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The Effects of Opedix < Sup > Tm < / Sup > Knee Support System

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THE EFFECTS OF OPEDIX ™ KNEE SUPPORT SYSTEM

ON LOWER EXTREMITY BIOMECHANICS

DURING WALKING AND JOGGING

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INTRODUCTION: Knee supports are often employed to decrease adductor angle and/or adductor moment and thus medial knee joint loading in persons with medial knee osteoarthritis. It is compelling that these gait alterations would also be considered beneficial in healthy individuals from a prophylactic application. While the Opedix product was designed specifically as a knee support system, in the present study lower extremity kinematic chain with emphasis on hip and knee were investigated.

PURPOSE: The purpose of this study was to test Opedix garments and describe the changes in sagittal (X), frontal (Y), and transverse (Z) planes for both kinematic and kinetic data at the ankle, knee, and hip during walking and jogging.

METHODS: Fifteen healthy subjects between the ages of 18-28 (20 ± 1.3) performed ten walking and ten jogging trials with (W) and without (WO) the knee support garment system. Subjects walked at a self-selected pace, which was then controlled by step length demarcations along the collection runway and was kept constant for all trials. Ankle, knee, and hip angles, joint reaction forces, joint reaction force integrals, and joint moment were all calculated in the sagittal (X), frontal (Y), and transverse (Z) planes of motion. Forces were displayed in 2 fashions, peak forces and force integrals – making this a novel study. Changes in these dependent variables were assessed while wearing and without wearing the garment in walking and jogging, independently utilizing paired t-tests.

RESULTS: While walking the following decrease occurred from without the garment to with the garment: Hip Angle-Z decreased 31.6%, Hip Force-X decreased 19.3%, Hip Force-Y decreased 34.4%, Hip-X moment decreased 13.7%, and Hip-Y moment decreased 15.4%. While jogging, the following decrease occurred from without the garment to with the garment: Hip Angle-X decreased 6.5%, Hip Angle-Y decreased 15.7%, Hip Angle-Z decreased 42.3%, Hip Force-X decreased 27.6%, Hip Force-Z decreased 3.6%, and Hip Moment-X was decreased 28.3%.

CONCLUSIONS: The garment had some kinematic and kinetic effect on joints tested, but consistencies did not exist at each plane. Based on the interpretation of joint reaction forces at the hip, this product can be used to slow the progression of OA.

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CHAPTER I

INTRODUCTION

Knee supports (rigid unloader braces and neoprene sleeves) are often employed to decrease adductor angle and/or adductor moment and thus medial knee joint loading in persons with medial knee osteoarthritis. It is compelling that these gait alterations would also be considered beneficial in healthy individuals from a prophylactic application. Yet, the comfort of rigid braces and neoprene sleeves in a young active population may pose wear-compliance issues. Retail apparel with 'built-in knee support systems' are being advocated to increase compliance for such purposes.

The Opedix product tested does not identify with either compression garments or tights, but rather as a knee support system. Regardless, compression garments, tights, and knee support systems are relatively new to market. Published research has only started to become available in the 1990s. Since then, what has been studied are the physiological effects (specifically during recovery) and subject performance. While the Opedix product was a knee support system, the hip was reviewed to determine if any changes occurred within the lower extremity kinematic chain.

The study design included both self-selected walking and jogging trials. Walking was defined as one foot remaining on the ground at all times, whereas jogging consisted of an airborne phase in which both feet were off the ground at a cadence faster than that of walking.

Osteoarthritis (OA) can be described as a result of repetitive mechanical loading, or repeated wear on a joint from forces over an extended period of time [1]. Osteoarthritis was reviewed as it was believed to be related to joint reaction forces. If an intervention could be made to reduce the loads, it is believed that the progression of OA may be slowed.

This study reviewed three joints of the lower extremity: the ankle, knee, and placed the greatest emphasis on the hip. During normal walking, forces comparable to that of 4 to 5 times body weight occur at the hip; which over time may lead to deterioration of the hip [2]. While the forces at any joint are often reported as peaks, what is novel within this manuscript is the additional presentation of joint forces as integrals. The integral of joint reaction forces was calculated as it is believed to provide a better depiction of the force exposure, including duration and magnitude, rather than instantaneous peaks.

The experimental protocol required the completion of ten walking and ten jogging trials with and without Opedix garments, totaling four conditions. These conditions were randomized in order, from subject to subject, to reduce the possibility of order bias. The experimental set-up consisted of 10 Vicon cameras and a force plate.

The purpose of this study was to test Opedix garments and describe the changes in sagittal (X: flexion (+) and extension (-)), frontal (Y: varus (+) and valgus (-)), and transverse (Z: internal (+) and external (-)) planes for both kinematic and kinetic data at the ankle, knee, and hip during walking and jogging. The investigators of this study hypothesized that the use of tights would change kinematics and kinetics of the lower extremity (during walking or jogging), due to the interrelationship of the kinematic chain. It was also the goal of this study to discuss the similarities of mechanical forces that contribute to osteoarthritis to the changes (if seen) between wearing Opdeix garments and not wearing them.

CHAPTER II

REVIEW OF RELATED LITERATURE

Phases of Gait

The gait cycle is complex and can be broken into subcategories. A gait cycle consists of alternating and successive strides and steps. A stride can be defined as the distance from a single limb to the subsequent ipsilateral limb contact with the floor. A step is defined as the distance between contralateral limbs. Multiple strides thus contribute to the creation of a gait cycle.

When taking a step, it is necessary to lift a foot off the ground. The term stance is designated as the period in which the foot is in contact with the floor whereas the term swing is classified as the time a foot is not in contact with the floor [3]. A general approximation is that an individual spends 60% of time in stance and 40% in swing [4]; there is an inverse relationship between walking speed and the duration of swing/stance periods [3].

Whether standing stationary or moving dynamically, stability is essential to prevent individuals from falling. Standing stability is dependent on functional balance, which is the alignment between the body and muscle activity at each joint [3]. Standing stability is put into challenge by a top-heavy distribution of mass, multi-segmented supporting limbs, and the geometry of lower extremity joints [3]. Internal forces acting on joints that effect stability are body weight, ligament tension, and muscle activity [3] [5].

When transitioning from a stationary position to one of motion, the distribution of one's mass shifts. Various muscles are called to action as the region of support changes from heel, to flat foot, to forefoot [3] [5]. It is important to remember that muscles alter bone positions, which alter joint kinematics. For this reason the activated muscles during gait will be highlighted. Earlier the gait cycle was broken into two phases: stance and swing. Now the gait cycle will be elaborated further to include active muscles. In an EMG and kinetic study, Jacqueline Perry hypothesized the roles of individual muscles as follows (all of which are from reference [3]):

Initial Contact: Quadricep, Hamstring, and Pretibial Muscles

Loading Response: Gluteus Maximus and Quadricep Muscles

Mid Stance: Gastrocnemius and Soleus Muscles

Terminal Stance: Gastrocnemius and Soleus Muscle

Pre-Swing: Adductor and Rectus Femoris

Initial Swing: Illiacus, Bicep Femoris, and Pretibial Muscles

Mid-Swing: Hip Flexors and Ankle Dorsiflexor Muscles

Terminal Swing: Hamstrings, Quadriceps, and Pretibial Muscles

In 2002, Anderson and Pandy quantified the contributions of individual muscles during normal gait through a three-dimensional muscle-actuated model of the body and a dynamic optimization solution for normal gait over one stride period [5]. From Heel Strike (0% of the gait cycle) to Foot Flat (~9%), the ankle dorsiflexors were the primary supporters [5]. From Foot Flat (~9%) to Contralateral Toe Off (15%), the most significantly contributing muscles were the Gluteus Maximus, Vasti Muscles, Posterior Gluteus Medius, and Posterior Gluteus Minimus [5]. Midstance is a result of both Anterior/Posterior Gluteus Medius and Gluteus Minimus [5]. While approaching Contralateral Heel Strike (50%), also known as late stance, the majority of support is contributed by the Soleus and Gastrocnemius [5]. Between Metatarsal Off (58%) and Toe Off (65%), all support was a result of the ligaments crossing the metatarsal joints [5].

Relevant Motion at Each Joint

When comparing data, it was important to have a known and accepted dataset. This study used normative curve graphs dating back as early as Perry et al's 1992 study. Some may discount this data due to outdated collection methods and technology. Despite the advancements in technology, variations in data can result from variations in a lab's ability to consistently place markers between subjects, calibration of equipment, and calculations of joint centers. In 2004, Al-Obaidi et al tested young adults aged 20 to 29 from two countries, Kuwait and Sweden [6]. While studying both spatial and temporal gait parameters, significant differences were found between the two subject groups [6]. In 2008, Chester et al studied two populations, children aged 3 to 13 years and adults [7] [8]. The study found differences between the two age groups. The researcher stressed the importance of utilizing age-matched normative data [7] [8]. These two studies accounted for variations in comparing data between studies. Therefore, it can be concluded that the most accurate control for age, gender, and geographic location is the use of subjects serving as their own control. For reference purposes, three data sets served as a general outline for accepted values of motion for the hip, knee, and ankle.

The first data set reviewed within this study was by Perry et al (1992). This dataset was chosen as it had the greatest number of joints for which lower extremity ranges of motion were present while walking. In a normal stride, there are two arcs of motion that occur in the sagittal plane of motion, for a total range of motion ranging from 40^{o} to 48^{o} at the hip [9] [10] [3]. From 0% to 50% of the gait cycle, the hip is in extension [3]. From 50% to 100% of the gait cycle, the hip is in flexion [3]. The coronal plane accounts for 10^{o} of adduction and abduction [3]. From 0% to 45% of the gait cycle, there is a first curve of 5^{o} resulting in both adduction and abduction [11]. From 45% to 100% there is a second curve of 5^{o} including both adduction and abduction [11]. The knee was described as the articulation of the femur and tibia. During gait, motion occurs in all three planes. The sagittal plane allows for the greatest movement with 60^{o} of motion, and is responsible for forward progression [3]. The first curve spans from 0% of the gait cycle to 45% of the gait cycle with 20^{o} of motion [3]. The second curve is from 45% to 100% of the gait cycle and ranges in 60^{o} of motion [3]. It is important to recognize that the degree of motion is dependent on the walking cadence. The coronal plane is responsible for vertical balance over a limb [3]. There is roughly 11^{o} of coronal movement while walking [3] [12] [13]. From 0% to 60% of the gait cycle, there is minor movement. From 60% to 75% there is one curve of both adduction and abduction and a second curve of both movements from 75% to 100% [11]. The ankle was described as the joint between the leg (tibia) and the foot (talus); it is also referred to as the tibiotalar joint [3]. Motion at the ankle can be broken into dorsiflexion and plantar flexion, which are responsible for four arcs of motion [3]. Ankle range of motion during walking, in the sagittal plane, range between 20^{o} to 40^{o} [14]. From 0% to 10% of the gait cycle, there is a 5^{o} curve consisting of both flexion and extension [11]. From 10% to 60% there is a second curve ranging in 25^o [11]. The curve ends with 15^o of flexion from 60% to 100% [11].

In a 2012 study by Park et al, fifteen healthy female subjects, aged 21 through 24 years old, participated in a gait study [15]. The excluding criteria consisted of injury or neurologic deficits of the hip and lower extremity within the past three months [15]. Participants were required to complete three walking trials with tight pants and without the tight pants [15]. While not wearing the tight pants (control), the hip had $44.4^o \pm 11.0^o$ of motion in the sagittal plane, $16.8^o \pm 3.7^o$ of motion in the frontal plane, and $34.4^o \pm 11.8^o$ of motion in the horizontal plane [15]. All data was collected with eight Vicon infrared cameras; sampling at a rate of 100Hz [15].

In a 2012 study by Pietraszewski et al, seventeen male subjects, aged 21 through 23 years old, participated in a study to establish a reference data for human gait pattern of men [16]. No participants had suffered a lower extremity injury and all were in healthy condition [16]. The subjects were instructed to walk 10 meters at three self selected speeds; high, preferred, and low [16]. All data was collected with a BTS Smart-E motion analysis system [16]. While 8 repetitions occurred at each speed, the first and last gait cycle was excluded from each condition [16]. During preferred speeds the hip had 45.5^o of motion in the sagittal plane, 11^o of motion in the frontal plane, and 15.1^o of motion in the horizontal plane [16]. In the sagittal plane, the knee had 57.8^o of motion and the ankle had 27.4^o of motion [16].

Gait Speed

The current study design included both self-selected walking and jogging trials. Walking was defined as one foot remaining on the ground at all times, whereas jogging consisted of an airborne phase in which both feet were off the ground at a cadence faster than that of walking. Based on the study by Keller et al, impact forces increased as subjects adopted a higher and less fixed center of gravity [17]. For this reason, the rationale for testing at varied velocities was to observe the response of tights as Ground Reaction Forces increased.

It was the goal of investigators to refrain from having highly variable cadence conditions. Therefore, subjects were instructed to select a self selected walking/jogging pace. Once the subject was able to maintain a speed, steps were marked leading towards the force plate. This ensured that step length was consistent during each trial. Since step length was maintained by researchers, speed was indirectly controlled. Regardless, gait was still variable. Averages of each condition were calculated providing a single value to represent a subject's condition.

Joints of Concern

This study reviewed three joints of the lower extremity: the ankle, knee, and placed the greatest emphasis on the hip. Individuals suffering from hip OA can achieve pain relief and increased hip function by undergoing a total hip arthroplasty (THA) [18]. Typically, a high neck-shaft angle is present in hip prostheses, which reduces the femoral offset, potentially altering the mechanical axes [19]. Shakoor et al revealed that following a unilateral THA, the medial compartment load on the contralateral knee was significantly higher [20]. Following a 10-year follow up study, Umeda et al concluded that the mechanical axes passed through a more medial point of the knee contralateral to the THA side, which most likely led to a faster progression of medial tibiofemoral OA

[18]. Therefore, a THA does not guarantee relief from pain in the lower extremity as discomfort may begin to develop at the knee.

It was important to recognize that a disturbance in the kinematic chain would affect joints throughout the system [21] [22]. Therefore, with the onset of OA at the hip or knee, one must be aware of the likelihood of OA occurring at other joints [23].

Joint Reaction Force at the Hip

During normal walking, forces comparable to that of 4 to 5 times body weight occur at the hip; which over time may lead to deterioration of the hip [2]. In a study by Correa et al, hip contact forces during gait were reviewed. Based on a dynamic optimization solution for walking, muscle contributions to the hip contact force were calculated [24]. The forces reported were those acting on the acetabulum, calculated from the model [25]. The total contributions to peak hip contact force (force/BW) were Anterior: 1.06 N/kg, Superior: 3.94 N/kg, and Medial: 1.48 N/kg [25]. One body weight was reported to be 697N [24]. The contributions to hip contact impulse [(force/BW)*time] were Anterior 34.72 seconds, Superior, 160.38 seconds, and Medial 57.15 seconds [25].

