TRACK group which are collegiate sprinters usually complete majority of their sprints overground and lack the experience that was shown from the CONTROL group. Furthermore, the TRACK group were recruited in their competition season after their major conference championship. Subjects from this group might have been exhausted due to their prior conference championship performance. However, we still believe their performance was at the peak of their season due to the testing being close to the championships. Overall, subjects performed overground modality first and motorized treadmill modality second. The results gathered from using this specific order of modality maybe different if the order was randomized.

## **Future Research**

This study suggest that future research should examine motorized treadmill training in order to understand how sprint parameters (SL and SF) are affected over time. Treadmill training can create an optimal learning environment; however, more research needs to be done to highlight the benefits of training on a treadmill over several weeks. Currently there are no training guidelines proposed within the literature. There are similarities between the supramaximal speed achieved via assisted towing and high speed treadmill running where the speed attained is greater than an individual can achieve unassisted. Recommendations of speeds no greater than 106% - 110% of maximum running speed, with a given rep lasting no longer than 40 m (Cissik, 2005; Faccioni, 1994; Majdell & Alexander, 1991; Plisk, 2000). Potential guidelines could use similar percentage (106% - 110%) lasting between 3 – 6 seconds per repetitions.

## **Conclusion**

This study aimed to examine the differences in key variables SL and SF between two modalities (overground and motorized treadmill) across different groups at maximal speed. Our hypothesis was supported where both SL and SF increased on the treadmill based of the values recorded overground, with SF being significantly different. Furthermore, the parameters of sprinting were able to be observed during maximal sprinting overground, with CT, FT and SF being a predictor of speed while SL was unrelated. For the motorized treadmill testing all variables became a predictor of sprint speed. The reason behind this difference is unclear but could be due to the running style adapted in the modality. It was clear that the optimal ratio used by groups were affected in the motorized treadmill condition, which warrants future investigation to be done at an intra-athlete and inter-athlete level. Future investigation may wish to assess subjective feedback from participants in order to determine possible underlying mechanism behind gait alterations. Furthermore, research should examine what are the benefits for athletes who are reliant on SL or SF for speed and whether training on a motorized treadmill lead towards SF reliance or un-reliance when maximizing speed abilities.

## **Practical Applications**

Sprinting on a high-speed motorized treadmill typically allow one to a achieve a higher maximal sprint speed than that produced overground using free sprinting. From our results, the motorized treadmill can be used as an assistive tool for sprint training, particularly in the area of improving SF. However, the motorized treadmill should not entirely replace overground sprinting as the sprint kinetics and kinematics between overground and motorized treadmill conditions are different. Our results showed that the predictors found to be influencers of sprint



overground may increase and depending on the population, the same influencer may become non influential. We believe the optimal ratio freely used overground is altered in the motorized treadmill setting. Alterations may lead to a new learning curve ultimately affecting the optimal ratio often produced overground. Therefore, the motorized treadmill can be used as a supplemental training tool to induce supramaximal running, in aid of acquiring neural muscular adaptations.

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## **APPENDICES**

Appendix 1: Tables and Figures

Appendix 2: Informed Consent Form

Appendix 3: Health Status

Appendix 4: Exercise Background Questionnaire

Appendix 5: Exercise Behavioral Questionnaire

Appendix 6: Subject Data Sheet

Appendix 7: Warm Up Protocol

Appendix 8: Overground Testing set up

## Appendix 1

Table 1. Mean  $\pm$  standard deviation of anthropometric measurements of all subjects.

	Mean All SD n= 40	Mean CONTROL SD n = 20	Mean TRACK SD n = 20
Age (yrs.)	21.30 $\pm$ 1.92	22.0 $\pm$ 1.75	20.6 $\pm$ 1.88
Weight (kg)	70.24 $\pm$ 10.61	72.44 $\pm$ 10.44	68.05 $\pm$ 10.58
Height (cm)	169.01 $\pm$ 8.60	166.70 $\pm$ 7.99	171.32 $\pm$ 8.77
Leg Length (cm)	90.44 $\pm$ 5.14	87.90 $\pm$ 4.15	92.98 $\pm$ 4.84
Thigh Circumference (cm)	56.64 $\pm$ 4.64	58.79 $\pm$ 4.84	54.49 $\pm$ 3.33

Table 2. Overground vs motorized treadmill sprint performance for both groups (CONTROL and TRACK) (n = 40).

	Overground		Motorized Treadmill			
	mean $\pm$ SD	95% CI	mean $\pm$ SD	95% CI	p	r
Speed (m/s)	8.20 $\pm$ 1.14	7.83 – 8.56	8.41 $\pm$ 1.20	8.03 – 8.80	0.01*	0.94**
CT (s)	0.14 $\pm$ 0.02	0.13 – 0.14	0.15 $\pm$ 0.02	0.14 – 0.46	0.01*	0.68**
FT (s)	0.11 $\pm$ 0.01	0.10 – 0.11	0.21 $\pm$ 0.24	0.13 – 0.29	0.17	0.22
SL (cm)	369.98 $\pm$ 42.59	355.35 – 382.60	434.30 $\pm$ 78.91	409.06 – 459.54	0.68	-0.06
SF (steps/s)	4.09 $\pm$ 0.34	3.98 – 4.20	4.56 $\pm$ 0.40	4.43 – 4.68	0.01*	0.65**

\*Denotes significant p value < 0.05.

\*\*Denotes a large correlation between overground sprinting and motorized treadmill.

Table 3. Overground vs motorized treadmill sprint performances for CONTROL group (n = 20).

	Overground		Motorized Treadmill		p	r
	mean $\pm$ SD	95% CI	mean $\pm$ SD	95% CI		
Speed (m/s)	7.46 $\pm$ 0.98	7.00 – 7.92	7.63 $\pm$ 0.87	7.22 – 8.03	0.01*	0.91**
CT (s)	0.16 $\pm$ 0.02	0.15 - 0.17	0.17 $\pm$ 0.02	0.16 - 0.18	0.04*	0.46**
FT (s)	0.10 $\pm$ 0.01	0.10 - 0.11	0.27 $\pm$ 0.34	0.11 - 0.43	0.88	-0.03
SL (cm)	361.10 $\pm$ 33.64	345.35 – 376.85	423.70 $\pm$ 99.97	376.91 – 470.49	0.64	-0.11
SF (steps/s)	3.95 $\pm$ 0.29	3.81 – 4.09	4.38 $\pm$ 0.28	4.25 – 4.51	0.01*	0.56**

\*Denotes significant p value < 0.05.

\*\*Denotes a large correlation between overground sprinting and motorized treadmill.

Table 4. Overground vs motorized treadmill sprint performances for TRACK group (n = 20).

	Overground		Motorized Treadmill		p	r
	mean $\pm$ SD	95% CI	mean $\pm$ SD	95% CI		
Speed (m/s)	8.94 $\pm$ 0.74	8.59 – 9.29	9.20 $\pm$ 0.95	8.75 – 9.65	0.01*	0.93**
CT (s)	0.12 $\pm$ 0.01	0.12 - 0.13	0.14 $\pm$ 0.01	0.13 - 0.14	0.02*	0.50**
FT (s)	0.11 $\pm$ 0.01	0.10 - 0.12	0.15 $\pm$ 0.03	0.13 - 0.16	0.15	0.33
SL (cm)	376.85 $\pm$ 49.61	353.63 – 400.07	444.90 $\pm$ 50.51	421.26 – 468.54	0.64	-0.10
SF (steps/s)	4.23 $\pm$ 0.32	4.08 – 4.39	4.74 $\pm$ 0.44	4.54 – 4.95	0.01*	0.62**

\*Denotes significant p value < 0.05.

\*\*Denotes a large correlation between overground sprinting and motorized treadmill.

Table 5. Overground vs motorized treadmill sprint performances for all males (CONTROL and TRACK) (n = 20).

	Overground		Motorized Treadmill			
	mean $\pm$ SD	95% CI	mean $\pm$ SD	95% CI	p	r
Speed (m/s)	8.83 $\pm$ 0.86	8.43 – 9.24	8.98 $\pm$ 1.06	8.48 – 9.48	0.01*	0.92**
CT (s)	0.13 $\pm$ 0.01	0.13 – 0.14	0.15 $\pm$ 0.02	0.14 – 0.16	0.01*	0.67**
FT (s)	0.10 $\pm$ 0.01	0.10 – 0.11	0.19 $\pm$ 0.23	0.08 – 0.30	0.97	0.01
SL (cm)	373.20 $\pm$ 38.77	355.05 – 391.35	441.40 $\pm$ 52.25	416.94 – 465.86	0.06	-0.42
SF (steps/s)	4.21 $\pm$ 0.21	4.11 – 4.31	4.63 $\pm$ 0.33	4.48 – 4.79	0.10	0.37

\*Denotes significant p value < 0.05.

\*\*Denotes a large correlation between overground sprinting and motorized treadmill.