Available Research on Compression Garments

Within this study compression garments and tights were viewed as the same, despite a variance in nomenclature. The Opedix garments tested in this study does not identify with either compression garments or tights, but rather as a knee support system. Regardless, compression garments, tights, and knee support systems are relatively new to market. Published research has only started to become available in the 1990s. Since then, what has been studied are the physiological effects (specifically during recovery) and subject performance. It is the goal of this study to focus on the varying biomechanics while wearing Opedix knee support system.

In a study by Kraemer et al (1998), compression shorts were examined to review total work capacity and force production capabilities in repetitive, high intensity, open and closed kinetic chain exercise movements in the lower body [26]. The activities ranged from squat exercises to isokinetic knee extensions and isokinetic knee flexions. Through all three test conditions, no significant differences were noted between the compression shorts and control [26]. It is important to recognize that the compression shorts tested were not intended to act as high pressure garments, which would be classified as a super bench shirt [26]. In conclusion, the shorts tested did not promote a performance enhancement strategy nor did they have a negative effect on performance [26].

Bringard et al (2005) focused on physiological responses, specifically oxygen cost and sensation responses during submaximal running exercises while wearing compression gear. Compression tights, compression stockings, and a control of nonconforming shorts were compared. A noticeable difference in aerobic energy cost was seen between both the elastic and compression tights when compared to standard shorts, in speeds 10 km/h to 14 km/h [27]. Based on this study, it can be concluded that lower extremity compression garments reduce muscle fatigue and energy consumption by applying pressure in ways in which active muscles are supported [27].

In a study by Bernhardt et al (2005), compression shorts (Coreshorts) were reviewed to measure active range of motion, balance, agility, proprioception, endurance, and power. Statistical differences were noted between braced and non-braced conditions during hip flexion. However, there was no significant difference between hyperextension and abduction of the thigh [28]. The compression shorts may not be advantageous to preventing injury during functional movements [28]. The study primarily focused on healthy populations before testing on injured individuals.

Doan et al (2011) focused on the performance results based off of wearing compression shorts. The study confirmed that there was a reduction in muscle oscillation and an increase during the jump-power test [29]. Of importance to this study, the kinematics showed a decrease in the hip joint range of motion while sprinting [29]. While the same speed was achieved, there was no loss in ROM [29]. Mechanical testing revealed that torque was generated by the garment at the hip [29]. This torque may be advantageous during the gait cycle (during the end of swing phase), specifically when slowing the leg at the end of hip flexion in running; if not, muscle tears can occur [29].

Koldenhoven et al completed a study using Opedix gear [30]. After testing nine females through walking trials, the results of this study suggested that sagittal and frontal knee kinematics were influenced by the garment, but did not alter kinetics [30]. The garment caused an average of 5.7^{o} increase in sagittal plane knee flexion angle (p=0.02) and an average of 1.5^{o} reduction in frontal plane knee adductor angle (p=0.04) at the time of the peak adductor moment. [30] The current study will expand on the sample size, look at additional lower extremity joints, and increase the load on the garment.

Osteoarthritis

For individuals aged 65 years and older, the leading chronic medical condition of disability is arthritis [31]. The term arthritis is encompassing, covering over 100 various types of inflammatory or degenerative diseases at joints [32]. Osteoarthritis (OA) can be described as a result of repetitive mechanical loading, or repeated wear on a joint from forces over an extended period of time [1]. Exercise intensity levels, occupation, Body Mass Index (BMI), obesity, and multiple factors of activity (including sports participation) can affect the risk of OA [33]. Ultimately with OA, articular cartilage deteriorates and its contact area is reduced. Loading cannot be completely eliminated as joints require loading and compression in order for an exchange of nutrients and waste to occur [34].

OA can be explained as the degenerative changes in biological, mechanical, and structural components of articular cartilage [35]. The integrity of cartilage is dependent on the body's ability to balance the degeneration of cartilage and the elements that maintain cartilage [35]. While the root cause of OA is still unknown, it is also unclear why there is a variance of rate in the progression of OA between patients [36]. Through the research of F. Guilak et al, animal and clinical studies have suggested altered and abnormal joint loading can lead to changes in metabolism, structure, mechanical properties, and composition of both joint tissue and articular cartilage, which is believed to collectively contribute to OA [37].

A paradox exists between clinical and laboratory reports (of the knee) when reviewing the mechanical factors on the progression of OA [35]. Clinical studies suggest that subjects with existing OA and increased loads have a higher rate of cartilage breakdown compared to patients with decreased loads [38]. Laboratory studies suggest that loading can enhance the mechanical properties of articular cartilage as a result of an adaptive response [39].

It has been reported that static and dynamic loading patterns have an effect on the regulation of catabolic (break down of molecules) and anabolic (synthesis of molecules) activities of cartilage [33]. During static compression, decreased metabolic activities occur at cartilage, which is dependent on the amount of stress [37].

One hypothesis for the cause of hip osteoarthritis is believed to be a result of abnormal contact stresses [40]. Harris et al reviewed cartilage contact stresses at the hip during walking, stair climbing, and descending stairs within a healthy population [40]. While performing tasks, the loading direction of the cartilage changed as the contact locations moved [40]. Despite the contact location changing between activities, the contact area remained the same with no significant differences [40]. The distribution of cartilage contact stress was non-uniform, suggesting that even within a healthy population the mechanics of contact are specific to the individual [40]. As joint reaction forces increased with activity, the peak stresses at the cartilage also increased [40].

Research Question

The purpose of this study was to test Opedix garments and describe the changes in the three-dimensional kinematic and kinetic data at the ankle, knee, and hip during walking and jogging.

CHAPTER III

METHODOLOGY

Instrumentation

The experiment set-up consisted of 10 Vicon cameras. Sampling rates were set to 200 Hz during data trial capture. For kinematic analysis, thirty-nine reflective markers of varying diameters were attached to specific anatomical landmarks (Figure 1) (Plug-In Gait Marker Set, Vicon Peak, Oxford, UK) on each subject. Figure 1 is a representation of where markers were applied on a subject. Markers varied in size from 14 millimeters to 37 millimeters (mm). The 37 mm markers were placed on the left (L) and right (R) shoulder, L and R ASIS, and the L and R PSIS. The 25 mm markers were placed on the L and R upper arm, L and R elbow, C7, T10, clavicle, Sternum, R scapula, L and R thigh, L and R knee, and L and R heel. The 19 mm markers were placed on the L and R forearm, L and R shank, L and R ankle, and L and R toe. The 14mm markers were placed on the L and R anterior wrist, L and R posterior wrist, L and R finger, and 4 head markers.

Vicon Nexus software (Nexus 1.8.5, Vicon, Oxford, UK) allowed for the reconstruction of all thirty-nine markers in a three-dimensional coordinate system. Joint center positions were calculated based on the three-dimensional model, “Plug-In Gait Model” (Vicon Peak, Oxford, UK). This model divided the body into upper and lower models [41]. The upper body model included the head, thorax, the left and right humerus, radius, and hand [42]. The lower body model consisted of rigid bodies including the pelvis, the left and right femur, tibia, and foot [43]. Joint centers were calculated based on subject specific anthropometric values measured on each subject and consisted of height, weight, shoulder offset, elbow width, wrist width, hand thickness, leg length, knee width, and ankle width.

The angular conventions defined in the data collection system's coordinate system were represented by flexion (+) and extension (-) in the sagittal (X) plane, varu (+) and valgus (-) in the frontal (Y) plane, and internal (+) and external (-) rotation in the transverse (Z) plane.

One AMTI OR6 series force plate, set to collect at 1,000 Hz, was used to collect force data. While the kinetic data was being collected at a sampling rate five times the kinematic data, additional data points were stored but not utilized when calculating joint kinematics.

Participants

Fifteen participants volunteered in this study. Exclusion criteria included individuals who had suffered lower extremity injuries within the last two months and/or had a history of dizziness, vestibular, neurologic, visual, or unstable medical problems that may have restricted their ability to participate in recreational activities. Inclusion criteria consisted of male and female participants aged 18-28 who were recreationally active. Each participant was informed of the experimental risks of the study and was required to sign an informed consent form as approved by the Institutional Review Board (IRB Number 2013-0419) prior to data collection.

The study's participant design was modeled off a study by P. Devita et al. where healthy subjects were deliberately used as an initial test of the hypothesis to eliminate any potential adaptive mechanisms found in ACL-injured individuals, which may have altered the study's outcome [44]. For this study, healthy subjects rather than osteoarthritic subjects were tested.

Procedures

Each participant was brought into the laboratory on two occasions. The first day consisted of completing an IRB consent form and collecting anthropometric values. At this time any concerns by the subjects, regarding the study, were addressed. During the second day, subjects arrived in self selected athletic gear. A warm-up consisted of the subject stretching, walking, and jogging down the 17.0 meter collection runway. There was a 9.0 meter acceleration region prior to the 0.5 meter force platform where subjects could achieve a consistent speed of gait followed by a 7.5 meter deceleration region following the force platform. Coordinating an appropriate starting point for both walking and jogging collections was determined such that full foot contact was made within the force plate. The speeds for both walking and jogging activities were self-selected, but once consistent foot placement was achieved on the force place, this speed was set and controlled by the investigators. Walking was defined as one foot remaining on the ground at all times, whereas jogging consisted of an airborne phase in which both feet were off the ground at a cadence faster than that of walking. All subjects supplied their own athletic footwear.

Cameras were calibrated and sampling rates were set to 200 Hz during data trial capture. The force plate was manually and digitally set to zero to ensure that no force was registered when no mass was present; the force plate was set to collect at 1,000Hz. Ultimately, force data was interpolated down to 200Hz to temporally align the camera data and force data for each trial.

Markers were secured on the subjects using both athletic tape and rubber bands. Marker placement and sizes remained consistent between trials and subjects. A static calibration of the subject was then taken with markers attached. The static calibration was needed to calculate segment lengths as well as the mass of segments.

The experimental protocol required the completion of ten walking and ten jogging trials with and without Opedix garments, totaling four conditions. These conditions were randomized in order, from subject to subject, to reduce the possibility of order bias. Appropriate sizing of the tights were based on manufacturer guidelines. Trials were initiated by audio cues. A trial was considered to be successful if full contact was made, from heel to toe, within the force plate. Following data collections of all four conditions, subjects were required to complete a cool down which consisted of five minutes of walking.

Data Processing

Prior to analyzing any data, the first step required was to ensure that full contact was made from the foot onto the force plate during collections. Upon playback of a trial, it was imperative to note that no markers of interest were missing. If markers were missing and not accounted for, finding joint angles would be impossible. Therefore if markers were missing, a gap filling method was used to fill in missing markers. Gap fill utilized a marker's known trajectory before and after the missing time period to best predict the anticipated trajectory with a cubic spline function. Once all markers were accounted for, it was essential to recheck that all markers were correctly labeled, as the auto labeling of markers occasionally inverted left and right limbs. Both XYZ trajectories and force data were smoothed using a 4^{th} order Butterworth cut off set to a frequency of 20Hz.

The hip, knee, and ankle joints were analyzed in three planes during this study, creating nine points of data per variable. The three planes were represented as X (Sagittal), Y (Frontal), and the Z (Transverse). There were four variables measured: angles, force, the integral of force, and moments. With four variables, each with nine data points, there were a total of thirty-six dependent variables.

The integral of joint reaction forces was taken as it is believed to provide a better depiction of the force exposure, including duration and magnitude, rather than instantaneous peaks.

Data Extraction

Following fifteen subjects, each with forty trials, a total of six hundred trials were present. In order to consistently compare the data, a reliable time frame was needed. It was determined that the time frame would be the stance phase, which was represented by the presence of a vertical ground reaction force (GRF). A representative graph of this curve is presented in Figure 2 for walking and Figure 6 for jogging.

A custom program was created to minimize human error and consistently extract the intended dependent variables. The dependent variables were graphed similar to the representative curves for angular (Figure 3 & 7), force (Figure 4 & 8), and moment curves (Figure 5 & 9). The maximum and minimum values of the thirty six dependent variables, within the time frame established by the vertical GRF, were obtained. The differences between the two values were then compiled into a meaningful data set. One subject was eliminated from the study as a result of data recording failure for one condition; thus leaving fourteen subjects for analysis (Table 1).

Statistical Analysis

A paired sample t-test is similar to a Repeated Measures Analysis of Variance test (RM-ANOVA) when only two conditions are present. Both can be used to compare groups in varying conditions. The two tests differentiate on how many independent variables can be compared. A paired t-test is used when the independent variable has two levels. An RM-ANOVA is used when more than two levels are present. The kinematics and kinetics of walking and jogging are known to be different from numerous previous studies and these differences are well understood. Our study was not interested in identifying these inherent differences nor did we wish to adjust reduce our post-hoc power if the larger, an RM-ANOVA was executed. Thus, a paired samples t-test were conducted on walking and data and then on jogging data independently.

Differences between conditions were examined utilizing a paired samples t-test in IBM SPSS 16.0 with a p-value = 0.05.

CHAPTER IV

RESULTS AND DISCUSSION

Results

To remain consistent with the tables presented the three planes of motion were as follows: X represented the sagittal plane where + indicated flexion and – indicated extension, Y represented the frontal plane where + indicated varus and – indicated valgus, and Z represented the transverse plan where + indicated internal rotation and – indicated external rotation.

Table 2 and Table 3 contain the averaged ranges of walking dependent variable differences for all 14 subjects. Table 6 depicts the statistical results between variables during walking with and without the Opedix garment. Walking had 4 significant differences out of a possible 9 dependent variables. They consisted of the Hip Angle-Z decreasing 31.6% from without to with the garment ($6.38^o \pm 10.26$), Knee Angle-Z decreasing 15.6% from without to with the garment ($2.64^o \pm 3.67$), Ankle Angle-Y decreasing 42.8% from without to with the garment ($2.44^o \pm 2.40$), and Ankle Angle-Z decreasing 24.3% from without to with the garment ($5.4^o \pm 5.22$). When reviewing the kinetics of the lower extremity, there were no significant differences seen at the ankle. Hip Force-X decreased 19.3% from without to with the garment ($1.94N \pm 2.52$), Hip Force-Y decreased 34.4% from without to with the garment ($1.01N \pm 1.07$), and Knee

Force-Y decreased 25% from without to with the garment (0.50N ± 0.81); all of which were significantly different. The moments of the lower extremity were significant at Hip-X decreasing 13.7% from without to with the garment (457.41mm*N ±599.45), Hip-Y decreasing 15.4% from without to with the garment (227.81mm*N ± 308.59), and Knee-X decreasing 15.4% from without to with the garment (215.13mm*N ± 275.02).

Table 4 and Table 5 contain the averaged ranges of jogging dependent variable differences for all 14 subjects. Table 7 depicts the statistical results between variables during jogging conditions. Jogging had 7 significantly different values. They consisted of Hip Angle-X decreasing 6.5% from without to with the garment ($3.53^{o} \pm 4.95$), Hip Angle-Y decreasing 15.7% from without to with the garment ($2.31^{o} \pm 3.59$), Hip Angle-Z decreasing 42.3% from without to with the garment ($6.83^{o} \pm 9.53$), Knee Angle-X decreasing 8.6% from without to with the garment ($2.97^{o} \pm 2.78$), Knee Angle-Y decreasing 31.2% from without to with the garment ($3.44^{o} \pm 5.54$), Ankle Angle-X decreasing 8.41% from without to with the garment ($4.46^{o} \pm 5.72$), and Ankle Angle-Y decreasing 30% from without to with the garment ($2.11^{o} \pm 2.93$). When reviewing the kinetics of the lower extremity, there were significant differences of forces seen at all three joints. Hip Force-X decreased 27.6% from without to with the garment (3.37N ± 2.99), Hip Force-Z decreased 3.6% from without to with the garment (0.82N ± 0.61), Knee Force-Z decreased 1.9% from without to with the garment (0.43N ± 0.75), and Ankle Force-X decreased 2.5% from without to with the garment (0.61N ± 0.97); all of which were significant. The only significant joint reaction force integral was Ankle Force-Y, which increased 25% from without to with the garment (0.04N±0.07). The Hip

Moment-X was significant decreasing 28.3% from without to with the garment (1027.34mm*N±967.99).

Several abbreviations were utilized when presenting data. The following abbreviations were used in tables 2-5: R = right, Δ = delta (change in values), Mom = moments, S _ = subject _ , and XYZ = plane of motion measured. In addition to the previous abbreviations, tables 6 and 7 also used the following: wo = without tights, with = tights, diff = difference in values, and integ = integral.

Discussion

The hypothesis of the study was that the use of tights would change kinematics and kinetics of the lower extremity (during walking or jogging), due to the interrelationship of the kinematic chain.

Kinematic changes were seen in all joints while walking and jogging, but did not consistently occur at each plane. For example: if there was a statistical difference at the ankle in the x-plane, it did not necessarily mean there was a difference at the knee or hip in the x-plane. The kinematic changes are of importance as any change in kinematics is clinically different. However, the concern is if we can accurately detect these changes within our methods.

Joint reaction forces were reported in two fashions. The differences between the maximum and minimum force were reported, as well as the integral of joint reaction force curves. It is atypical to see integral curves, but it can provide an alternative interpretation to data. Joint reaction force integrals took into consideration the duration and magnitude of a given force. When looking at the 18 variables of force integrals between walking and jogging, only 1 variable had a significant joint reaction force integral difference. This is of particular interest as this confirms that there was minimal change in the exposure (duration and magnitude) of a joint to a force, suggesting that the exposure of force did not change whether participants were wearing or not wearing the garments. While two clinical interpretations can be made from the 2 presentations of the joint reaction force data, it is up to the reader to interpret the data as they see fit.

The researchers of this study hoped to draw a link between a reduction in forces from wearing Opedix tights to slowing the progression of OA based on the idea that OA can be described as a result of repetitive mechanical loading, or repeated wear on a joint from forces over an extended period of time [1].Based on the force integrals, with the exception of the Ankle-Y, there were no changes within a specific task. However (based on the moments) if an individual is developing signs of OA at the hip, Opedix garments may slow the progression at the hip, as hip joint reaction force peaks were reduced. This statement was made with the knowledge that a moment is a result of the moment arm and joint reaction force.

Limitations

One limitation of this study was the use of surface markers to estimate the position of joints. Joint centers were estimated based on the subject specific anthropometric values, placement of the markers on the surface of the skin, and did not account for any movement of markers while activities were completed. The lab's ability to consistently place markers is also a concern. Within the same lab conditions, the investigator of this study had a marker placement which fell within the 99% confidence interval [45]. This equated to roughly 3^{o} of error. While some values may appear significant, it is possible that it was a result of marker placement error. A solution to this dilemma is the utilization of a biplane fluoroscopy system. Biplane Fluroscopy systems directly depict bones, eliminating the surface marker motion artifacts in estimating joint positions.

A second limitation of this study was the lack of a normative dataset of accepted ranges of motion in all three planes during a single collection. Cappozoo et al only reviewed the sagittal plane of motion during his research, stating that other planes were associated with higher measurement error [46]. It would be beneficial to present and create datasets that also included frontal and transverse planes of motion.

A third limitation was fit size of the garment. While garment size was determined by the manufacturer's waist sizing chart, it did not account for height. Two subjects may have had the same waist size but could greatly differ in height, which would create different garment coverage at the hip and ankle. In addition, the typical varus position for males and the typical valgus position for females should also be taken into consideration. For ideal sizing, each garment should also take into consideration the individual's height.

While the current study was an evaluation of the acute effects of the garment, it may be of interest for future research to observe the adaptations (if any) that occur during chronic exposure to wearing the garment. During a longitudinal study, it would also be of interest to note any changes in the integrity of the Opedix tights as there would be an increased exposure to sweat and laundry detergent; both of which deteriorate fabrics.

CHAPTER V

CONCLUSION

We hypothesized that the use of tights would change kinematics and kinetics of the lower extremity (during walking or jogging), due to the interrelationship of the kinematic chain.

Kinematic changes were seen in all joints while walking and jogging, but did not consistently occur at each plane. Range of motion was decreased while wearing the Opedix garment. Joint reaction forces had reduced peaks when wearing Opedix garments, but the joint reaction force integrals remained constant. The investigators of this study used force peaks to determine that joint reaction forces were reduced at the hip when wearing the Opedix knee support system. Therefore, the progression of OA at the hip can be slowed when wearing this product.

CHAPTER VI

ACKNOWLEDGMENTS AND DISCLOSURES

Opedix Inc is acknowledged for providing the support garments to conduct this study. The Gustafson Family Foundation is also acknowledged for their monetary donation to the ISU biomechanics lab to support the “teaching through research” educational endeavors of the lab. Neither Opedix Inc nor the Gustafson Family Foundation participated in the planning or conduct of this study. Dr. Michael Torry acknowledges he has the financial disclosures of consulting (on an as needed basis) for Opedix Inc and has a non-realized stock ownership in the Opedix Inc.

TABLE 1. Subject Profiles

Subject	Gender	Height (mm)	Weight (kg)	Age
S3	M	1524.0	88.4	20.0
S7	M	1095.0	86.1	21.0
S10	M	1676.4	71.2	21.0
S15	M	1778.0	87.5	20.0
Male Avg:		1518.4	83.3	20.5
S1	F	1562.1	47.2	23.0
S4	F	1498.6	52.2	20.0
S5	F	1651.0	57.6	23.0
S6	F	1600.0	52.2	20.0
S8	F	1625.6	54.4	21.0
S9	F	1651.0	59.0	20.0
S11	F	1574.8	55.7	18.0
S12	F	1727.2	62.1	18.0
S13	F	1714.5	58.9	22.0
S14	F	1663.7	58.5	21.0
Female Avg:		1626.9	55.8	20.6
Total Avg:		1595.85	63.64	20.6

TABLE 2. Walking Data (Kinematics & Forces) – Page 1

	Walk - Sheet 1	RHip Angle - X (deg)	RHip Angle - Y (deg)	RHip Angle - Z (deg)	RKnee Angle - X (deg)	RKnee Angle - Y (deg)	RKnee Angle - Z (deg)	RAnk Angle - X (deg)	RAnk Angle - Y (deg)	RAnk Angle - Z (deg)	RHip Force - X (N)		RHip Force - Y (N)		RHip Force - Z (N)		RKnee Force - X (N)		RKnee Force - Y(N)	
		?	?	?	?	?	?	?	?	?	?	Integral	?	Integral	?	Integral	?	Integral	?	Integral
Gender	Walk Without																			
M	S3	42.130	18.259	14.908	43.702	13.819	14.908	26.037	2.747	13.693	16.381	0.100	2.504	-0.232	11.937	-3.625	5.962	1.074	1.870	-0.321
M	S7	52.625	9.005	10.675	40.892	4.715	16.957	29.754	2.186	20.481	7.475	0.004	2.083	-0.453	13.695	-3.612	5.598	1.056	1.602	-0.056
M	S10	49.350	18.968	14.577	43.226	4.314	28.780	28.014	3.811	15.532	9.341	0.632	1.955	-0.298	12.035	-3.827	6.108	0.814	1.829	-0.352
M	S15	49.885	14.806	15.827	44.043	8.971	15.565	25.789	4.449	19.199	7.486	0.870	1.454	-0.167	12.159	-4.227	5.942	0.791	2.269	-0.608
M - Avg.		48.497	15.260	13.997	42.966	7.955	19.053	27.399	3.298	17.226	10.171	0.402	1.999	-0.287	12.457	-3.823	5.903	0.934	1.893	-0.334
M - STD		4.481	4.549	2.277	1.423	4.441	6.541	1.860	1.021	3.154	4.232	0.417	0.432	0.122	0.831	0.287	0.216	0.152	0.277	0.226
F	S1	33.681	8.456	46.539	32.296	19.254	15.791	31.492	8.775	37.558	3.435	0.279	1.907	0.290	10.737	-4.232	3.641	1.021	3.157	-1.139
F	S4	51.438	13.945	24.494	32.291	7.302	10.047	25.338	5.764	23.407	12.737	0.406	3.663	-0.480	11.622	-3.052	6.342	1.040	1.807	-0.294
F	S5	47.182	11.708	22.596	31.370	18.052	19.779	28.420	4.786	18.937	9.724	0.278	3.710	-0.438	13.252	-3.336	6.682	0.872	3.749	-0.755
F	S6	42.233	15.636	15.472	32.622	23.393	11.725	45.781	8.868	23.952	9.227	0.328	4.094	0.099	13.213	-4.069	5.044	1.209	3.171	0.306
F	S8	53.865	12.476	38.623	42.159	12.549	18.869	23.351	9.148	27.719	10.321	-0.133	3.624	-0.672	11.205	-3.640	6.025	1.149	1.715	-0.329
F	S9	46.640	14.632	10.437	29.109	22.295	12.527	42.201	9.471	22.938	7.284	0.368	3.853	0.062	12.627	-3.442	4.835	0.966	3.070	0.076
F	S11	51.568	12.564	16.868	47.279	9.399	19.288	37.273	4.459	30.848	10.112	0.363	1.871	-0.216	12.778	-3.905	5.464	0.911	1.873	-0.264
F	S12	48.777	15.247	13.798	37.823	9.971	19.844	32.404	5.451	22.628	10.104	0.480	3.655	0.313	12.244	-3.718	6.796	0.837	2.624	-0.148
F	S13	48.000	12.968	13.828	34.223	12.930	15.754	37.947	4.636	18.485	12.989	0.091	4.829	0.074	15.350	-3.632	6.432	0.965	3.220	0.327
F	S14	55.442	16.289	24.987	30.022	5.884	14.826	27.107	5.206	16.785	11.425	0.568	2.269	-0.255	12.971	-3.425	5.598	0.296	1.700	-0.474
F- Avg.		47.882	13.392	22.764	34.919	14.103	15.845	33.131	6.656	24.326	9.736	0.303	3.347	-0.122	12.600	-3.645	5.686	0.927	2.609	-0.269
F - STD		6.286	2.300	11.666	5.807	6.257	3.577	7.459	2.115	6.280	2.770	0.199	0.990	0.339	1.292	0.355	0.983	0.250	0.768	0.454
Total Avg.		48.058	13.926	20.259	37.218	12.346	16.762	31.493	5.697	22.297	9.860	0.331	2.962	-0.170	12.559	-3.696	5.748	0.929	2.404	-0.288
Total STD		5.663	3.034	10.598	6.168	6.322	4.582	6.822	2.412	6.378	3.080	0.264	1.059	0.299	1.149	0.336	0.831	0.221	0.734	0.395
Gender	Walk With																			
M	S3	40.599	17.623	11.996	43.545	18.412	15.577	26.152	1.424	16.224	11.107	0.376	3.555	-0.221	11.779	-3.652	5.966	0.819	2.375	-0.636
M	S7	51.125	8.727	6.414	41.217	4.860	19.097	25.139	3.907	17.370	7.220	0.329	1.619	-0.372	13.438	-3.658	5.066	0.971	1.567	-0.352
M	S10	49.409	13.249	9.316	42.494	3.179	21.055	26.045	2.512	13.671	7.695	0.468	1.062	-0.059	11.701	-3.824	5.805	1.022	1.911	-0.460
M	S15	47.049	17.246	7.894	42.569	4.519	13.181	30.125	3.916	19.774	5.879	0.542	1.663	-0.223	11.867	-4.300	5.353	1.145	1.522	-0.206
M - Avg.		47.045	14.211	8.905	42.456	7.742	17.227	26.865	2.940	16.760	7.975	0.429	1.975	-0.219	12.196	-3.859	5.547	0.989	1.844	-0.414
M - STD		4.611	4.157	2.377	0.955	7.150	3.523	2.220	1.207	2.536	2.225	0.095	1.088	0.128	0.831	0.305	0.413	0.135	0.394	0.181
F	S1	43.577	13.362	7.590	35.647	7.282	11.042	40.195	4.993	23.309	7.674	0.256	1.565	-0.229	11.427	-4.339	5.520	1.658	1.785	-0.060
F	S4	44.504	8.750	22.583	30.472	12.494	12.242	22.821	3.249	18.145	6.776	0.503	2.485	-0.285	11.558	-3.168	5.511	0.978	1.442	-0.282
F	S5	46.115	13.833	18.576	38.761	2.814	10.712	31.715	2.295	12.316	8.334	0.456	1.991	-0.241	13.914	-3.355	6.229	0.971	1.687	-0.222
F	S6	42.920	14.978	11.730	38.130	14.803	9.461	33.119	3.314	16.282	6.810	0.569	1.503	-0.130	12.870	-3.817	5.899	1.047	1.877	-0.316
F	S8	48.079	12.997	27.061	35.345	5.264	14.125	18.331	4.184	21.150	5.880	0.104	1.890	-0.668	10.124	-3.700	4.118	0.556	1.945	-0.642
F	S9	41.883	11.323	14.952	34.584	12.549	12.673	25.893	1.840	13.851	6.740	0.632	1.754	-0.045	11.845	-3.596	5.277	0.835	2.190	-0.479
F	S11	49.597	9.517	9.482	45.251	3.929	12.279	39.767	3.630	16.639	9.563	0.430	2.047	0.106	12.901	-3.888	5.316	1.126	2.204	-0.390
F	S12	46.423	13.427	17.565	39.078	3.908	16.123	24.619	2.485	13.531	9.033	0.645	1.734	0.068	12.071	-3.645	6.416	0.601	2.010	-0.529
F	S13	47.843	11.763	10.116	36.616	13.421	16.647	33.515	3.292	19.163	10.174	0.312	2.656	-0.090	16.497	-3.800	7.435	0.782	1.875	-0.078
F	S14	47.547	11.294	19.026	31.954	12.480	13.408	28.990	4.498	14.692	7.994	0.202	1.790	0.041	11.868	-3.207	5.239	1.053	2.182	-0.391
F- Avg.		45.849	12.124	15.868	36.584	8.894	12.871	29.897	3.378	16.908	7.898	0.411	1.941	-0.147	12.507	-3.652	5.696	0.961	1.920	-0.339
F - STD		2.529	1.963	6.244	4.132	4.677	2.288	7.140	0.997	3.540	1.388	0.186	0.374	0.227	1.731	0.350	0.879	0.311	0.244	0.187
Total Avg.		46.191	12.721	13.879	38.262	8.565	14.116	29.031	3.253	16.866	7.920	0.416	1.951	-0.168	12.418	-3.711	5.654	0.969	1.898	-0.360
Total STD		3.106	2.759	6.241	4.428	5.218	3.265	6.201	1.033	3.188	1.574	0.162	0.609	0.202	1.502	0.340	0.761	0.267	0.280	0.182