Table 6. Overground vs motorized treadmill sprint performance of males for CONTROL group (n = 10)

	Overground		Motorized Treadmill			
	mean $\pm$ SD	95% CI	mean $\pm$ SD	95% CI	p	r
Speed (m/s)	8.19 $\pm$ 0.61	7.75 – 8.63	8.20 $\pm$ .64	7.74 – 8.66	0.08	0.57
CT (s)	0.14 $\pm$ 0.01	0.13 – 0.15	0.17 $\pm$ 0.01	0.16 – 0.18	0.28	0.37
FT (s)	0.10 $\pm$ 0.01	0.09 – 0.11	0.24 $\pm$ 0.33	0.01 – 0.47	0.48	-0.24
SL (cm)	374.60 $\pm$ 40.60	345.56 – 403.64	426.70 $\pm$ 59.23	384.33 – 469.07	0.08	-0.57
SF (steps/s)	4.11 $\pm$ 0.23	3.94 – 4.27	4.50 $\pm$ 0.25	4.32 – 4.68	0.29	0.36

\*Denotes significant p value < 0.05.

\*\*Denotes a large correlation between overground sprinting and motorized treadmill.



Table 7. Overground vs motorized treadmill sprint performances of males for TRACK group (n = 10).

	Overground		Motorized Treadmill		p	r
	mean $\pm$ SD	95% CI	mean $\pm$ SD	95% CI		
Speed (m/s)	9.48 $\pm$ 0.54	9.09 – 9.86	9.76 $\pm$ 0.79	9.20 – 10.33	0.01*	0.16**
CT (s)	0.12 $\pm$ 0.00	0.12 – 0.13	0.13 $\pm$ 0.01	0.12 – 0.15	0.11	0.52
FT (s)	0.10 $\pm$ 0.00	0.10 – 0.11	0.14 $\pm$ 0.02	0.12 – 0.15	0.54	0.21
SL (cm)	371.80 $\pm$ 38.99	343.90 – 399.70	456.10 $\pm$ 42.14	425.95 – 486.25	0.39	-0.30
SF (steps/s)	4.32 $\pm$ 0.13	4.22 – 4.41	4.76 $\pm$ 0.35	4.51 – 5.02	0.75	0.11

\*Denotes significant p value < 0.05.

\*\*Denotes a large correlation between overground sprinting and motorized treadmill.

Table 8. Overground vs motorized treadmill sprint performances of all females (CONTROL and TRACK) (n = 20).

	Overground		Motorized Treadmill		p	r
	mean $\pm$ SD	95% CI	mean $\pm$ SD	95% CI		
Speed (m/s)	7.56 $\pm$ 1.03	7.08 – 8.05	7.84 $\pm$ 1.08	7.34 – 8.35	0.01*	0.51**
CT (s)	0.15 $\pm$ 0.03	0.13 – 0.16	0.16 $\pm$ 0.02	0.14 – 0.17	0.01*	0.74**
FT (s)	0.11 $\pm$ 0.02	0.10 – 0.12	0.23 $\pm$ 0.26	0.10 – 0.36	0.24	0.27
SL (cm)	364.75 $\pm$ 46.73	342.88 – 386.62	427.20 $\pm$ 99.73	380.52 – 473.88	0.59	0.12
SF (steps/s)	3.97 $\pm$ 0.40	3.78 – 4.16	4.50 $\pm$ 0.47	4.27 – 4.72	0.01*	0.78**

\*Denotes significant p value < 0.05.

\*\*Denotes a large correlation between overground sprinting and motorized treadmill.

Table 9. Overground vs motorized treadmill sprint performances of females for CONTROL group (n = 10).

	Overground		Motorized Treadmill		p	r
	mean $\pm$ SD	95% CI	mean $\pm$ SD	95% CI		
Speed (m/s)	6.72 $\pm$ 0.68	6.23 – 7.21	7.05 $\pm$ 0.68	6.56 – 7.54	0.01*	0.91**
CT (s)	0.17 $\pm$ 0.02	0.16 – 0.19	0.17 $\pm$ 0.02	0.15 – 0.19	0.03*	0.66**
FT (s)	0.10 $\pm$ 0.01	0.09 – 0.12	0.30 $\pm$ 0.37	0.03 – 0.57	0.78	0.09
SL (cm)	347.60 $\pm$ 18.35	334.47 – 360.73	420.70 $\pm$ 132.55	325.87 – 515.53	0.70	0.13
SF (steps/s)	3.79 $\pm$ 0.28	3.59 – 3.99	4.27 $\pm$ 0.26	4.08 – 4.46	0.14	0.49

\*Denotes significant p value < 0.05.

\*\*Denotes a large correlation between overground sprinting and motorized treadmill.

Table 10. Overground vs motorized treadmill sprint performances of females for TRACK group (n = 10).

	Overground		Motorized Treadmill		p	r
	mean $\pm$ SD	95% CI	mean $\pm$ SD	95% CI		
Speed (m/s)	8.40 $\pm$ 0.49	8.05 – 8.75	8.64 $\pm$ 0.78	8.08 – 9.20	0.01*	0.91**
CT (s)	0.13 $\pm$ 0.02	0.11 – 0.14	0.14 $\pm$ 0.01	0.13 – 0.15	0.19	0.44
FT (s)	0.12 $\pm$ 0.02	0.10 – 0.14	0.16 $\pm$ 0.03	0.13 – 0.19	0.31	0.35
SL (cm)	381.90 $\pm$ 60.16	338.86 – 424.94	433.70 $\pm$ 57.72	392.40 – 475.00	0.94	0.02
SF (steps/s)	4.15 $\pm$ 0.43	3.84 – 4.46	4.72 $\pm$ 0.53	4.34 – 5.10	0.02*	0.70**

\*Denotes significant p value < 0.05.

\*\*Denotes a large correlation between overground sprinting and motorized treadmill.

Table 11. Comparison of mean variables between TRACK (n = 20) and CONTROL (n = 20) groups.

	P value	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
				Lower	Upper
OG speed m/s	0.001*	-1.481	0.275	-2.039	-0.923
TM speed m/s	0.001*	-1.575	0.290	-2.163	-0.987
OG-CT(s)	0.001*	0.032	0.006	0.019	0.046
TM-CT(s)	0.001*	0.030	0.006	0.018	0.043
OG-FT(s)	0.155	-0.007	0.005	-0.018	0.003
TM-FT(s)	0.129	0.120	0.077	-0.036	0.276
OG-SL(cm)	0.247	-15.750	13.405	-42.888	11.388
TM-SL (cm)	0.403	-21.200	25.047	-71.905	29.505
OG-SF(step/s)	0.007*	-0.284	0.098	-0.483	-0.084
TM-SF (step/s)	0.004*	-0.359	0.116	-0.596	-0.122

\*Denotes significant p value < 0.05.

Table 12. Comparison variables through Paired Sample T-tests analysis of overground and motorized treadmill modalities (n = 40).

	Correlation	Sig.	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		Mean Difference	Std. Error Difference
						Lower	Upper		
OG speed (m/s) & TM speed (m/s)	0.948**	0.001*	-0.214	0.384	0.060	-0.337	-0.091	-3.527	0.001
OG-CT(s) & TM-CT(s)	0.687**	0.001*	-0.010	0.020	0.003	-0.017	0.004	-3.364	0.002
OG-FT(s) & TM-FT(s)	0.054	0.739	-0.101	0.248	0.039	-0.181	-0.021	-2.578	0.014
OG-SL(cm) & TM-SL (cm)	-0.167	0.302	-65.325	95.750	15.139	-95.947	-34.703	-4.315	0.001
OG-SF(step/s) & TM-SF (step/s)	0.667**	0.001*	-0.471	0.311	0.049	-0.571	-0.372	-9.586	0.001

\*Denotes significant p value < 0.05.

\*\*Denotes a large correlation between overground sprinting and motorized treadmill

Table 13. Sex differences during overground sprint condition.

	Males		Females		Mean Diff $\pm$ SED	p
	mean $\pm$ SD	95% CI	mean $\pm$ SD	95% CI		
Speed (m/s)	8.83 $\pm$ 0.87	8.42 – 9.24	7.56 $\pm$ 1.03	7.08 – 8.05	1.271 $\pm$ 0.302	0.01*
CT (s)	0.13 $\pm$ 0.01	0.13 - 0.14	0.15 $\pm$ 0.03	0.13 - 0.16	-0.015 $\pm$ 0.008	0.01*
FT (s)	0.10 $\pm$ 0.01	0.10 - 0.11	0.11 $\pm$ 0.02	0.10 - 0.12	-0.008 $\pm$ 0.005	0.32
SL (cm)	373.05 $\pm$ 38.77	355.05 – 391.35	364.75 $\pm$ 46.73	342.88 – 386.62	8.450 $\pm$ 13.578	0.23
SF (steps/s)	4.21 $\pm$ 0.21	4.11 – 4.31	3.97 $\pm$ 0.40	3.78 – 4.16	0.238 $\pm$ 0.101	0.01*

\*Denotes significant p value < 0.05

Table 14. Sex differences during motorized treadmill sprint condition.

	Males		Females		Mean Diff $\pm$ SED	p
	mean $\pm$ SD	95% CI	mean $\pm$ SD	95% CI		
Speed (m/s)	8.98 $\pm$ 1.06	8.48 – 9.48	7.84 $\pm$ 1.08	7.34 – 8.35	1.137 $\pm$ 0.339	0.02*
CT (s)	0.15 $\pm$ 0.02	0.14 - 0.16	0.16 $\pm$ 0.02	0.14 - 0.17	-0.005 $\pm$ 0.007	0.01*
FT (s)	0.19 $\pm$ 0.23	0.08 - 0.30	0.23 $\pm$ 0.02	0.10 - 0.36	-0.043 $\pm$ 0.079	0.27
SL (cm)	441.40 $\pm$ 52.26	416.94 – 465.86	427.20 $\pm$ 99.73	380.52 – 473.88	14.200 $\pm$ 25.177	0.13
SF (steps/s)	4.63 $\pm$ 0.33	4.48 – 4.79	4.50 $\pm$ 4.46	4.27 – 4.72	0.135 $\pm$ 0.128	0.15

\*Denotes significant p value < 0.05.