TABLE 3. Walking Data (Forces & Moments) – Page 2

Walk - Sheet 2

Gender		RKnee Force - Z (N) ?	RKnee Force - Z (N) Integral	RAnk Force - X (N) ?	RAnk Force - X (N) Integral	RAnk Force - Y (N) ?	RAnk Force - Y (N) Integral	RAnk Force - Z (N) ?	RAnk Force - Z (N) Integral	RHip Mom - X(mm.N) ?	RHip Mom - Y(mm.N) ?	RHip Mom - Z(mm.N) ?	RKnee Mom - X (mm.N) ?	RKnee Mom - Y (mm.N) ?	RKnee Mom - Z (mm.N) ?	Rank Mom- X(mm.N) ?	Rank Mom- Y(mm.N) ?	Rank Mom- Z(mm.N) ?
	Walk Without																	
M	S3	11.832	-4.137	11.515	2.357	1.490	-0.260	4.317	0.298	4586.737	1458.400	312.809	1375.745	705.798	188.182	1610.420	162.320	206.938
M	S7	13.023	-4.246	13.087	2.244	1.408	-0.202	4.514	0.510	3098.324	1613.997	446.598	1637.552	696.564	193.899	1820.492	191.866	203.098
M	S10	11.483	-4.476	11.380	2.387	1.591	-0.288	4.005	0.354	3225.361	1432.522	298.880	804.415	714.225	234.722	1774.277	150.281	273.181
M	S15	11.580	-4.985	11.971	2.709	2.303	-0.039	4.038	0.354	3129.968	1184.214	291.964	1065.173	876.116	235.342	2019.653	157.964	187.452
M - Avg.		11.979	-4.461	11.988	2.424	1.698	-0.197	4.218	0.379	3510.097	1422.283	337.563	1220.721	748.175	213.036	1806.210	165.608	217.667
M - STD		0.711	0.377	0.775	0.199	0.410	0.111	0.242	0.091	719.788	177.802	73.205	362.990	85.598	25.507	168.439	18.199	37.957
F	S1	10.698	-4.661	10.793	2.606	1.441	-0.307	3.906	0.385	1536.756	973.649	135.140	957.775	712.089	293.069	1572.824	128.756	253.191
F	S4	11.823	-3.533	12.162	2.041	1.626	-0.313	3.778	0.237	3504.768	1626.947	486.109	1183.859	655.532	338.133	1843.475	146.716	335.035
F	S5	12.530	-3.787	13.021	2.129	2.140	-0.072	4.928	0.266	3448.433	2365.752	274.584	1483.089	946.244	236.309	1908.406	133.211	269.122
F	S6	12.292	-4.565	12.431	2.513	2.273	-0.386	2.997	0.071	3034.834	1376.479	405.565	1540.552	608.225	309.870	1710.699	166.647	309.806
F	S8	11.851	-4.271	11.678	2.708	1.028	-0.182	3.467	0.078	3530.817	1470.237	490.534	1776.608	666.393	213.624	1884.371	102.058	225.436
F	S9	12.380	-3.980	11.996	2.191	3.354	-0.581	3.953	0.113	2865.808	1725.968	484.016	1528.739	877.321	343.323	1838.505	243.528	502.472
F	S11	12.659	-4.555	12.354	2.566	1.960	-0.249	3.593	0.262	2842.305	1318.881	415.202	1281.900	867.403	205.163	1649.159	247.454	228.709
F	S12	12.315	-4.343	12.162	2.325	2.675	-0.506	5.109	0.355	4118.035	1354.795	289.387	1765.919	711.161	281.402	2057.188	172.811	438.441
F	S13	15.648	-4.134	14.278	2.301	2.508	-0.323	4.948	0.273	3871.246	1395.247	344.451	2100.298	683.070	242.654	2282.794	295.715	420.650
F	S14	11.752	-4.143	11.601	2.300	1.298	-0.223	3.372	-0.005	3911.359	1388.967	406.370	1049.137	849.094	304.458	1764.815	214.686	250.138
F- Avg.		12.395	-4.197	12.248	2.368	2.030	-0.314	4.005	0.204	3266.436	1499.692	373.136	1466.787	757.653	276.800	1851.224	185.158	323.300
F - STD		1.274	0.360	0.925	0.221	0.709	0.150	0.738	0.131	749.265	363.178	113.997	356.543	116.036	49.733	205.160	62.486	98.254
Total Avg.		12.276	-4.273	12.174	2.384	1.935	-0.281	4.066	0.254	3336.054	1477.575	362.972	1396.483	754.945	258.582	1838.363	179.572	293.119
Total STD		1.130	0.371	0.864	0.209	0.641	0.146	0.633	0.143	721.990	316.111	102.526	362.936	105.034	52.498	190.085	53.513	97.305
Gender	Walk With																	
M	S3	11.358	-4.195	10.785	2.327	1.581	-0.329	4.425	0.480	3636.891	1634.135	312.455	925.553	873.327	254.978	1627.847	179.586	261.030
M	S7	13.361	-4.334	13.681	2.378	1.543	-0.197	3.545	0.175	2657.911	1436.497	449.057	1184.046	802.578	232.659	2015.972	247.898	220.103
M	S10	11.322	-4.408	11.549	2.382	1.551	-0.281	3.712	0.294	2985.098	942.381	295.353	838.280	643.619	269.784	1929.430	151.577	289.990
M	S15	11.395	-4.964	11.865	2.762	1.434	-0.301	3.361	0.300	2408.626	1209.701	322.129	1089.158	661.007	247.223	1923.997	129.108	242.298
M - Avg.		11.859	-4.475	11.970	2.462	1.527	-0.277	3.761	0.312	2922.131	1305.678	344.748	1009.259	745.132	251.161	1874.312	177.042	253.355
M - STD		1.002	0.338	1.228	0.201	0.065	0.057	0.465	0.126	531.773	297.878	70.415	156.178	111.229	15.483	169.626	51.553	29.603
F	S1	11.286	-4.787	11.395	2.769	1.378	-0.311	3.786	0.275	2270.195	1094.505	233.427	1233.277	527.786	190.896	1360.642	126.110	175.700
F	S4	11.252	-3.653	11.584	2.071	1.596	-0.314	3.946	0.353	2400.403	1183.469	352.153	1088.721	522.923	285.032	1791.912	219.676	287.984
F	S5	13.069	-3.855	13.299	2.359	1.568	-0.241	4.716	0.405	3076.327	1343.447	283.229	1379.576	626.995	217.840	1854.268	143.100	247.941
F	S6	12.158	-4.357	12.460	2.367	1.796	-0.345	3.404	0.139	3052.299	1408.698	386.035	1268.509	770.432	317.480	1758.938	153.793	322.362
F	S8	10.453	-4.400	10.424	2.696	1.527	-0.197	2.535	-0.027	1876.449	1179.127	456.626	1156.090	760.416	252.487	1925.511	172.814	248.706
F	S9	11.822	-4.147	11.635	2.298	1.938	-0.383	4.383	0.320	2593.174	1371.824	357.734	1054.204	908.657	302.644	1858.053	198.690	312.257
F	S11	12.569	-4.470	12.368	2.530	2.139	-0.291	4.518	0.313	2722.428	1078.063	333.818	1236.225	857.171	239.332	1574.672	195.594	276.872
F	S12	12.458	-4.288	12.289	2.313	1.948	-0.342	4.976	0.379	4128.690	1064.438	267.881	1364.886	782.380	249.984	2084.817	235.817	264.782
F	S13	16.782	-4.330	16.181	2.421	1.694	-0.262	5.120	0.319	3657.528	1387.989	333.876	1580.547	883.251	231.692	2445.318	277.022	271.928
F	S14	11.274	-3.704	11.380	2.146	2.234	-0.353	2.818	0.038	2834.894	1162.441	375.334	1139.812	804.472	337.121	1711.644	179.364	322.071
F- Avg.		12.312	-4.199	12.302	2.397	1.782	-0.304	4.020	0.251	2861.239	1227.400	338.011	1250.185	744.448	262.451	1836.577	190.198	273.060
F - STD		1.752	0.361	1.572	0.220	0.279	0.057	0.887	0.149	662.203	136.619	64.334	158.244	139.332	46.637	290.519	45.534	43.943
Total Avg.		12.183	-4.278	12.207	2.416	1.709	-0.296	3.946	0.269	2878.636	1249.765	339.936	1181.349	744.644	259.225	1847.359	186.439	267.430
Total STD		1.550	0.365	1.443	0.209	0.263	0.056	0.780	0.141	607.995	186.400	63.400	189.003	127.653	39.863	255.704	45.681	40.304

TABLE 4. Jogging Data (Kinematics & Forces) – Page 1

	Jog - Sheet 1	RHip Angle - X (deg)	RHip Angle - Y (deg)	RHip Angle - Z (deg)	RKnee Angle - X (deg)	RKnee Angle - Y (deg)	RKnee Angle - Z (deg)	RAnk Angle - X (deg)	RAnk Angle - Y (deg)	RAnk Angle - Z (deg)	RHip Force - X (N)		RHip Force - Y (N)		RHip Force - Z (N)		RKnee Force - X (N)		RKnee Force - Y(N)	
		?	?	?	?	?	?	?	?	?	?	Integral	?	Integral	?	Integral	?	Integral	?	Integral
Gender	Without																			
M	S3	44.402	18.379	9.437	26.946	6.662	18.744	46.310	5.769	28.238	11.642	-0.355	3.379	-0.099	19.851	-2.675	10.989	1.116	3.618	-0.379
M	S7	45.068	8.403	10.111	37.621	7.850	21.865	47.402	3.588	34.042	16.024	-0.731	5.918	-0.382	25.331	-2.753	16.183	1.431	4.350	-0.285
M	S10	46.431	12.046	11.820	40.412	11.171	32.794	55.715	8.055	31.377	10.255	-0.515	2.487	-0.131	24.928	-3.026	12.554	1.425	8.250	-0.840
M	S15	46.932	15.151	15.283	32.342	7.910	17.783	43.377	5.921	25.273	9.702	-0.254	2.918	-0.024	21.125	-3.285	9.300	1.210	7.145	-0.933
M - Avg.		45.708	13.495	11.663	34.330	8.398	22.797	48.201	5.833	29.733	11.906	-0.464	3.675	-0.159	22.809	-2.935	12.256	1.295	5.840	-0.609
M - STD		1.174	4.267	2.614	5.953	1.936	6.889	5.290	1.825	3.803	2.864	0.208	1.539	0.155	2.735	0.278	2.936	0.157	2.211	0.325
F	S1	35.323	8.061	44.594	38.431	11.732	43.250	61.631	9.868	38.944	6.910	-0.249	1.951	0.116	18.840	-2.810	10.879	1.278	7.128	-0.895
F	S4	44.698	19.352	17.045	28.833	12.252	16.868	38.135	6.373	26.457	12.506	-0.190	5.374	-0.487	19.072	-2.344	11.568	1.267	3.840	-0.352
F	S5	45.239	15.080	14.287	33.050	15.410	31.265	47.482	7.195	24.100	18.672	-0.418	4.436	-0.148	23.682	-2.860	11.037	1.199	11.787	-1.130
F	S6	35.836	17.914	13.475	26.279	12.634	14.519	60.634	8.521	27.634	8.911	-0.322	5.365	-0.433	17.918	-3.111	9.356	1.404	2.832	0.406
F	S8	52.281	13.090	24.440	37.040	18.067	39.923	51.917	12.896	38.570	15.120	-0.566	8.057	-0.733	20.957	-2.747	12.969	1.543	8.372	-0.715
F	S9	45.974	20.398	7.391	30.697	16.722	15.293	59.931	7.358	23.784	10.094	-0.163	6.559	-0.427	21.389	-2.768	12.453	1.395	2.816	0.209
F	S11	45.739	11.541	12.844	36.005	11.665	32.317	66.510	6.081	37.663	13.617	-0.402	2.200	-0.127	23.343	-2.856	13.360	1.226	5.249	-0.356
F	S12	45.955	11.586	14.538	40.252	7.506	26.007	48.937	5.907	24.070	12.807	-0.260	3.880	0.099	22.864	-2.855	12.786	1.228	3.356	-0.201
F	S13	56.670	14.898	14.997	39.473	12.283	29.421	56.981	3.663	19.293	16.391	-0.510	3.502	-0.133	25.464	-2.822	16.387	1.435	3.504	0.087
F	S14	49.924	19.101	18.345	37.307	5.263	27.633	48.341	7.672	24.336	10.462	-0.187	3.298	-0.215	20.231	-2.602	9.631	0.868	4.867	-0.460
F- Avg.		45.764	15.102	18.196	34.737	12.353	27.650	54.050	7.553	28.485	12.549	-0.327	4.462	-0.249	21.376	-2.778	12.043	1.284	5.375	-0.341
F - STD		5.456	3.235	4.437	4.602	3.878	8.222	8.136	2.370	6.168	2.991	0.139	1.702	0.237	2.266	0.198	2.009	0.184	2.848	0.448
Total Avg.		45.748	14.643	16.329	34.621	11.223	26.263	52.379	7.062	28.842	12.365	-0.366	4.237	-0.223	21.785	-2.822	12.104	1.288	5.508	-0.417
Total STD		4.571	3.449	4.145	4.279	3.716	7.570	7.525	2.265	5.570	2.892	0.166	1.658	0.216	2.291	0.223	2.160	0.163	2.566	0.436
Gender	Jog With																			
M	S3	42.956	17.469	12.170	25.982	11.784	20.858	46.261	2.697	30.052	11.724	-0.101	4.016	-0.047	19.594	-2.826	9.264	0.912	5.547	-0.680
M	S7	38.733	8.573	7.741	35.069	5.204	20.903	39.175	7.275	31.067	8.023	-0.482	2.655	-0.254	24.045	-2.906	12.471	1.242	5.717	-0.559
M	S10	45.244	10.614	13.586	38.812	8.662	26.490	51.774	5.500	29.418	9.025	-0.597	2.926	-0.029	23.495	-3.096	14.206	1.727	8.379	-0.896
M	S15	36.451	11.795	10.607	30.191	6.708	18.944	50.607	5.295	27.397	9.408	-0.455	3.364	-0.324	19.633	-3.329	10.837	1.489	4.266	-0.468
M - Avg.		40.846	12.113	11.026	32.514	8.089	21.799	46.954	5.192	29.483	9.545	-0.409	3.240	-0.163	21.692	-3.039	11.695	1.342	5.977	-0.651
M - STD		3.742	1.602	2.394	3.694	1.544	3.201	5.685	0.982	1.504	0.687	0.080	0.320	0.127	1.994	0.177	1.434	0.210	1.705	0.184
F	S1	44.858	14.657	8.955	30.994	5.957	19.288	60.469	7.148	34.915	8.059	-0.427	4.430	-0.383	18.236	-2.817	12.154	1.656	2.099	-0.076
F	S4	39.186	10.439	10.841	25.733	12.319	18.727	39.769	3.440	20.388	8.157	-0.026	5.164	-0.382	18.528	-2.363	10.637	1.201	2.629	-0.263
F	S5	41.256	14.988	9.400	29.874	4.487	18.791	43.653	3.881	20.963	10.526	-0.277	4.790	-0.307	23.943	-2.692	13.706	1.310	3.629	-0.302
F	S6	36.357	15.944	10.802	28.146	8.456	15.159	49.809	5.457	27.042	7.724	-0.235	3.773	-0.440	17.832	-3.169	9.485	1.446	1.847	-0.189
F	S8	46.533	12.599	15.412	35.450	5.215	20.394	43.962	4.547	20.791	9.597	-0.504	3.252	-0.498	19.539	-2.739	9.229	1.055	7.049	-0.870
F	S9	41.821	14.978	9.352	28.264	9.342	18.531	47.076	2.091	15.952	8.456	-0.021	3.812	-0.331	19.698	-2.863	10.741	1.282	4.242	-0.475
F	S11	43.635	6.504	4.285	35.449	4.058	24.150	61.304	4.095	18.723	8.561	-0.302	3.425	-0.042	22.810	-2.838	12.717	1.358	5.993	-0.564
F	S12	42.764	6.878	9.573	36.927	4.554	23.848	40.551	4.223	21.907	9.584	-0.101	2.736	0.073	22.576	-2.918	10.419	1.032	5.321	-0.565
F	S13	45.881	12.244	5.221	30.712	9.156	27.343	46.692	4.184	24.855	9.866	-0.358	3.630	-0.239	24.095	-2.987	12.795	1.195	4.244	-0.330
F	S14	45.318	14.949	4.997	31.379	12.938	33.352	49.676	9.472	31.206	7.136	-0.404	3.407	-0.232	19.407	-2.643	11.535	1.308	4.778	-0.486
F - Avg.		42.761	12.418	8.884	31.293	7.648	21.958	48.296	4.854	23.674	8.767	-0.265	3.842	-0.278	20.667	-2.803	11.342	1.284	4.183	-0.412
F - STD		3.123	3.352	3.346	3.631	3.226	5.243	6.107	1.922	4.353	1.047	0.159	0.715	0.173	2.274	0.216	1.460	0.129	1.523	0.196
Total Avg.		42.214	12.331	9.496	31.642	7.774	21.913	47.913	4.950	25.334	8.989	-0.306	3.670	-0.245	20.959	-2.870	11.443	1.301	4.696	-0.480
Total STD		3.328	2.969	3.136	3.745	2.802	4.626	5.769	1.759	4.876	0.935	0.177	0.705	0.160	2.207	0.241	1.479	0.175	1.705	0.207

TABLE 5. Jogging Data (Forces & Moments) – Page 2

	Jog - Sheet 2	RKnee Force - Z (N)		RAnk Force - X (N)		RAnk Force - Y (N)		RAnk Force - Z (N)			RHip Mom - X(mm.N)	RHip Mom - Y(mm.N)	RHip Mom - Z(mm.N)	RKnee Mom - X (mm.N)	RKnee Mom - Y (mm.N)	RKnee Mom - Z (mm.N)	Rank Mom- X(mm.N)	Rank Mom- Y(mm.N)	Rank Mom- Z(mm.N)
		?	Integral	?	Integral	?	Integral	?	Integral		?	?	?	?	?	?	?	?	?
Gender	Without																		
M	S3	20.068	-2.859	22.204	1.700	2.318	-0.164	5.759	0.204		3507.584	2444.997	479.477	2720.866	1124.363	221.546	2879.322	117.188	251.261
M	S7	24.358	-2.980	27.006	1.715	2.029	-0.043	9.208	0.492		4966.731	3208.225	924.062	4242.658	1150.233	169.460	3354.577	272.434	195.329
M	S10	23.518	-3.111	26.088	1.781	3.235	-0.109	8.275	0.478		3063.516	2851.053	616.916	2823.911	2339.071	348.378	2975.088	324.931	410.600
M	S15	19.288	-3.448	21.379	2.174	3.711	-0.240	6.561	0.306		2270.871	1790.203	352.947	1909.473	1887.915	425.544	2872.764	224.989	499.765
M - Avg.		21.808	-3.099	24.169	1.842	2.823	-0.139	7.451	0.370		3452.176	2573.619	593.351	2924.227	1625.395	291.232	3020.438	234.885	339.239
M - STD		2.503	0.254	2.791	0.223	0.784	0.084	1.573	0.139		1131.884	608.270	245.416	969.434	593.032	116.890	227.616	88.447	140.607
F	S1	17.636	-2.825	21.170	1.756	3.511	-0.183	5.532	0.267		2359.730	755.944	98.861	2129.795	1272.479	130.736	2602.124	251.193	435.783
F	S4	17.110	-2.455	19.413	1.554	2.004	-0.159	6.202	0.274		3458.578	2122.531	608.929	2294.159	875.372	337.201	2475.131	158.698	327.383
F	S5	21.662	-2.877	25.093	1.812	4.919	-0.168	9.003	0.416		5049.445	2995.582	408.629	2241.130	2219.499	272.338	3058.962	286.748	663.915
F	S6	17.954	-3.270	20.040	1.982	1.515	-0.029	4.680	0.126		2887.448	1818.429	475.518	2779.927	835.751	152.421	2176.743	123.623	234.031
F	S8	20.058	-2.879	24.527	1.887	4.106	-0.183	6.048	0.158		4553.787	2983.856	1100.424	3701.388	2649.255	207.557	2870.013	187.031	343.384
F	S9	19.673	-2.884	23.270	1.807	2.166	-0.113	6.112	0.100		3084.914	2469.689	655.671	3167.864	444.665	424.902	2826.650	201.180	366.782
F	S11	21.468	-3.054	23.964	1.870	5.476	-0.307	6.201	0.117		3604.596	2444.289	626.820	3146.795	2136.184	555.685	2684.598	276.945	495.620
F	S12	21.556	-3.060	24.266	1.798	4.900	-0.364	6.275	0.212		3444.033	1784.225	306.695	3566.401	1418.302	409.821	2790.053	159.732	437.846
F	S13	23.234	-2.969	26.411	1.880	2.885	-0.080	6.511	0.161		5161.810	1753.806	367.774	4449.842	1057.262	357.341	3178.772	220.897	273.706
F	S14	19.926	-2.886	21.845	1.757	2.000	-0.154	5.695	0.026		3306.012	2054.447	461.141	2530.061	1622.783	223.674	2372.265	227.836	223.837
F- Avg.		20.028	-2.916	23.000	1.810	3.348	-0.174	6.226	0.186		3691.035	2118.280	511.046	3000.736	1453.155	307.168	2703.531	209.388	380.229
F - STD		1.818	0.207	2.201	0.112	1.437	0.099	1.078	0.107		806.877	459.649	223.807	685.627	699.205	119.499	305.739	51.429	132.629
Total Avg.		20.536	-2.968	23.334	1.819	3.198	-0.164	6.576	0.238		3622.790	2248.377	534.562	2978.876	1502.367	302.615	2794.076	216.673	368.517
Total STD		2.074	0.226	2.293	0.138	1.256	0.093	1.284	0.148	#	882.499	507.128	219.984	735.621	642.373	112.382	316.968	55.427	126.633
Gender	Jog With																		
M	S3	19.768	-3.025	21.109	1.709	3.173	-0.238	7.079	0.379		3610.563	2470.512	311.359	1872.302	1523.964	377.161	2882.434	164.431	440.269
M	S7	23.911	-3.096	26.973	1.826	1.627	-0.100	6.198	0.254		1754.480	2571.395	567.459	2867.786	1392.007	108.304	3562.831	442.313	194.998
M	S10	21.543	-3.047	25.350	1.816	5.020	-0.252	8.244	0.478		2502.426	1939.821	449.989	3086.096	2126.191	301.076	3224.386	292.327	521.540
M	S15	19.124	-3.472	21.809	2.150	3.019	-0.268	5.968	0.281		2154.349	2114.502	574.656	2528.323	1415.310	368.610	2965.199	171.599	372.816
M - Avg.		21.087	-3.160	23.810	1.875	3.210	-0.215	6.872	0.348		2505.454	2274.057	475.866	2588.627	1614.368	288.787	3158.712	267.668	382.406
M - STD		1.967	0.191	2.202	0.158	1.393	0.076	1.024	0.100		356.806	268.287	63.384	258.690	341.071	111.272	248.991	112.062	133.834
F	S1	16.742	-2.832	20.391	1.897	1.267	-0.052	5.711	0.254		2221.204	2059.807	560.399	2843.387	454.679	106.775	2544.156	113.150	154.812
F	S4	17.142	-2.457	19.256	1.558	1.537	-0.152	6.368	0.328		2385.368	1711.292	408.715	2193.856	733.754	322.420	2487.865	238.436	307.895
F	S5	22.942	-2.805	25.830	1.692	1.567	-0.091	8.370	0.373		3010.174	2281.215	390.617	3076.599	859.327	178.536	3026.598	241.000	237.783
F	S6	17.885	-3.317	20.102	2.009	0.976	-0.118	4.999	0.193		2133.827	1632.990	474.310	2471.197	496.072	147.871	2250.744	92.440	188.095
F	S8	19.275	-2.965	21.457	1.858	4.912	-0.302	5.522	0.052		2726.452	2051.475	743.143	2278.446	1873.351	258.596	2792.319	261.610	586.684
F	S9	19.104	-2.980	21.971	1.822	3.039	-0.200	6.838	0.264		2575.210	2220.318	453.626	2420.754	1324.936	383.749	2737.712	234.667	390.114
F	S11	21.016	-2.919	24.257	1.807	5.841	-0.361	5.404	0.210		2720.968	1698.301	383.432	3129.979	2156.449	534.256	2535.121	178.290	482.083
F	S12	21.543	-3.119	23.203	1.769	5.243	-0.386	6.847	0.290		2808.544	1446.746	218.667	3028.032	1822.353	392.431	2700.649	205.121	435.232
F	S13	22.947	-3.173	24.949	1.927	3.111	-0.162	8.190	0.295		2825.197	2149.286	427.907	2939.525	1639.217	375.381	3360.782	373.990	384.346
F	S14	18.489	-2.744	21.403	1.747	3.046	-0.248	5.484	0.049		2907.457	1483.908	425.683	3184.401	1611.481	300.754	2554.028	180.058	338.143
F - Avg.		19.708	-2.931	22.282	1.809	3.054	-0.207	6.373	0.231		2631.440	1873.534	448.650	2756.618	1297.162	300.077	2698.997	211.876	350.519
F - STD		2.030	0.241	2.096	0.124	1.651	0.100	1.156	0.108		258.216	305.422	128.766	375.762	541.875	111.785	306.680	71.727	115.567
Total Avg.		20.102	-2.996	22.719	1.828	3.098	-0.209	6.516	0.264		2595.444	1987.969	456.426	2708.620	1387.792	296.851	2830.344	227.817	359.629
Total STD		2.045	0.250	2.248	0.139	1.528	0.091	1.095	0.115		344.567	333.593	117.455	336.572	494.450	110.086	370.577	87.124	115.675