Table 15. Summary of linear regression on sprint speed during overground condition (CONTROL and TRACK groups n = 40).

	Model				
	F	P	R	R <sup>2</sup>	Adj. R <sup>2</sup>
	34.66	0.00	0.89	0.79	0.77
Coefficients					
Variables	B	Std. Error	Beta	T	p
(Constant)	26.180	3.901		6.711	0.001
CT (s)	-58.928	7.394	-1.369	-7.970	0.001
FT (s)	-38.036	7.709	-0.578	-4.934	0.001
SL (cm)	0.003	0.002	0.125	1.541	0.132
SF (steps/s)	-1.544	0.532	-0.460	-2.901	0.006

This model shows that CT, FT, and SF are predictors of sprint speed on overground for all subjects. Beta shows that CT is the stronger predictor of sprint speed on overground with a -1.369 Beta. Stride length is not a predictor of sprint speed on overground. This model explains 79% (R<sup>2</sup>) of the variance.

Table 16. Summary of linear regression on sprint speed during motorized treadmill condition (CONTROL and TRACK groups n = 40).

	Model				
	F	P	R	R <sup>2</sup>	Adj. R <sup>2</sup>
	15.23	0.00*	0.79	0.63	0.59
Coefficients					
Variables	B	Std. Error	Beta	T	p
(Constant)	6.069	3.133		1.937	0.061
CT (s)	-22.304	7.182	-0.454	-3.105	0.004
FT (s)	-1.159	0.517	-0.239	-2.244	0.031
SL (cm)	0.005	0.002	0.306	2.214	0.033
SF (step/s)	0.890	0.372	0.301	2.391	0.022

This model shows that CT, FT, SL, and SF are all predictors of sprint speed on treadmill for all subjects. Beta shows that CT is the stronger predictor of sprint speed on overground with a -0.454 Beta. This model explains 63 % (R<sup>2</sup>) of the variance.

Table 17. Summary of linear regression on sprint speed during overground condition (CONTROL group, n = 20)

Model					
	F	P	R	R <sup>2</sup>	Adj. R <sup>2</sup>
	10.93	0.00*	0.86	0.74	0.67
Coefficients					
Variables	B	Std. Error	Beta	T	p
(Constant)	19.113	6.118		3.124	0.007
CT (s)	-43.372	11.335	-1.026	-3.827	0.002
FT (s)	-23.663	11.263	-0.375	-2.101	0.053
SL (cm)	0.002	0.004	-0.074	-0.522	0.610
SF (step/s)	-0.711	0.916	-0.216	-0.776	0.450

This model shows CT is the only predictor of sprint speed during treadmill while FT, SL and SF are not predictors of sprint speed in overground condition for CONTROL. This model explains 74% (R<sup>2</sup>) of the variance.

Table 18. Summary of linear regression on sprint speed during motorized treadmill condition (CONTROL group, n = 20)

Model					
	F	P	R	R <sup>2</sup>	Adj. R <sup>2</sup>
	2.24	0.11	0.61	0.37	0.20
Coefficients					
Variables	B	Std. Error	Beta	T	p
(Constant)	2.336	5.747		0.406	0.690
CT(s)	-11.160	11.575	-0.266	-0.964	0.350
FT(s)	-0.864	0.628	-0.341	-1.377	0.189
SL (cm)	0.004	0.003	0.468	1.482	0.159
SF (step/s)	1.303	0.860	0.418	1.516	0.150

This model shows that CT, FT, SF, or SL are not predictors of sprint speed on treadmill for CONTROL.

Table 19. Summary of linear regression on sprint speed during overground condition (TRACK group, n = 20)

Model					
	F	P	R	R <sup>2</sup>	Adj. R <sup>2</sup>
	8.48	0.00	0.83	0.69	0.61
Coefficients					
Variables	B	Std. Error	Beta	T	p
(Constant)	35.459	5.706		6.214	0.000
CT (s)	-83.648	15.551	-2.056	-5.379	0.000
FT (s)	-65.647	13.725	-1.630	-4.783	0.000
SL (cm)	0.007	0.003	0.471	2.272	0.038
SF (step/s)	-2.530	0.687	-1.104	-3.685	0.002

This model shows that CT, FT, SF, or SL are predictors of sprint speed on overground for TRACK. The stronger predictor of sprint speed on overground for TRACK appears to be CT with a Beta of -2.056. This model explains 69% (R<sup>2</sup>) of the variance.

Table 20. Summary of linear regression on sprint speed during motorized treadmill condition (TRACK group, n = 20)

Model					
	F	P	R	R <sup>2</sup>	Adj. R <sup>2</sup>
	13.29	0.00	0.88 <sup>a</sup>	0.78	0.72
Coefficients					
Variables	B	Std. Error	Beta	T	p
(Constant)	0.984	3.149		0.313	0.759
CT (s)	-6.160	8.888	-0.113	-0.693	0.499
FT (s)	-9.645	4.058	-0.346	-2.377	0.031
SL (cm)	0.017	0.003	0.920	5.333	0.000
SF (step/s)	0.591	0.289	0.271	2.047	0.059

This model shows FT and SL are predictors of sprint speed during treadmill while CT and SF are not predictors of sprint speed on treadmill for TRACK. This model explains 78% (R<sup>2</sup>) of the variance.



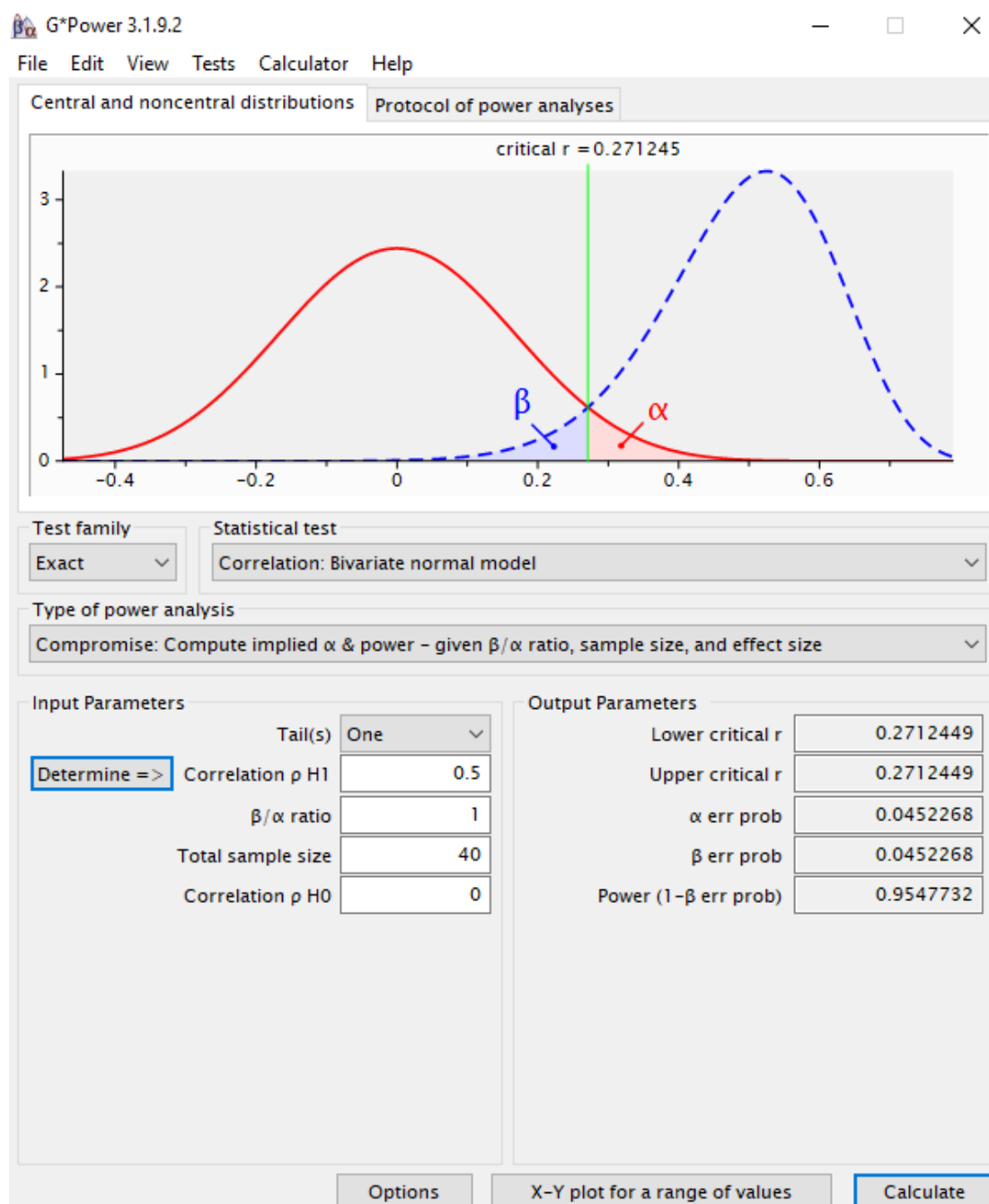


Figure 5. Power analysis for Pearson's test for total sample of 40 subjects combine.