TABLE 6. Statistical Results of Walking Dependent Variables

	Walking				Pair Differences	
	Pair	Condition	Sig. (2-tailed)		Mean ($\bar{x}$)	Std. Dev. (σ)
Kinematics	Pair 1	RHipAngXwo - RHipAngXwith	0.127		1.868	4.291
	Pair 2	RHipAngYwo - RHipAngYwith	0.17		1.205	3.101
	Pair 3	RHipAngZwo - RHipAngZwith	**0.037 ***		6.381	10.267
	Pair 4	RKneeAngXwo - RKneeAngXwith	0.312		-1.043	3.707
	Pair 5	RKneeAngYwo - RKneeAngYwith	0.053		3.781	6.661
	Pair 6	RKneeAngZwo - RKneeAngZwith	**0.018 ***		2.646	3.673
	Pair 7	RAnkAngXwo - RAnkAngXwith	0.196		2.463	6.757
	Pair 8	RAnkAngYwo - RAnkAngYwith	**0.002 ***		2.444	2.408
	Pair 9	RAnkAngZwo - RAnkAngZwith	**0.002 ***		5.432	5.229
Kinetics	Pair 10	RHipForceXDiffwo - RHipForceXDiffwith	**0.013 ***		1.940	2.525
	Pair 11	RHipForceXIntegwo - RHipForceXIntegwith	0.18		-0.085	0.225
	Pair 12	RHipForceYDiffwo - RHipForceYDiffwith	**0.004 ***		1.011	1.078
	Pair 13	RHipForceYIntegwo - RHipForceYIntegwith	0.978		-0.002	0.241
	Pair 14	RHipForceZDiffwo - RHipForceZDiffwith	0.43		0.140	0.645
	Pair 15	RHipForceZIntegwo - RHipForceZIntegwith	0.665		0.015	0.125
	Pair 16	RKneeForceXDiffwo - RKneeForceXDiffwith	0.706		0.094	0.915
	Pair 17	RKneeForceXIntegwo - RKneeForceXIntegwith	0.688		-0.040	0.366
	Pair 18	RKneeForceYDiffwo - RKneeForceYDiffwith	**0.036 ***		0.506	0.810
	Pair 19	RKneeForceYIntegwo - RKneeForceYIntegwith	0.574		0.072	0.469
	Pair 20	RKneeForceZDiffwo - RKneeForceZDiffwith	0.585		0.093	0.624
	Pair 21	RKneeForceZIntegwo - RKneeForceZIntegwith	0.907		0.005	0.171
	Pair 22	RAnkForceXdiffwo - RAnkForceXdiffwith	0.869		-0.033	0.738
	Pair 23	RAnkForceXIntegwo - RAnkForceXIntegwith	0.307		-0.032	0.111
	Pair 24	RAnkForceYdiffwo - RankForceYdiffwith	0.194		0.226	0.619
	Pair 25	RAnkForceYIntegwo - RAnkForceYIntegwith	0.64		0.015	0.121
	Pair 26	RAnkForceZdiffwo - RAnkForceZdiffwith	0.422		0.120	0.541
	Pair 27	RAnkForceZIntegwo - RAnkForceZIntegwith	0.695		-0.015	0.141
	Pair 28	RHipMomXDiffwo - RHipMomXDiffwith	**0.014 ***		457.417	599.457
	Pair 29	RHipMomYDiffwo - RHipMomYDiffwith	**0.016 ***		227.810	308.591
	Pair 30	RHipMomZDiffwo - RHipMomZDiffwith	0.175		23.036	60.012
	Pair 31	RKneeMomXDiffwo - RKneeMomXDiffwith	**0.012 ***		215.134	275.022
	Pair 32	RKneeMomYDiffwo - RKneeMomYDiffwith	0.811		10.302	158.338
	Pair 33	RKneeMomZDiffwo - RKneeMomZDiffwith	0.959		-0.643	45.988
	Pair 34	RAnkMomXDiffwo - RAnkMomXDiffwith	0.767		-8.996	111.345
	Pair 35	RAnkMomYDiffwo - RAnkMomYDiffwith	0.564		-6.867	43.393
	Pair 36	RAnkMomZDiffwo - RAnkMomZDiffwith	0.299		25.689	88.832
		* denotes a statistical difference				

TABLE 7. Statistical Results of Jogging Dependent Variables

	Jogging			Pair Differences	
	Pair	**Condition**	**Sig. (2-tailed)**	Mean ($\overline{x}$)	Std. Dev. (σ)
Kinematics	Pair 1	RHipAngXwo - RHipAngXwith	**0.019 ***	3.534	4.950
	Pair 2	RHipAngYwo - RHipAngYwith	**0.032 ***	2.312	3.591
	Pair 3	RHipAngZwo - RHipAngZwith	**0.019 ***	6.833	9.531
	Pair 4	RKneeAngXwo - RKneeAngXwith	**0.001 ***	2.979	2.782
	Pair 5	RKneeAngYwo - RKneeAngYwith	**0.037 ***	3.449	5.543
	Pair 6	RKneeAngZwo - RKneeAngZwith	0.088	4.350	8.838
	Pair 7	RAnkAngXwo - RAnkAngXwith	**0.012 ***	4.466	5.723
	Pair 8	RAnkAngYwo - RAnkAngYwith	**0.018 ***	2.112	2.930
	Pair 9	RAnkAngZwo - RAnkAngZwith	0.104	3.508	7.496
Kinetics	Pair 10	RHipForceXDiffwo - RHipForceXDiffwith	**0.001 ***	3.376	2.998
	Pair 11	RHipForceXIntegwo - RHipForceXIntegwith	0.192	-0.059	0.162
	Pair 12	RHipForceYDiffwo - RHipForceYDiffwith	0.295	0.567	1.947
	Pair 13	RHipForceYIntegwo - RHipForceYIntegwith	0.673	0.022	0.193
	Pair 14	RHipForceZDiffwo - RHipForceZDiffwith	**0 ***	0.826	0.619
	Pair 15	RHipForceZIntegwo - RHipForceZIntegwith	0.056	0.048	0.086
	Pair 16	RKneeForceXDiffwo - RKneeForceXDiffwith	0.288	0.661	2.233
	Pair 17	RKneeForceXIntegwo - RKneeForceXIntegwith	0.856	-0.013	0.272
	Pair 18	RKneeForceYDiffwo - RKneeForceYDiffwith	0.31	0.812	2.878
	Pair 19	RKneeForceYIntegwo - RKneeForceYIntegwith	0.627	0.063	0.472
	Pair 20	RKneeForceZDiffwo - RKneeForceZDiffwith	**0.049 ***	0.434	0.750
	Pair 21	RKneeForceZIntegwo - RKneeForceZIntegwith	0.332	0.028	0.105
	Pair 22	RAnkForceXdiffwo - RAnkForceXdiffwith	**0.035 ***	0.615	0.979
	Pair 23	RAnkForceXIntegwo - RAnkForceXIntegwith	0.652	-0.008	0.066
	Pair 24	RAnkForceYdiffwo - RankForceYdiffwith	0.788	0.100	1.359
	Pair 25	RAnkForceYIntegwo - RAnkForceYIntegwith	**0.042 ***	0.045	0.075
	Pair 26	RAnkForceZdiffwo - RAnkForceZdiffwith	0.844	0.060	1.120
	Pair 27	RAnkForceZIntegwo - RAnkForceZIntegwith	0.397	-0.026	0.111
	Pair 28	RHipMomXDiffwo - RHipMomXDiffwith	**0.002 ***	1027.345	967.994
	Pair 29	RHipMomYDiffwo - RHipMomYDiffwith	0.136	260.408	613.318
	Pair 30	RHipMomZDiffwo - RHipMomZDiffwith	0.211	78.136	222.008
	Pair 31	RKneeMomXDiffwo - RKneeMomXDiffwith	0.244	270.256	829.012
	Pair 32	RKneeMomYDiffwo - RKneeMomYDiffwith	0.495	114.575	609.962
	Pair 33	RKneeMomZDiffwo - RKneeMomZDiffwith	0.743	5.763	64.396
	Pair 34	RAnkMomXDiffwo - RAnkMomXDiffwith	0.312	-36.269	128.946
	Pair 35	RAnkMomYDiffwo - RAnkMomYDiffwith	0.652	-11.143	90.274
	Pair 36	RAnkMomZDiffwo - RAnkMomZDiffwith	0.855	8.888	177.872

* denotes a statistical difference

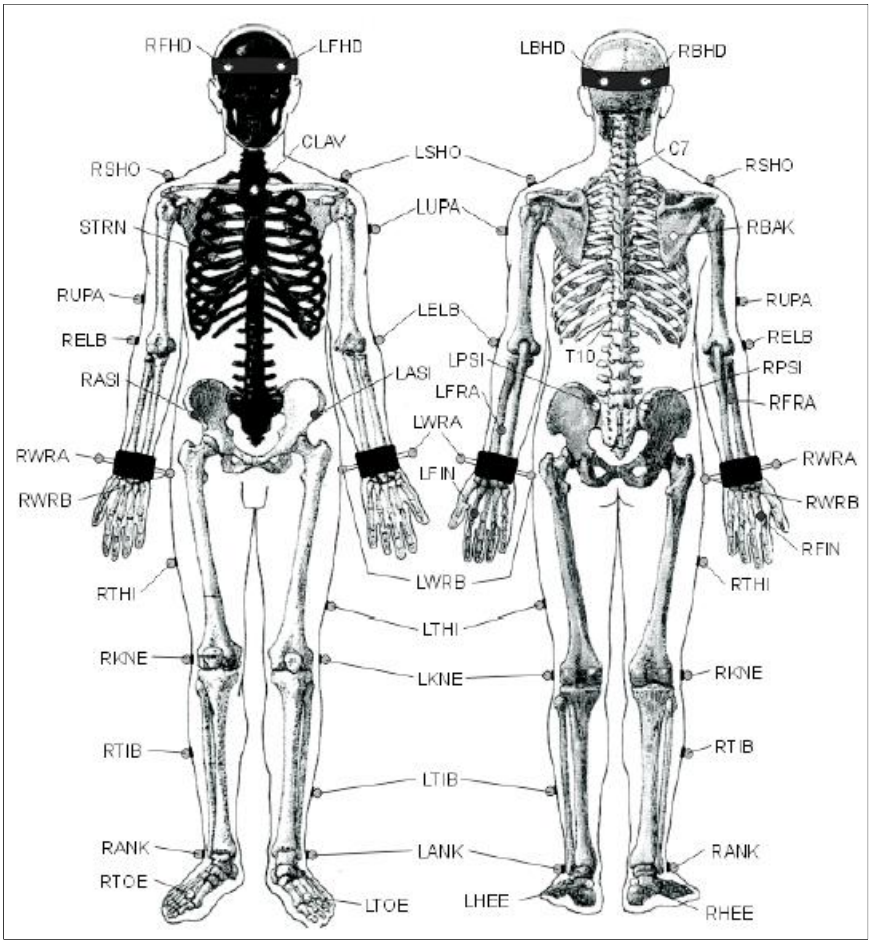
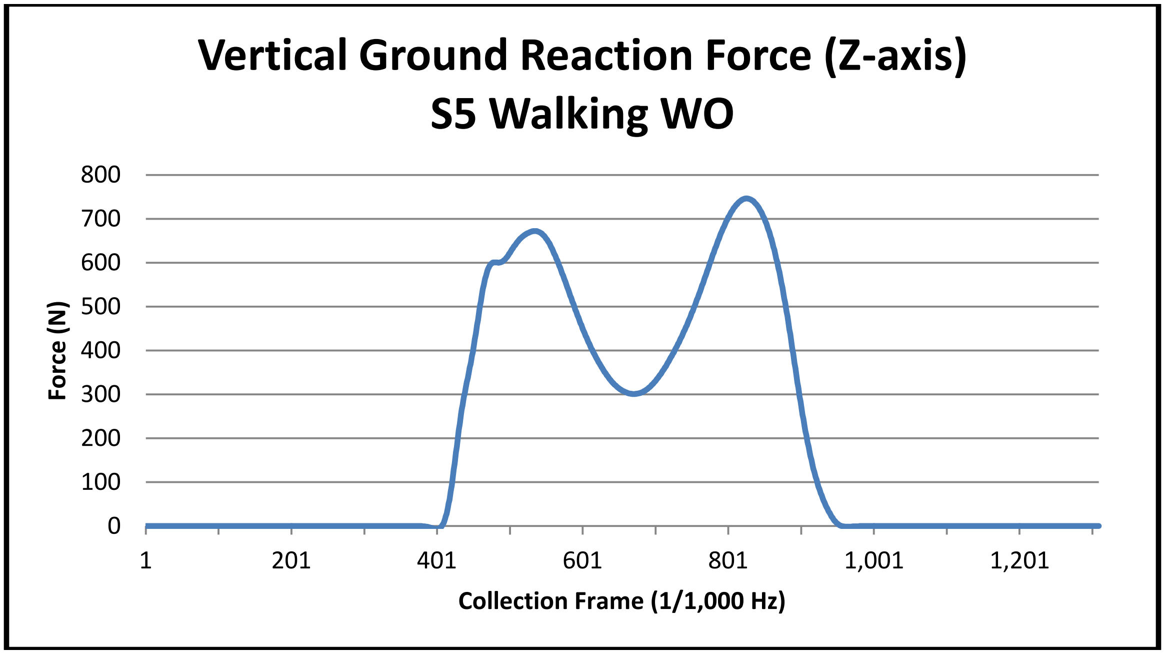


FIGURE 1. Marker Placement Used For Plug-In Gait Marker Set (Vicon, Oxford, UK)



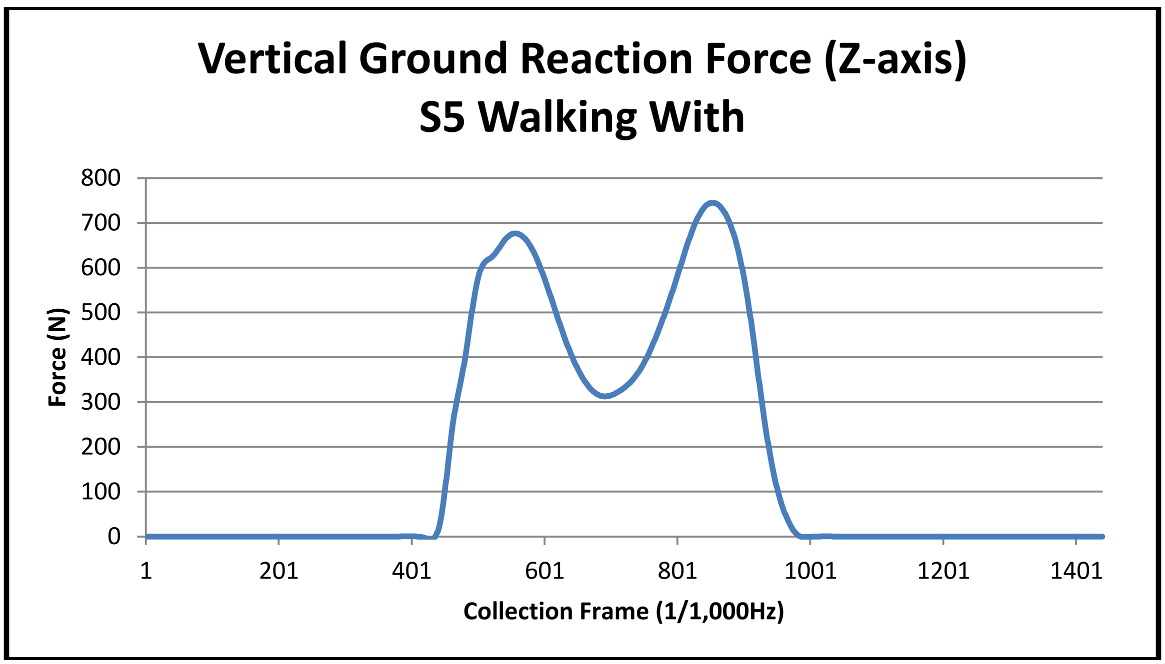
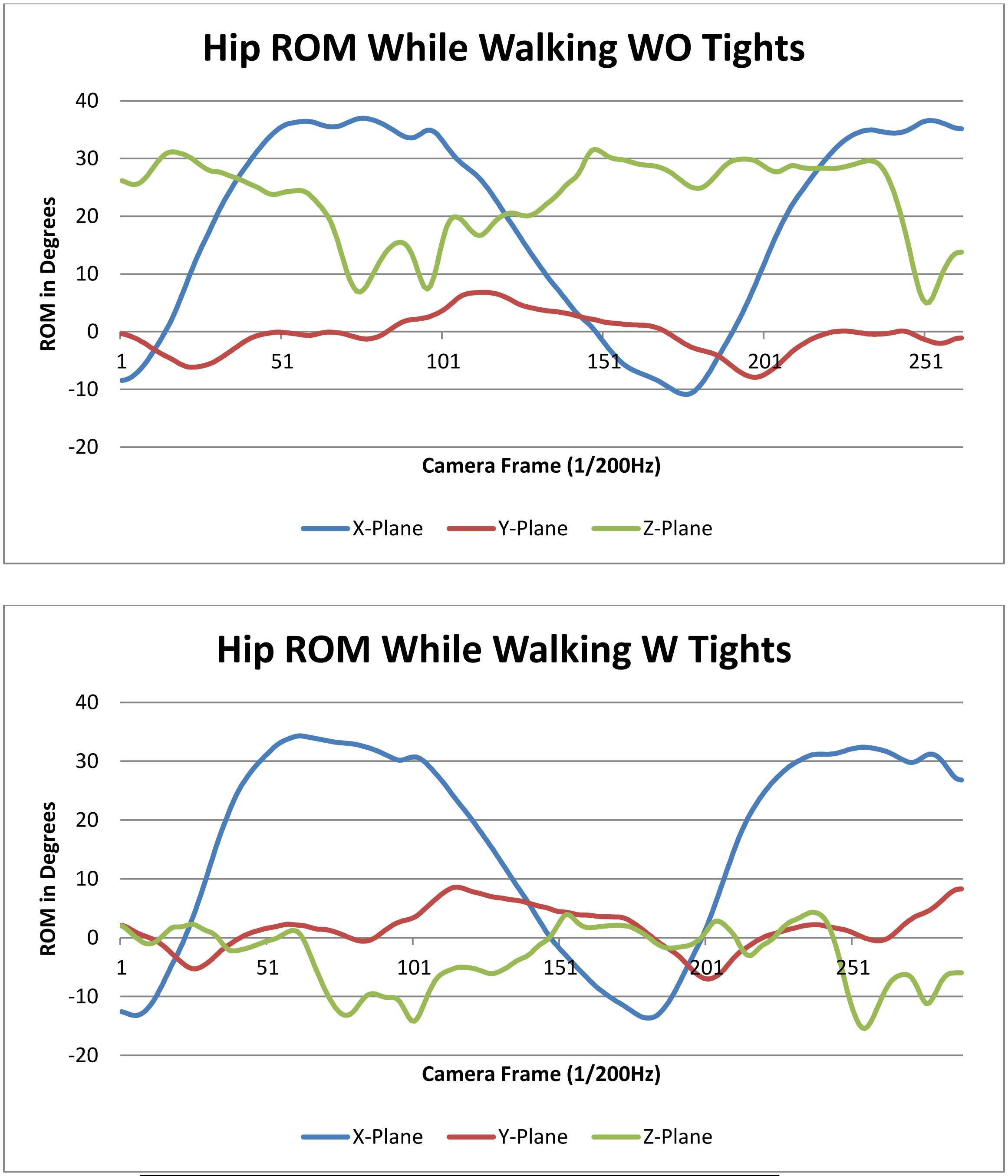
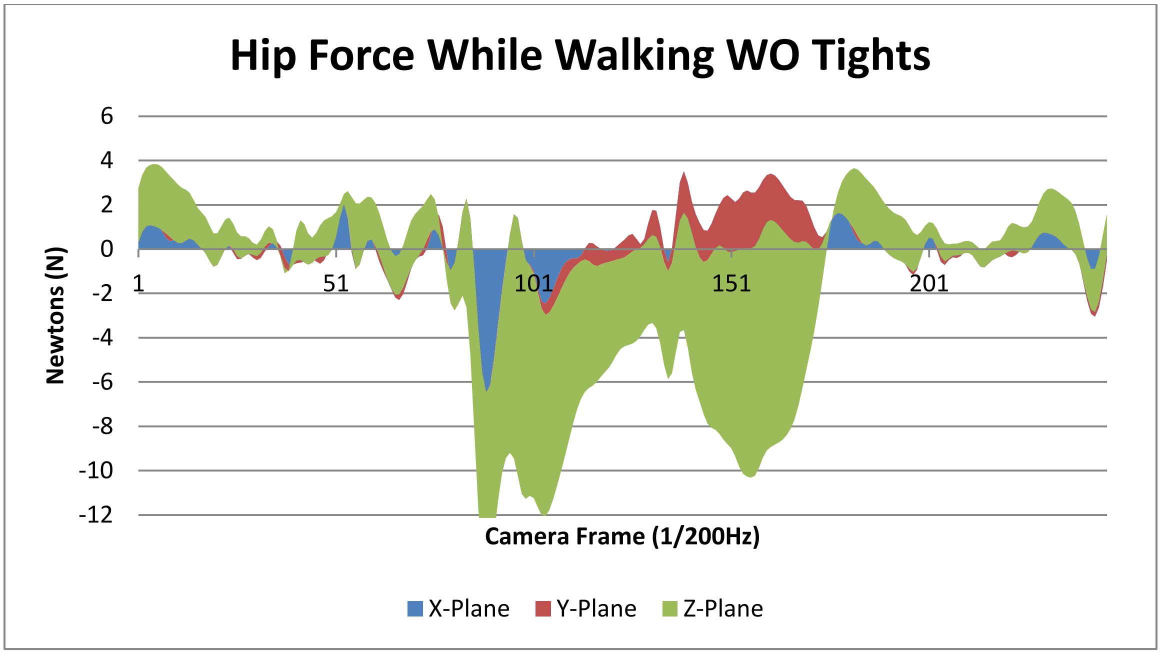


FIGURE 2. Representative Graph of Walking With & Without Tights: Ground Reaction Force (GRF)



Sagittal (X): Flexion (+) and Extension (-)
Frontal (Y): Varus (+) and Valgus (-)
Transverse (Z): Internal (+) and External (-)

FIGURE 3. Representative Graph of Walking With & Without Tights: Hip Range of Motion (ROM)



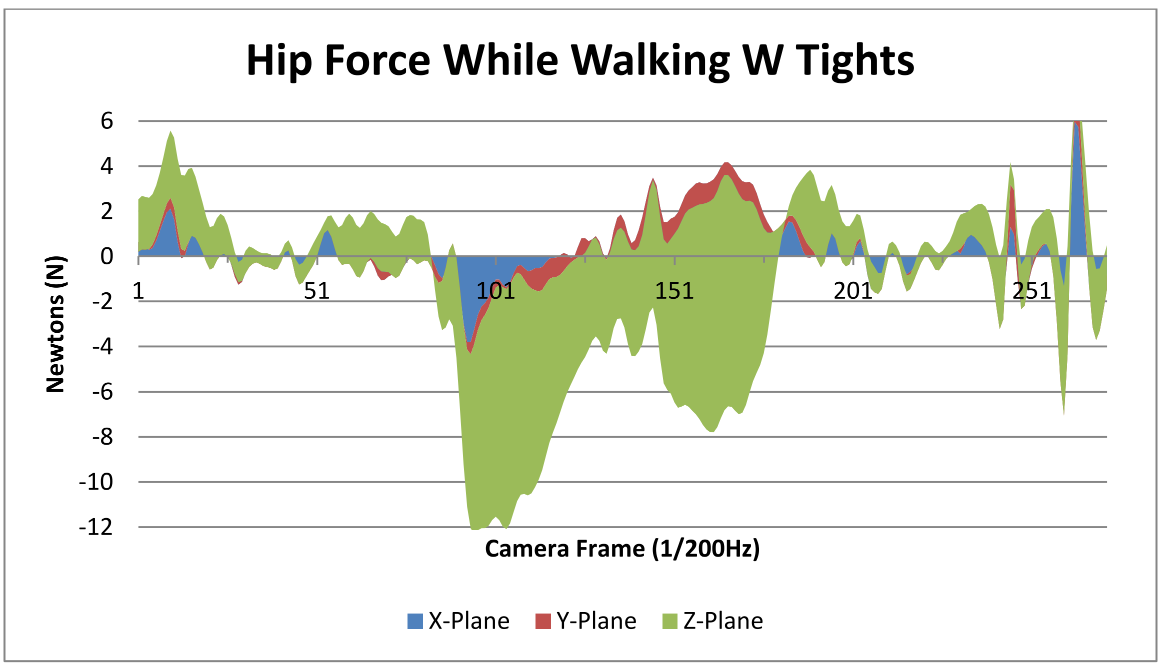
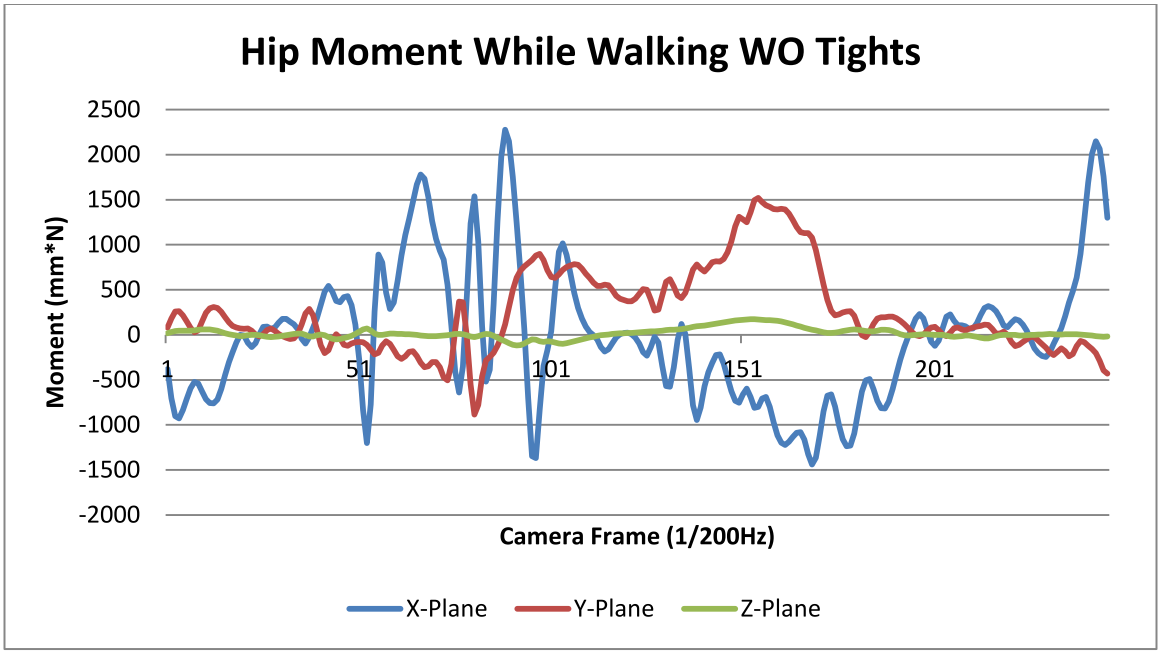


FIGURE 4. Representative Graph of Walking With & Without Tights: Hip Forces



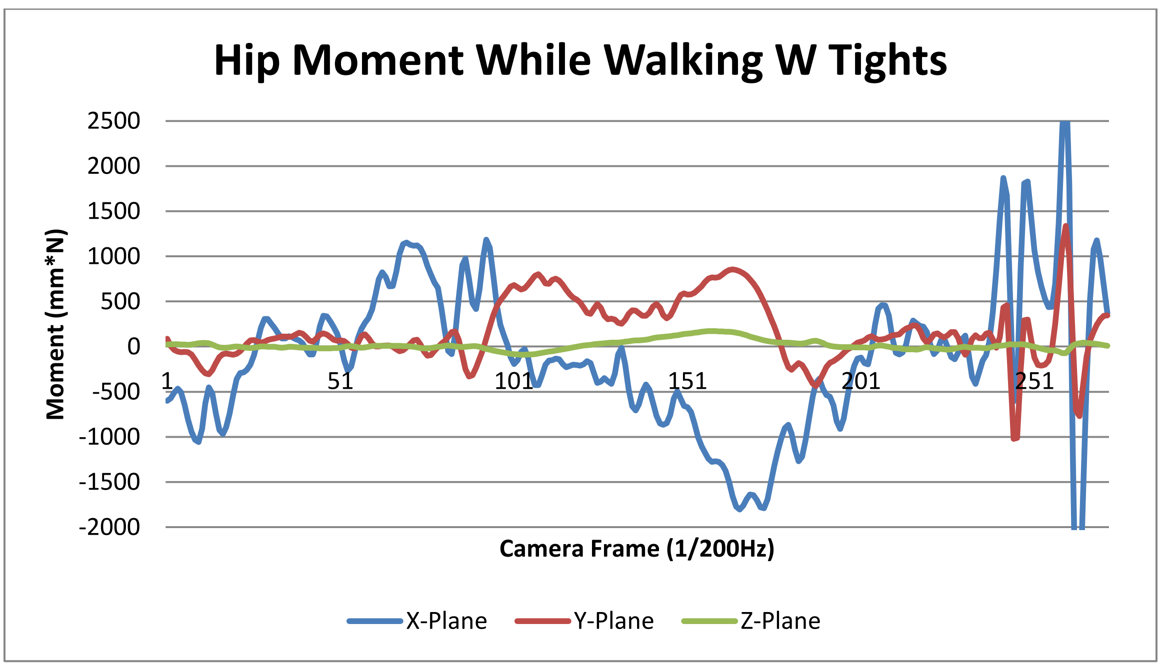
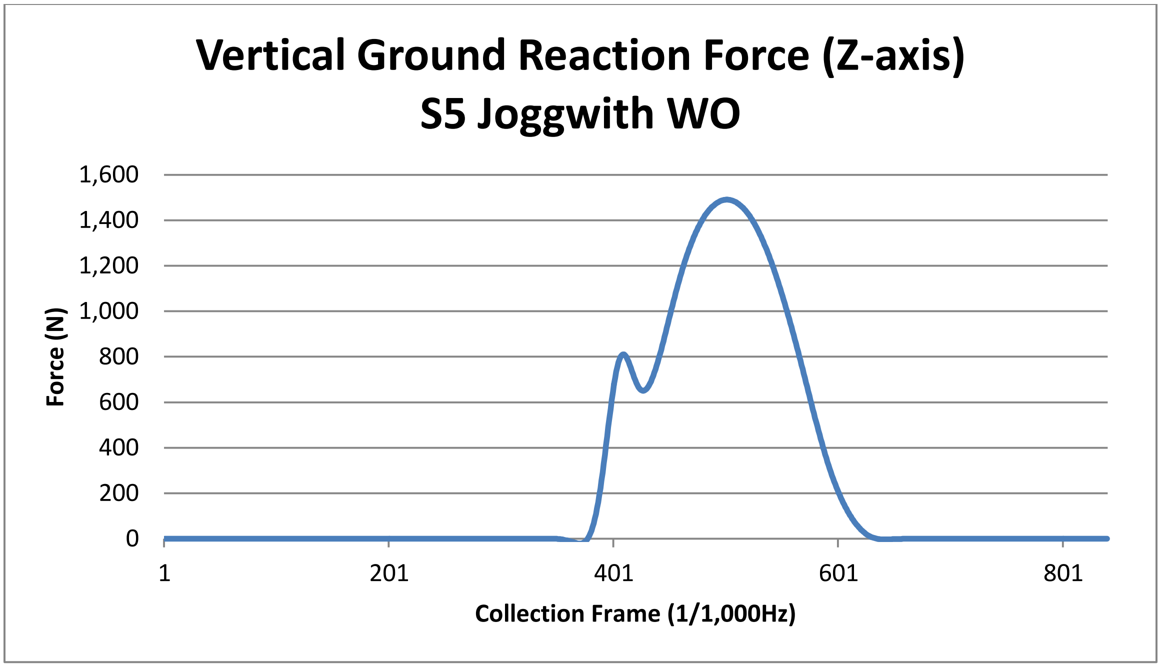