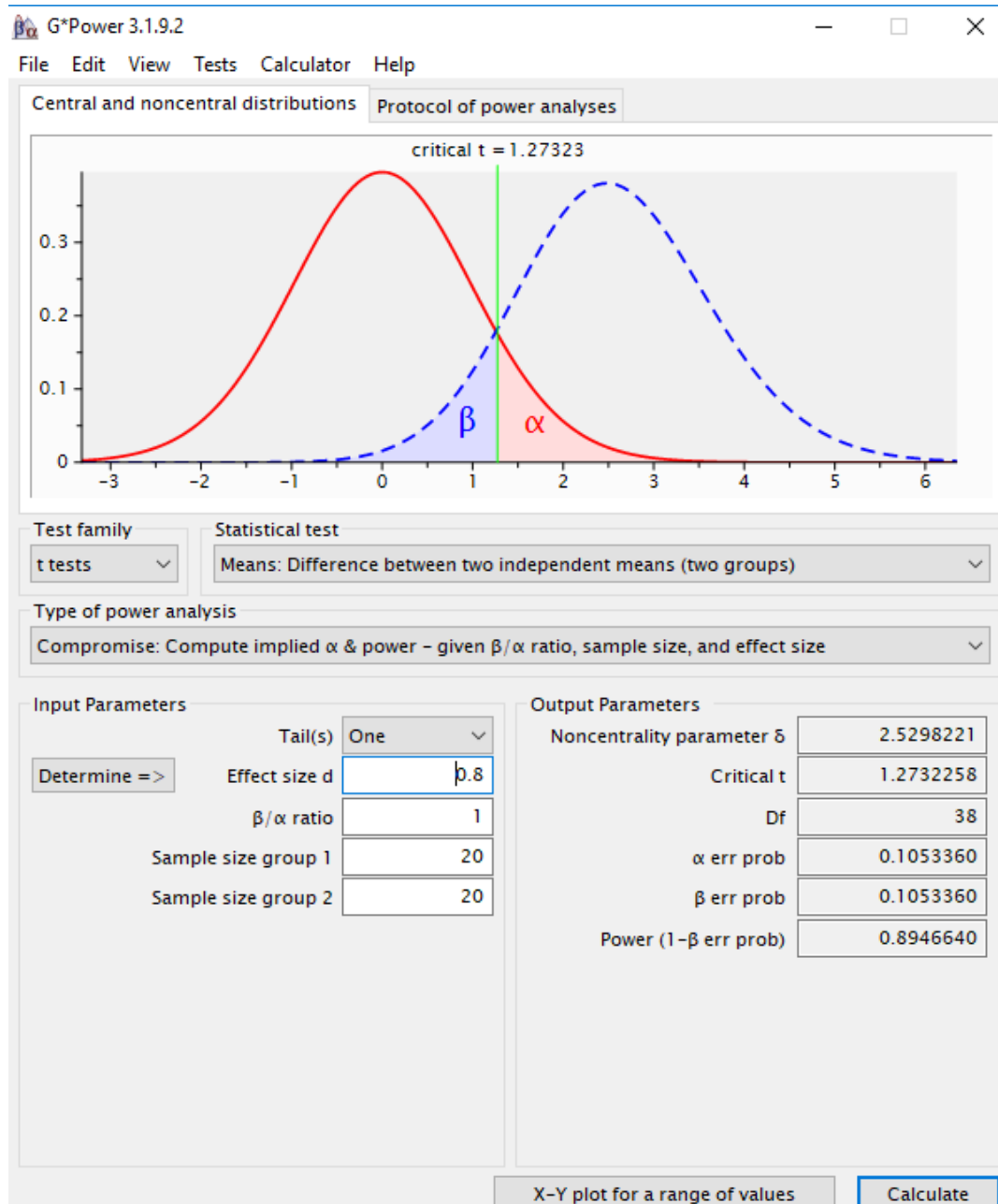


Figure 6. Power analysis for independent sample t-test of a sample size of 20

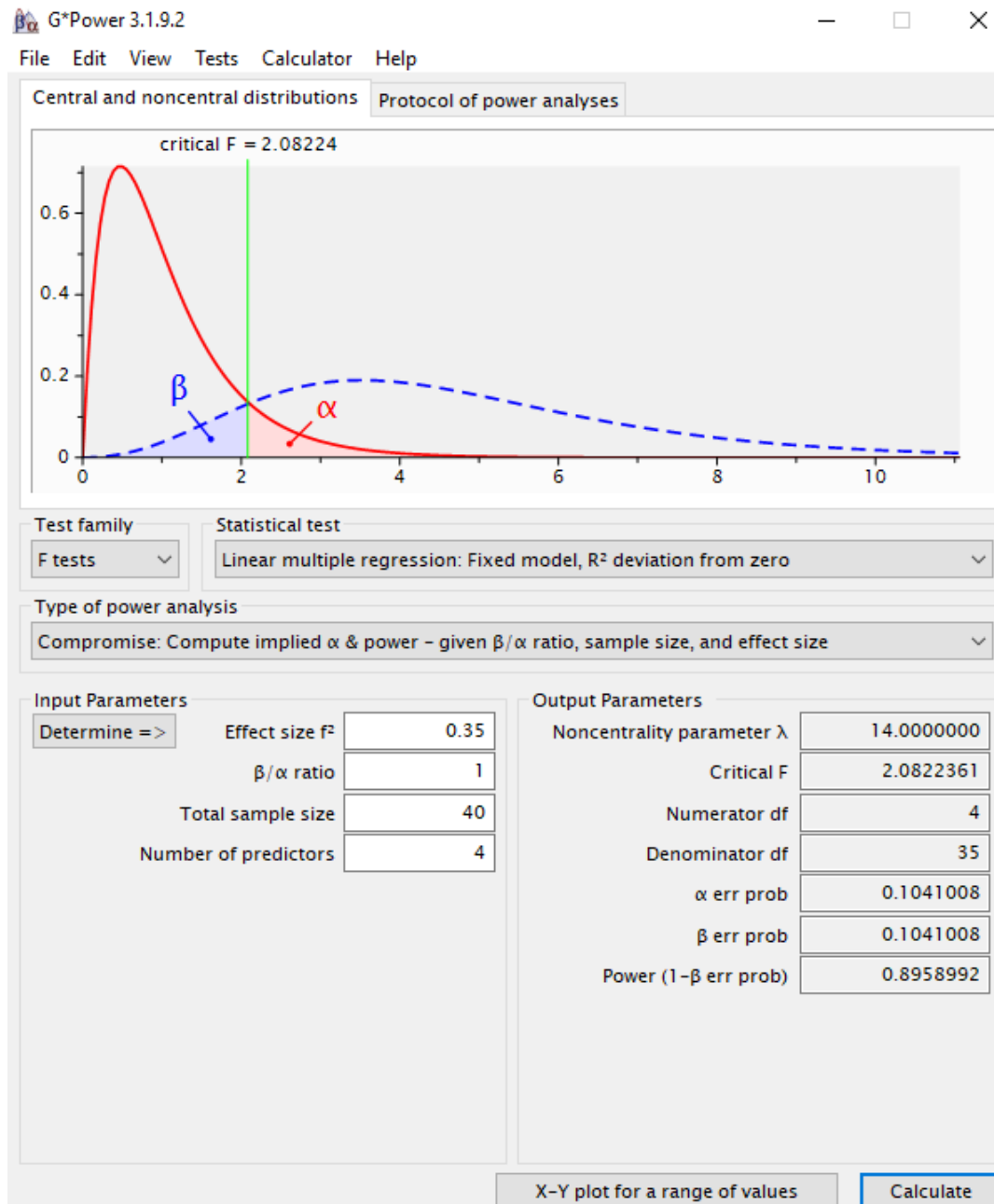


Figure 7. Power analysis for linear regression of a sample size of 40.

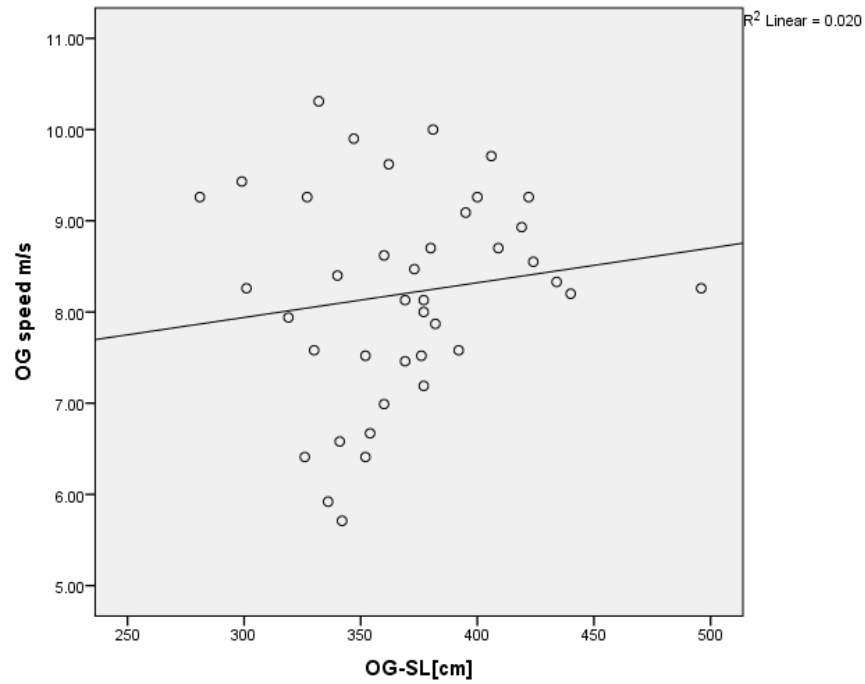


Figure 8. Relationship between overground stride length (SL) and overground sprint speed.

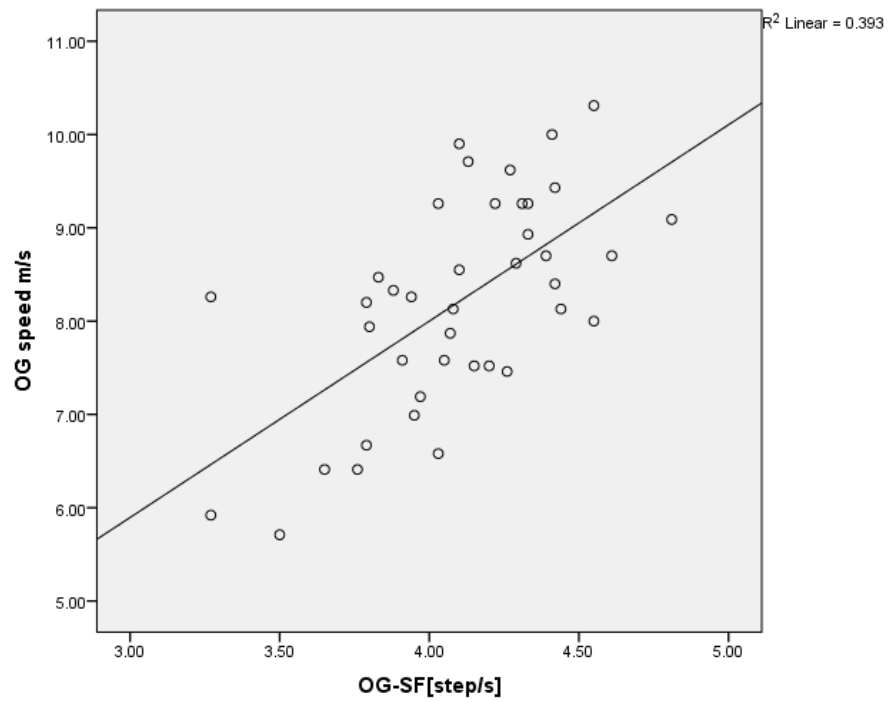


Figure 9. Relationship between overground stride frequency (SL) and overground sprint speed.

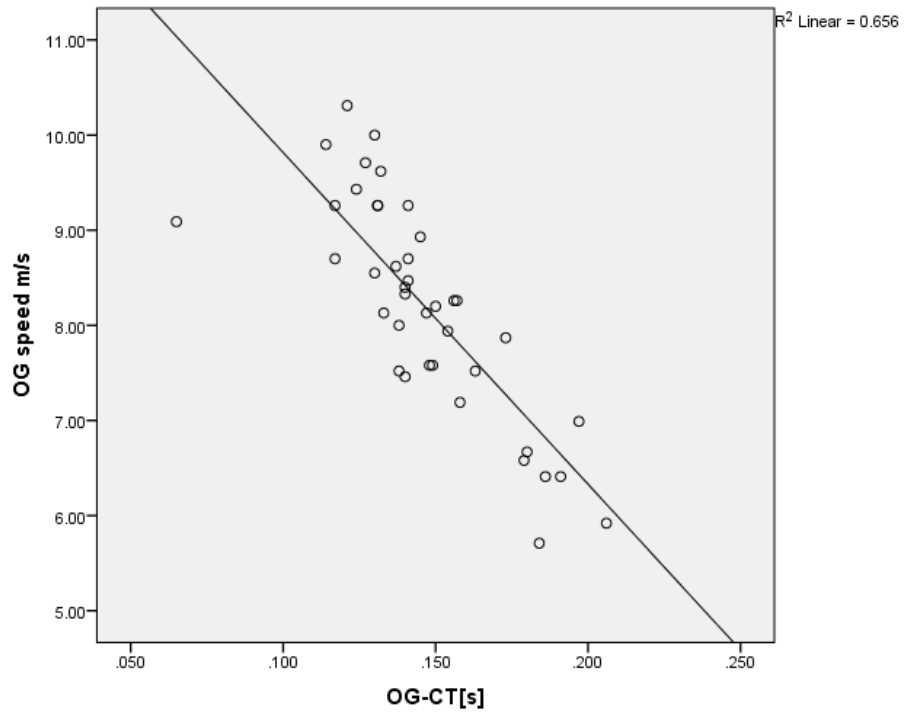


Figure 10. Relationship between overground contact time (CT) and overground sprint speed.

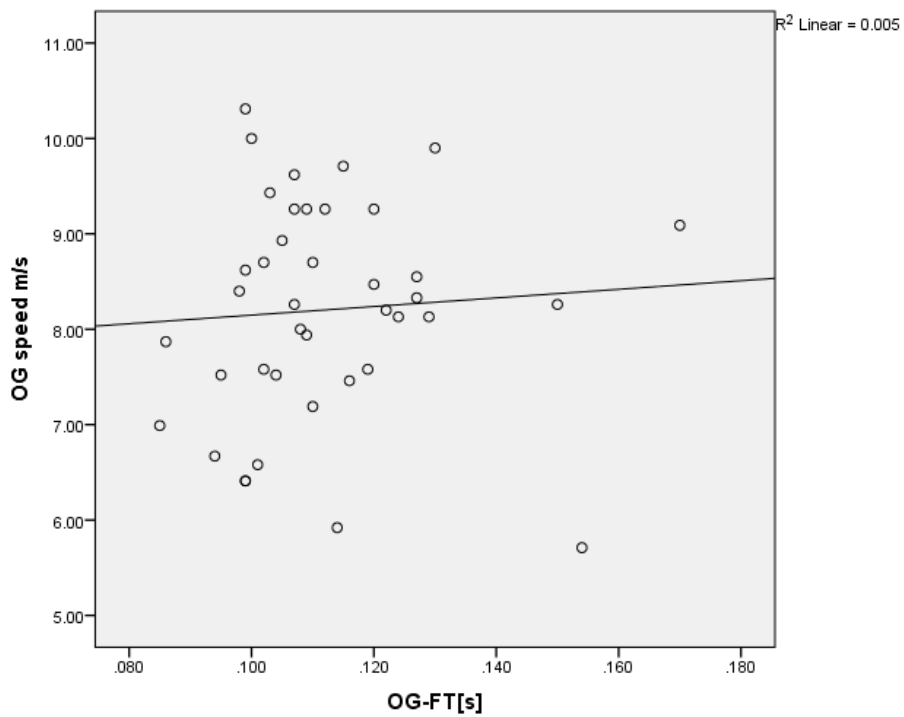


Figure 11. Relationship between overground flight time (FT) and overground sprint speed.

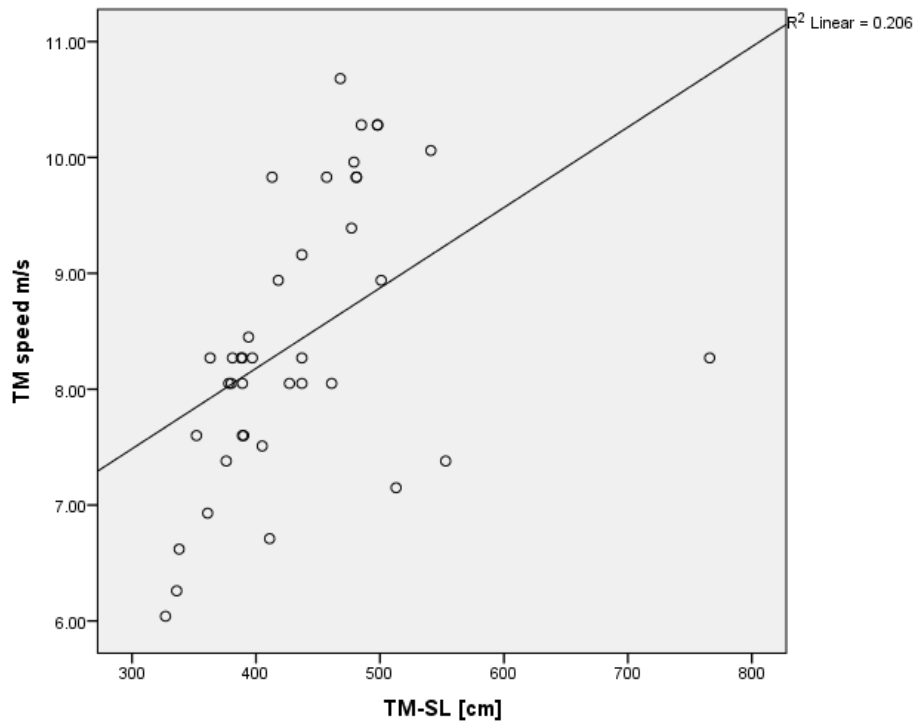


Figure 12. Relationship between motorized treadmill stride length (SL) and motorized treadmill sprint speed.

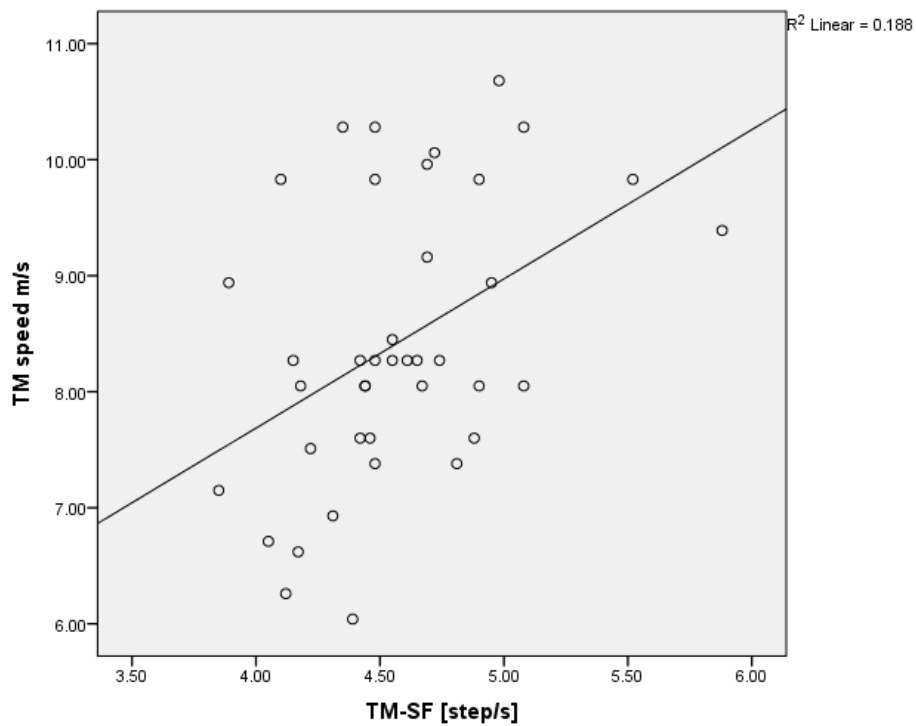


Figure 13. Relationship between motorized treadmill stride frequency (SF) and motorized treadmill sprint speed.

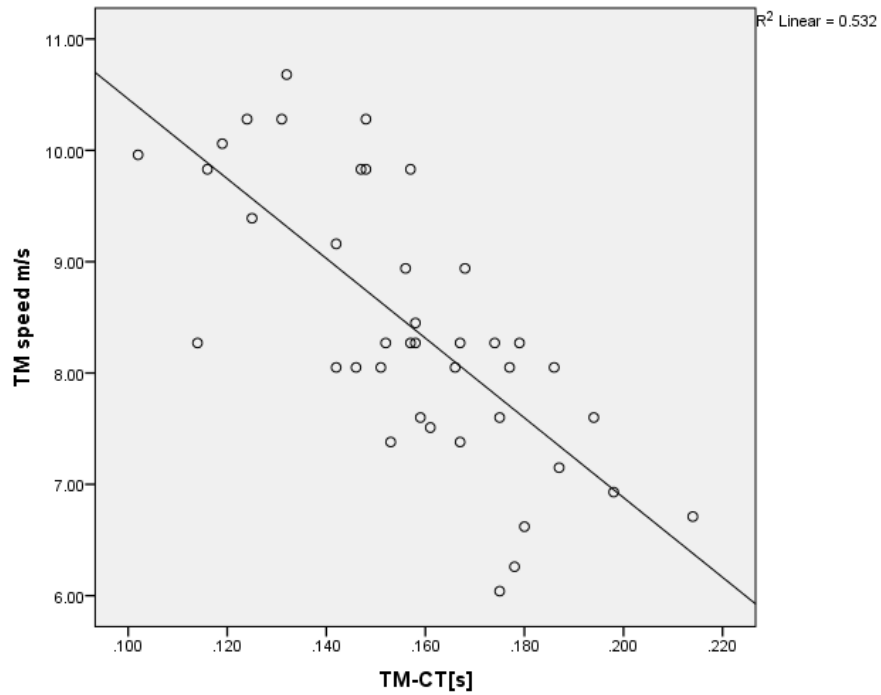


Figure 14. Relationship between motorized treadmill contact time (CT) and motorized treadmill sprint speed.

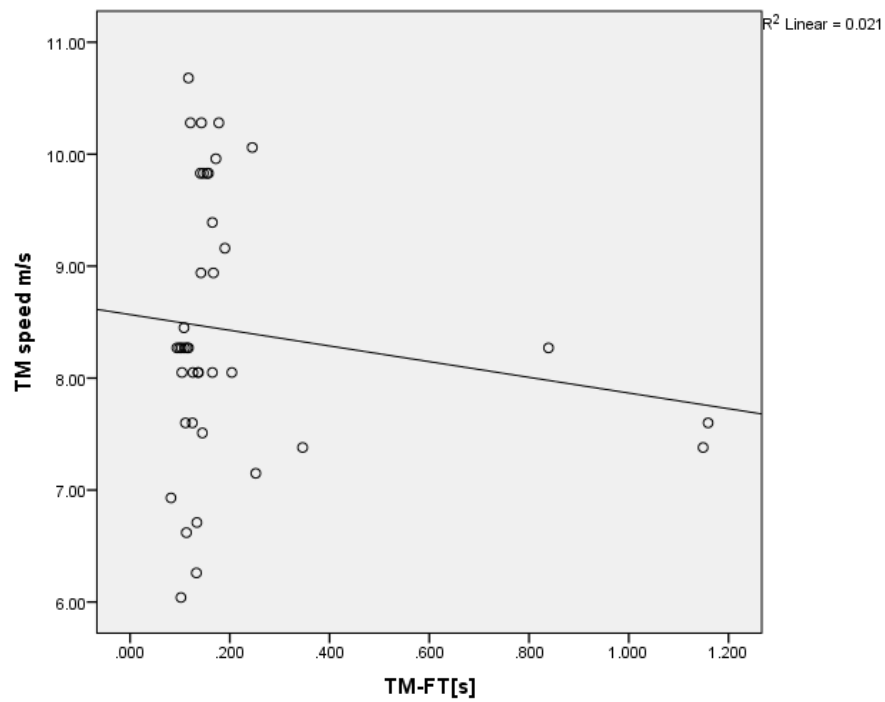


Figure 15. Relationship between motorized treadmill flight time (FT) and motorized treadmill sprint speed.

## Appendix 2



**THE UNIVERSITY OF TEXAS AT EL PASO**  
Office of the Vice President for Research and Sponsored Projects  
**Institutional Review Board**  
El Paso, Texas 79968-0587  
phone: 915 747-8841 fax: 915 747-5931

**FWA No: 00001224**

DATE: April 6, 2018

TO: Sandor Dorgo

FROM: University of Texas at El Paso IRB

STUDY TITLE: [808481-7] Comparison of the effectiveness of treadmill vs. overground sprint training

IRB REFERENCE #: College of Health Sciences

SUBMISSION TYPE: Revision

ACTION: APPROVED

APPROVAL DATE: April 6, 2018

EXPIRATION DATE: October 23, 2018

REVIEW TYPE: Expedited Review

Thank you for your submission of Revision materials for this research study. University of Texas at El Paso IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a study design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

**Your study has received approval at UTEP but may require further review and approval from the institutions listed in your application. Please verify with their IRB prior to engaging in research. Please ensure to forward a copy of all IRB approval letters to the UTEP IRB office.**

This study has received Expedited Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the study and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the study via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.



Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All SERIOUS and UNEXPECTED adverse events must be reported to this office. Please use the appropriate adverse event forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

Please report all NON-COMPLIANCE issues or COMPLAINTS regarding this study to this office.

Please note that all research records must be retained for a minimum of three years after termination of the project.

Based on the risks, this project requires Continuing Review by this office on an annual basis. Please use the appropriate renewal forms for this procedure.

If you have any questions, please contact the IRB Office at (915) 747-8841 or [irb.orsp@utep.edu](mailto:irb.orsp@utep.edu). Please include your study title and reference number in all correspondence with this office.

cc:

## Appendix 3

### University of Texas at El Paso (UTEP) Institutional Review Board Informed Consent Form for Research Involving Human Subjects

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**Protocol Title:** Comparison of the effectiveness of treadmill vs. overground sprint training  
Comparison of maximal sprint stride length and stride frequency patterns of various athletic populations across two different running modalities

**Investigators:** Sandor Dorgo; Katrina Fisher; Fayon Gonzales

**UTEP Department of Kinesiology**

#### 1. Introduction

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You are being asked to take part or you are asked to allow your child to take part voluntarily in the research project described below. Please take your time making a decision and feel free to discuss it with your friends and family. Before agreeing to take part in this research study, or allowing you child to participate, it is important that you read the consent form that describes the study. Please ask the study researcher or the study staff to explain any words or information that you do not clearly understand.

#### 2. Why is this study being done?

---

You have been asked or your child has been asked to take part in a research study investigating stride length/stride frequency when comparing overground and treadmill running at maximum speed of three subject groups: high school sprinters group (HS), collegiate sprinters group (CS) group, and collegiate football players group (FS). Approximately 60 study subjects will be enrolling in this study at UTEP. Based on your child's (children's) expressed interest you are being asked to allow their participation in the study, as he/she is between the ages of 14 and 30 and you are their parent or legal guardian. If you decide to enroll your child in this study, his/her active involvement will last for about 1 day.

#### 3. What is involved in the study?

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If you allow your child to take part in this study, he/she will be asked to complete the following:

- Fill out a questionnaire covering basic health information.
- Fill out the Physical Activity Questionnaire that assesses current exercise behavior.
- Fill out a set of questionnaires that assess your exercise confidence.
- Fill out the Athletic Training Questionnaire that assesses current athletic participation.



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- Participate in a pre-test procedure of anthropometric measures, including height, weight, upper thigh and body composition measures
- Participate in a body composition (DEXA) testing protocol.
- Participate in a maximal sprint speed (sprint performance) testing protocol on the 40 yard dash speed assessment test and the maximum speed treadmill assessment.
- On the final maximum speed treadmill assessment wear reflective markers to be video recorded for motor coordination analysis.
- Participate in a maximal aerobic power graded exercise testing protocol through peak treadmill velocity testing.
- Participate in a 8-week intervention program with two meetings a week to include:
  - o A follow up test session every two weeks to assess 40 yard dash sprint performance on turf and treadmill.
  - o Two training sessions weekly to practice skills and techniques of sprinting.
- Participate in a submaximal and maximal sprint speed (sprint performance) testing protocol of the 60 meters overground and maximum speed treadmill assessment.
- Participate in a one day testing session.

#### **4. What are the risks and discomforts of the study?**

---

Due to associated risks with the following conditions, I understand that my child's participation will be prohibited if he/she has cardiovascular problems or spine deformities, if she is pregnant, or under the age of 14.

There are no known major risks associated with this research. Minor discomfort, including muscle soreness, fatigue, muscle cramps or minor strains or sprains, may be resulted from the maximal sprint speed testing and peak treadmill velocity testing. I understand that the researchers will strive to protect my safety or my child's safety by providing supervision of qualified personnel. There are no known nonphysical risks associated with this study.

I understand that during a single DEXA test I will be exposed to or my child will be exposed to approximately 0.03 mrad of radiation. This exposure is less than 1% of the radiation received from a chest x-ray, or 0.5% of a dental x-ray, or less than 25% of the radiation exposure from six hours outdoors. The level of exposure to the participant and the technician is well within the Texas Regulation for the Control of Radiation (Part 21.106) and the safety guidelines of the UTEP Environmental Health & Safety Office which states (<http://www.utep.edu/eh&s/ppm/radiation-safety>) . "In no area that is unrestricted (uncontrolled)



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should radiation levels exist, such that a person could receive 2 mR in any one hour, 100 mR in any seven consecutive days, or 500 mR in any one year... In restricted areas exposure limits do not apply as personnel are monitored to determine their exposures. However, levels should be reduced to minimum where practicable to reduce exposure and no visitor should receive more than 100 mR in one week or 0.5 mr/hr in such areas."



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**5. What will happen if I am injured in this study?**

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The University of Texas at El Paso and its affiliates do not offer to pay for or cover the cost of medical treatment for research related illness or injury. No funds have been set aside to pay or reimburse you in the event of such injury or illness. You will not give up any of your legal rights by signing this consent form. You should report any such injury to Sandor Dorgo or Katrina Fisher, at 915-549-0004 or Fayon Gonzales at 915-328-7496 and to the UTEP Institutional Review Board (IRB) at (915-747-8841) or [irb.orsp@utep.edu](mailto:irb.orsp@utep.edu).

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**6. Are there benefits to taking part in this study?**

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Potentially, you or your child will know your/their maximal/submaximal stride length and stride frequency values. There will be no other direct benefits to you or your child for taking part in this study. This research may help us to understand the relationship between stride length/ and stride frequency patterns of various athletic populations across two different running modalities.

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**7. What other options are there?**

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You have the option of not permitting your child to take part in this study. There will be no penalties involved if you choose not to allow your child's participation in this study.

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**8. Who is paying for this study?**

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This study is not funded.

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**9. What are my costs?**

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There are no direct costs. You or your child will be responsible for travel to and from the research site.

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**10. Will I be paid to participate in this study?**

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Neither you nor your child will be paid for taking part in this research study.



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### **11. What if I want to withdraw, or am asked to withdraw from this study?**

Taking part in this study is voluntary. You have the right to choose not to take part or not allow your child to take part in this study. If you do not take part or do not allow him/her to take part in the study, there will be no penalty. If you choose to take part, or choose to grant permission for your child to take part, you have the right to withdraw your/their participation at any time. However, we encourage you to talk to a member of the research group so that they know why you are leaving the study or withdrawing your child's participation from the study. If there are any new findings during the study that may affect you or your child, whether you want to continue or allow your child to continue to take part, you will be told about them. The researcher may decide to stop your participation or your child's participation without your permission, if she thinks that being in the study may cause you or your child any harm.

#### **Exclusion Criteria**

- a) Subjects not within the 14-30 year age range.
- b) Subjects who are pregnant.
- c) Subjects with orthopedic limitations that prevent him/her from engaging in study methods.
- d) Subjects who have a chronic medical condition or have been recently diagnosed with a medical condition (musculoskeletal deformations, cardiac arrhythmias, impaired gait or limited range of motion).
- e) Subjects with spine deformities (scoliosis or lordosis).
- f) Subjects who have attained an injury within the past two years (broken bones, injured ankle, leg, foot, back, head injury, etc.).
- g) Subjects who have had a surgery within the past two years.
- h) Subjects who are not recreationally active for at least 2-3 days a week (doesn't engage in recreational sports; basketball, soccer, softball, etc. or regular training; swimming, running, cycling, etc.) or officially involved on one of the stated teams above

### **12. Who do I call if I have questions or problems?**

You may ask any questions you have now. If you have questions later, you may call Katrina Fisher or Fayon Gonzales (principal investigators), at (832) 231-4582 or (915) 328-7496 or by email at kmfisher@miners.utep.edu or fkgonzales@miners.utep.edu. If you have questions or concerns about your participation as a research subject, please contact the UTEP Institutional Review Board (IRB) at (915-747-8841) or irb.orsp@utep.edu.



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Study Number: 808481-7

**13. What about confidentiality?**

---

Your part or your child's part in this study is confidential. Your individual information or your child's individual information obtained from the questionnaire and from the tests will be known only by the researcher(s). None of the information will identify you or your child by name. Your name or child's name and any details that might identify you or him/her will be changed to a subject number in any written reports in order to protect confidentiality. Documents will be kept on the UTEP campus in the researcher's office in a locked cabinet and destroyed three years after completion of the research study. There will be no harmful use of the data collected in this study.

**14. Mandatory reporting**

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Not applicable.

**15. Authorization Statement**

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I have read each page of this paper about the study (or it was read to me). I know that being in this study or allowing my child to be in this study is voluntary. I choose to be in this study or choose to grant them permission to be in this study. I know I can stop or stop my child's participation in this study without penalty. I will get a copy of this consent form now and can get information on results of the study later if I wish.

Participant Name: \_\_\_\_\_

Parent/Legal Guardian's Name: \_\_\_\_\_ Date: \_\_\_\_\_

Parent/Legal Guardian's Signature: \_\_\_\_\_ Time: \_\_\_\_\_

Consent form explained/witnessed by: \_\_\_\_\_

Signature

Printed name: \_\_\_\_\_

Date: \_\_\_\_\_ Time: \_\_\_\_\_



Approved: 04/06/18  
Expires: 10/23/18  
Study Number: 808481-7

## Appendix 4

### Health Status Questionnaire

Please complete the following questions as accurately as possible.

Date of Birth: \_\_\_\_/\_\_\_\_/\_\_\_\_

Age: \_\_\_\_yr.

Weight: \_\_\_\_\_

Height: \_\_\_\_\_

#### Medical History

Is there any possibility that you are pregnant? Yes ☐

No ☐

Please mark and date all surgeries you have had:

<input type="checkbox"/> Back	____/____/____	<input type="checkbox"/> Lung	____/____/____
<input type="checkbox"/> Foot	____/____/____	<input type="checkbox"/> Shoulder	____/____/____
<input type="checkbox"/> Joint	____/____/____	<input type="checkbox"/> Neck	____/____/____
<input type="checkbox"/> Knee	____/____/____	<input type="checkbox"/> Heart	____/____/____
<input type="checkbox"/> Ankle	____/____/____	<input type="checkbox"/> abdominal	____/____/____
<input type="checkbox"/> Other	____/____/____		____/____/____

Please mark all of the following for which you have been diagnosed or treated by a physician or health professional:

<input type="checkbox"/> Alcoholism	<input type="checkbox"/> Emphysema	<input type="checkbox"/> Kidney problems
<input type="checkbox"/> Anemia, sickle cell	<input type="checkbox"/> Epilepsy	<input type="checkbox"/> Liver disease
<input type="checkbox"/> Anemia, other	<input type="checkbox"/> Eye problems	<input type="checkbox"/> Lung disease
<input type="checkbox"/> Asthma	<input type="checkbox"/> Gout	<input type="checkbox"/> Mental illness
<input type="checkbox"/> AIDS	<input type="checkbox"/> Hearing loss	<input type="checkbox"/> Neck strain
<input type="checkbox"/> Back Strain	<input type="checkbox"/> Heart problem	<input type="checkbox"/> Obesity
<input type="checkbox"/> Bleeding trait	<input type="checkbox"/> Heart murmur	<input type="checkbox"/> Phlebitis
<input type="checkbox"/> Bronchitis, chronic	<input type="checkbox"/> Hepatitis	<input type="checkbox"/> Rheumatoid
<input type="checkbox"/> Cancer	<input type="checkbox"/> High blood pressure	<input type="checkbox"/> arthritis
<input type="checkbox"/> Cirrhosis, liver	<input type="checkbox"/> Hypoglycemia	<input type="checkbox"/> Stroke
<input type="checkbox"/> Concussion # ____	<input type="checkbox"/> High Cholesterol	<input type="checkbox"/> Thyroid problem
<input type="checkbox"/> Congenital defect	<input type="checkbox"/> Infectious mononucleosis	<input type="checkbox"/> Ulcer
<input type="checkbox"/> Diabetes	<input type="checkbox"/> Joint problems	<input type="checkbox"/> Other _____
<input type="checkbox"/> Neuromuscular disorders (multiple sclerosis, vertigo, cong. myasthenia, etc.)		

Please mark all medications/supplements taken during the past 6 months:

- |  |   |                                      |
|--|---|--------------------------------------|
| <input type="checkbox"/> Blood thinner | <input type="checkbox"/> Epilepsy medication            | <input type="checkbox"/> Other _____ |
| <input type="checkbox"/> Diabetic      | <input type="checkbox"/> Heart medication               | <input type="checkbox"/> Other _____ |
| <input type="checkbox"/> Diuretic      | <input type="checkbox"/> High blood pressure medication | <input type="checkbox"/> Other _____ |
| <input type="checkbox"/> Insulin       | <input type="checkbox"/> Hormones                       | <input type="checkbox"/> Other _____ |

Please mark any of the following symptoms you have had recently:

- |  |   |
|--|---|
| <input type="checkbox"/> Abdominal pain                  | <input type="checkbox"/> Frequent urination                   |
| <input type="checkbox"/> Arm or shoulder pain            | <input type="checkbox"/> Leg pain/numbness                    |
| <input type="checkbox"/> Breathless with slight exertion | <input type="checkbox"/> Low blood sugar                      |
| <input type="checkbox"/> Blurred vision                  | <input type="checkbox"/> Low-back pain                        |
| <input type="checkbox"/> Blood in urine                  | <input type="checkbox"/> Palpitation or fast heart beat       |
| <input type="checkbox"/> Burning sensations              | <input type="checkbox"/> Shortness of breath                  |
| <input type="checkbox"/> Chest pain                      | <input type="checkbox"/> Significant emotional problem        |
| <input type="checkbox"/> Cough up blood                  | <input type="checkbox"/> Swollen joints                       |
| <input type="checkbox"/> Difficulty walking              | <input type="checkbox"/> Unusual fatigue with normal activity |
| <input type="checkbox"/> Dizziness                       | <input type="checkbox"/> Weakness in arms                     |
| <input type="checkbox"/> Feel faint                      |   |

Have you had any of the following injuries in the past 1 year?

- |                                     |                                     |
|-------------------------------------|-------------------------------------|
| <input type="checkbox"/> Pelvic     | <input type="checkbox"/> Shoulder   |
| <input type="checkbox"/> Elbow      | <input type="checkbox"/> Leg        |
| <input type="checkbox"/> Knee       | <input type="checkbox"/> Ankle      |
| <input type="checkbox"/> Lower back | <input type="checkbox"/> Upper back |
| <input type="checkbox"/> Neck       |                                     |



## Appendix 5

### Exercise Behavioral Questionnaire

Have you been exercising regularly in the past 6 months? ☐ Yes ☐ No

Do you or have you ever been exposed to sprint training? ☐ Yes ☐ No

What form of exercise do you engage in regularly?

Resistance training (bench press, back squat, deadlift, etc.) ☐

Aerobic training (jogging, swimming, biking, etc.) ☐

Fitness classes (step aerobic, cross fit, kick-boxing, etc.) ☐

Recreational sport activities (basketball, soccer, tennis, baseball etc.) ☐

Other type of activities, please specify: \_\_\_\_\_

Do you engage in any activity that involves running? ☐ Yes ☐ No

And if so please specify the activity: \_\_\_\_\_

How many times a week do you perform an activity that involves some form of running?

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

How long is your average exercise session? \_\_\_\_\_

Do you consider yourself a very active individual? ☐ Yes ☐ No

Do you engage in agility/speed training exercises? \_\_\_\_\_

What is the average rest time in between your sets? \_\_\_\_\_

Please check ALL exercises from the below list that you practice regularly:

☐ Agility drills

☐ Sprinting

☐ Plyometric (jump training)

☐ Stadiums

☐ High knees

☐ Jump squats

☐ Lunges

☐ Walking knee raises

☐ Walking toe touch

☐ Uphill sprinting

☐ Downhill sprinting

☐ Treadmill running

## Appendix 6

### Data Sheet

Name: \_\_\_\_\_

Sex: MALE / FEMALE

Group: TRACK / CONTROL

#### Anthropometrics

Height: \_\_\_\_\_cm

Weight: \_\_\_\_\_kg

Leg Length: \_\_\_\_\_cm

Thigh Circumference: \_\_\_\_\_cm

#### Overground Testing

Trial 1 \_\_\_\_\_

Trial 2 \_\_\_\_\_

#### Treadmill Testing

Trial 1 \_\_\_\_\_

Trial 2 \_\_\_\_\_

## **Appendix 7**

### **Testing Warm-up**

#### Overground Testing

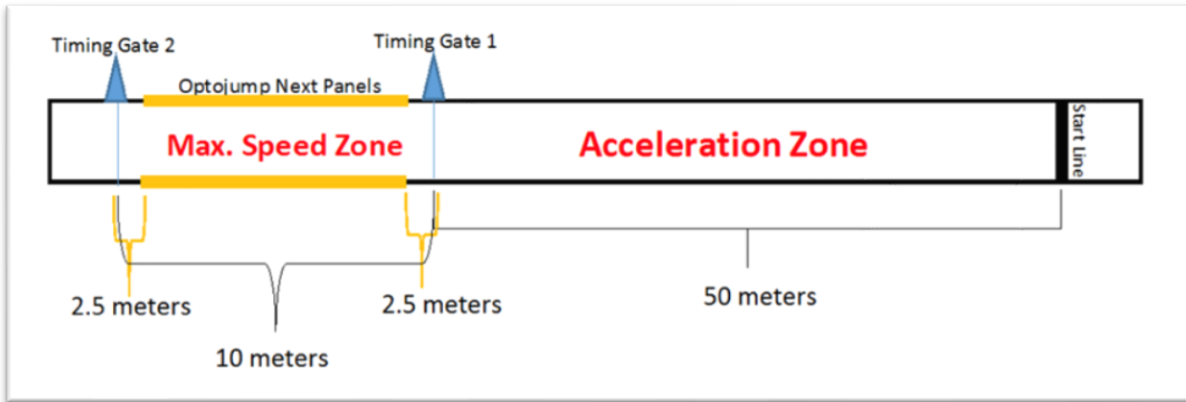
1. Two Laps (400m) (10-15 mins)
2. Stretches, upper body and lower body (L/R) (12 mins)
  - a. Toe touches
  - b. High knees
  - c. Butt kicks
  - d. Arm swings
  - e. Lunges (10 m) short sprint (10m)
  - f. Arm across the chest
  - g. Arm behind the head
  - h. Knees to the front
  - i. Leg to the back
  - j. Hamstring
  - k. Quadriceps
  - l. Calf stretch
  - m. 5 mins given for extra stretch if needed
3. Test Runs (2-5 mins rest)
  - a. 50% run on the side next to the set up
  - b. 80% run through equipment set up
4. Maximal Sprint Testing (5 mins rest in between sets)

#### Treadmill Testing

1. Stretches, upper body and lower body (L/R) if needed
2. Test runs (2-5 mins rest between trials)
  - a. 50% run, 80% run
  - b. Find Maximal speed
3. Maximal Sprint Testing (5 mins rest in between sets)

## Appendix 8

### Overground Testing Set-up



## **VITA**

Fayon Gonzales was born in St. Andrew, Jamaica. The last child of Lorenza and Tets Gonzales, she graduated from St. Jago High School, Spanish Town, St. Catherine, Jamaica, in spring 2012. By fall of 2012 she was enrolled in the University of Texas at El Paso after being granted a full scholarship from the Track and Field Team, where she participated in: Discus, Hammer, Javelin and Weight throw. She graduated from her undergraduate degree in Kinesiology with academic honors. After earning her bachelor's degree, she entered the University of Texas at El Paso's Kinesiology graduate program in the fall of 2016 and was employed as a teaching assistant. During her graduate studies, she was invited to attend the National Strength and Conditioning Association Conference in Indianapolis where she presented her pilot study on "Comparison of Stride Length and Stride Frequency Patterns of Sprint Performance in Overground vs Motorized Treadmill Sprinting". In the near future, her plan is to pursue a doctoral degree with a focus on strength and conditioning.