FIGURE 5. Representative Graph of Walking With & Without Tights: Hip Moments



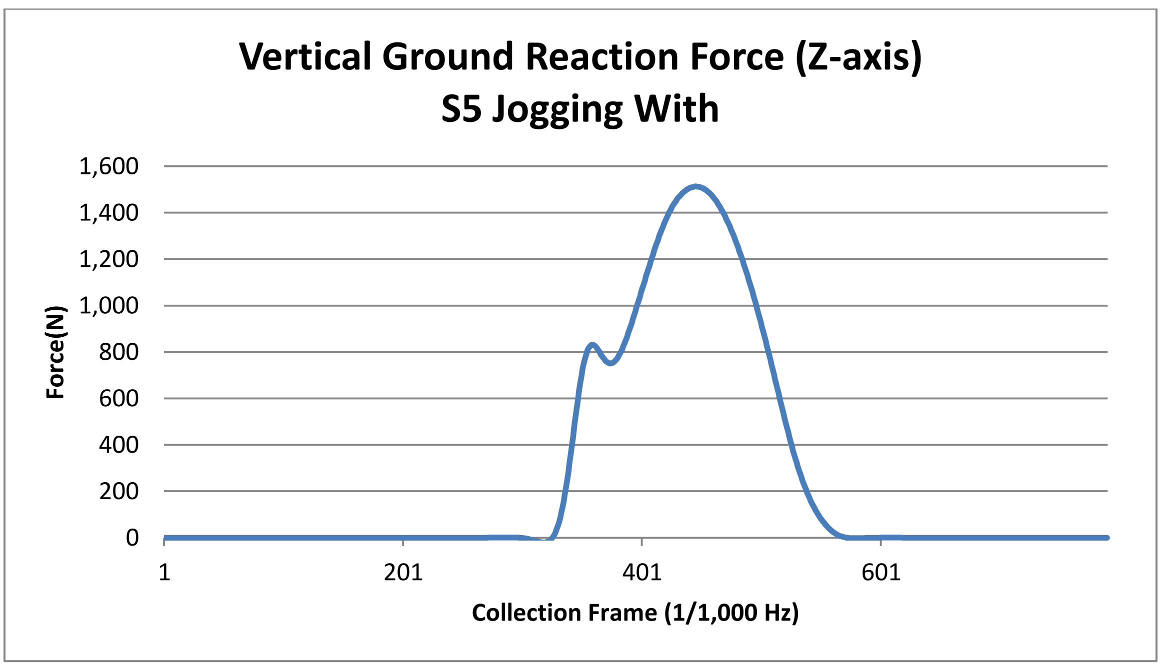
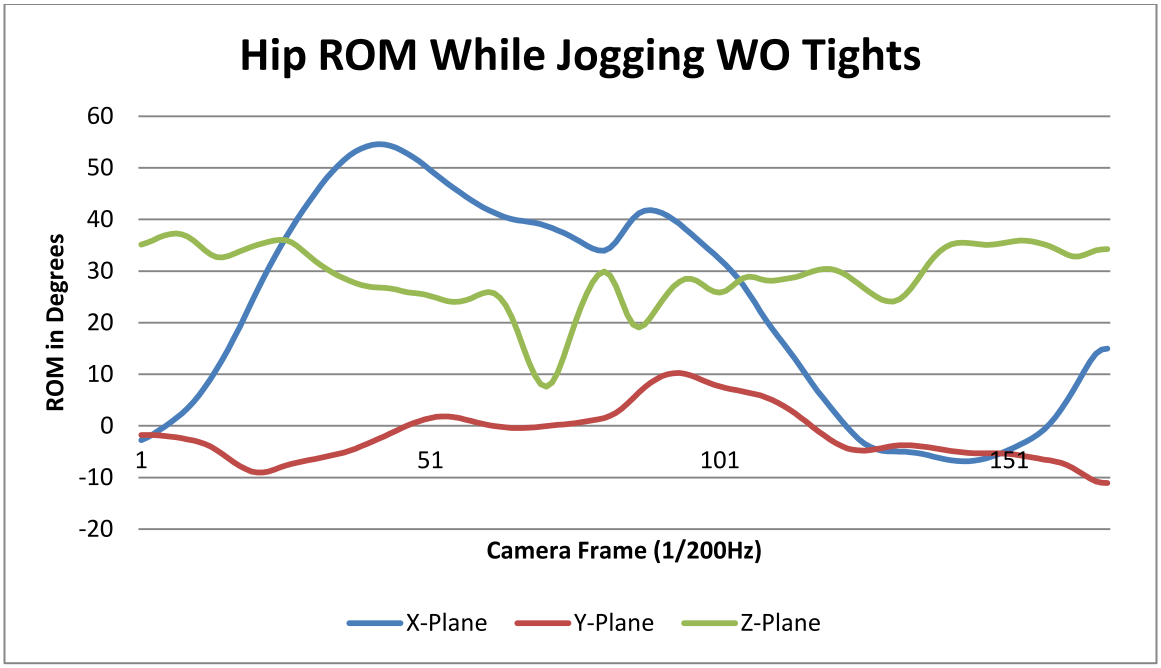
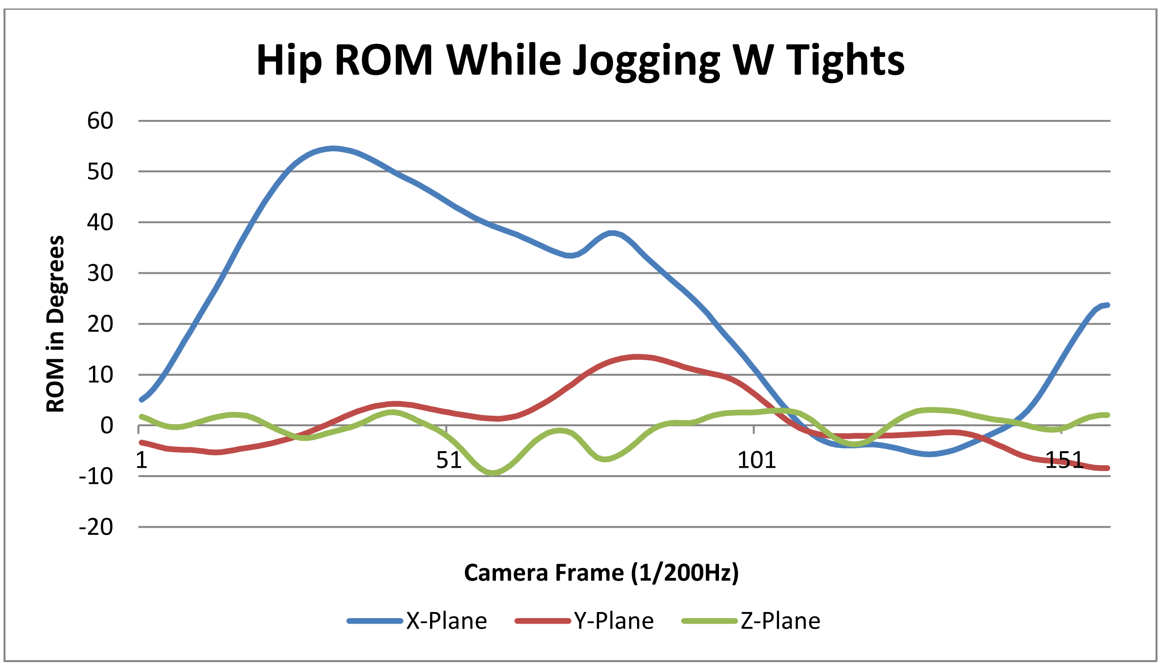


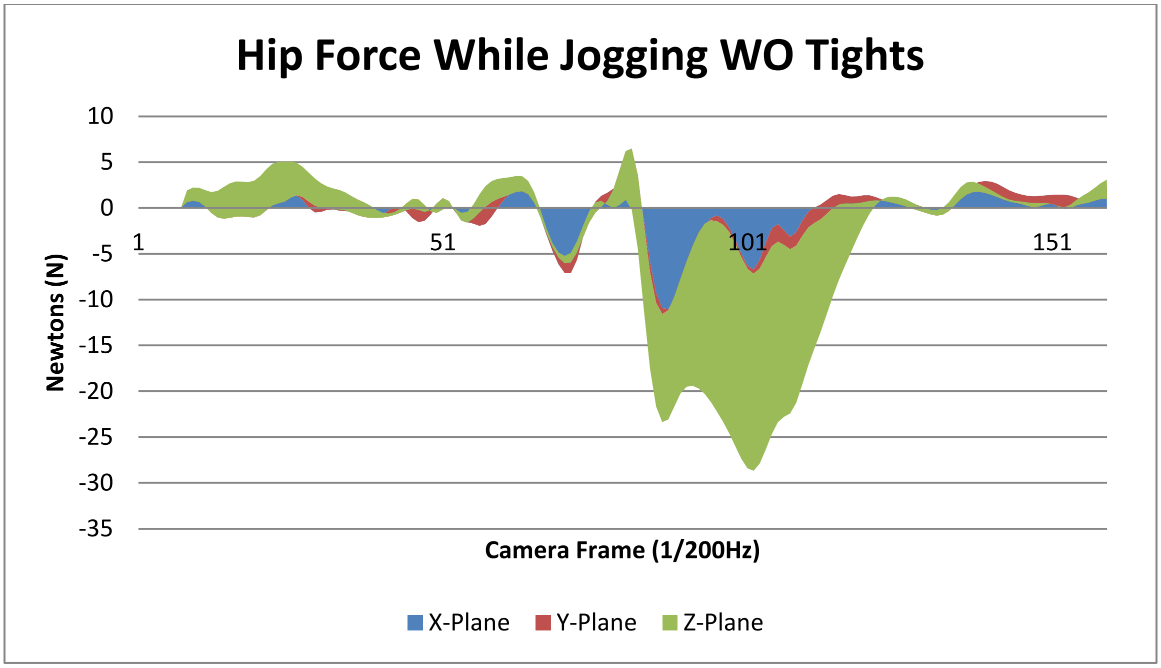
FIGURE 6. Representative Graph of Jogging With & Without Tights: Ground Reaction Force (GRF)





Sagittal (X): Flexion (+) and Extension (-)
Frontal (Y): Varus (+) and Valgus (-)
Transverse (Z): Internal (+) and External (-)

FIGURE 7. Representative Graph of Jogging With & Without Tights: Hip Range of Motion (ROM)



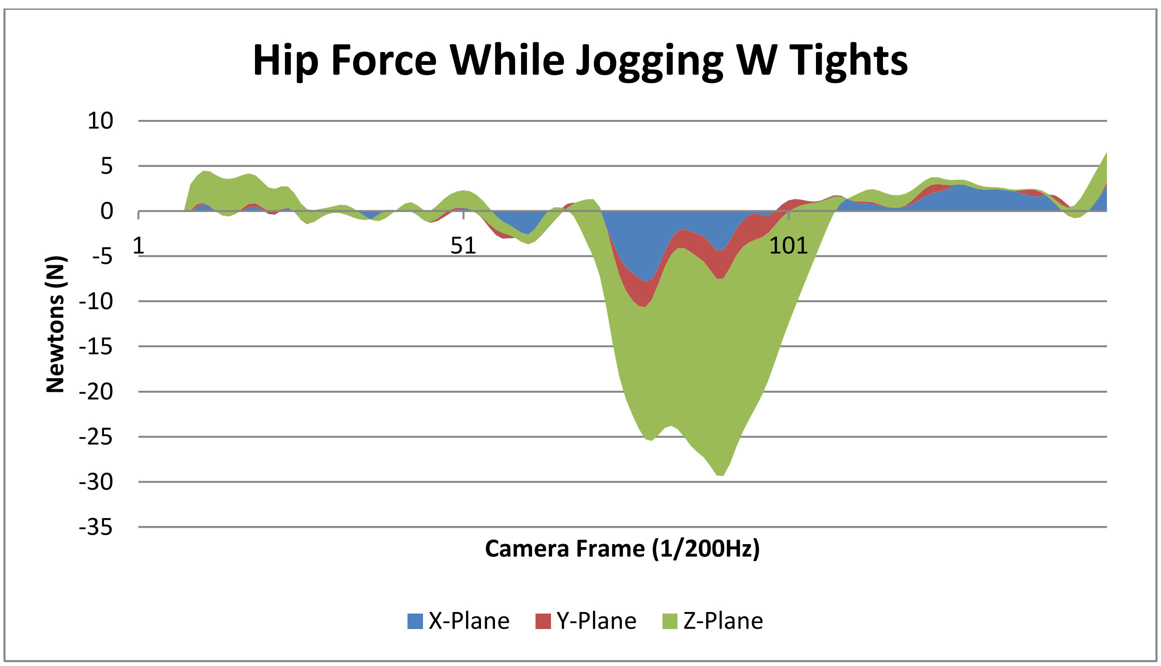
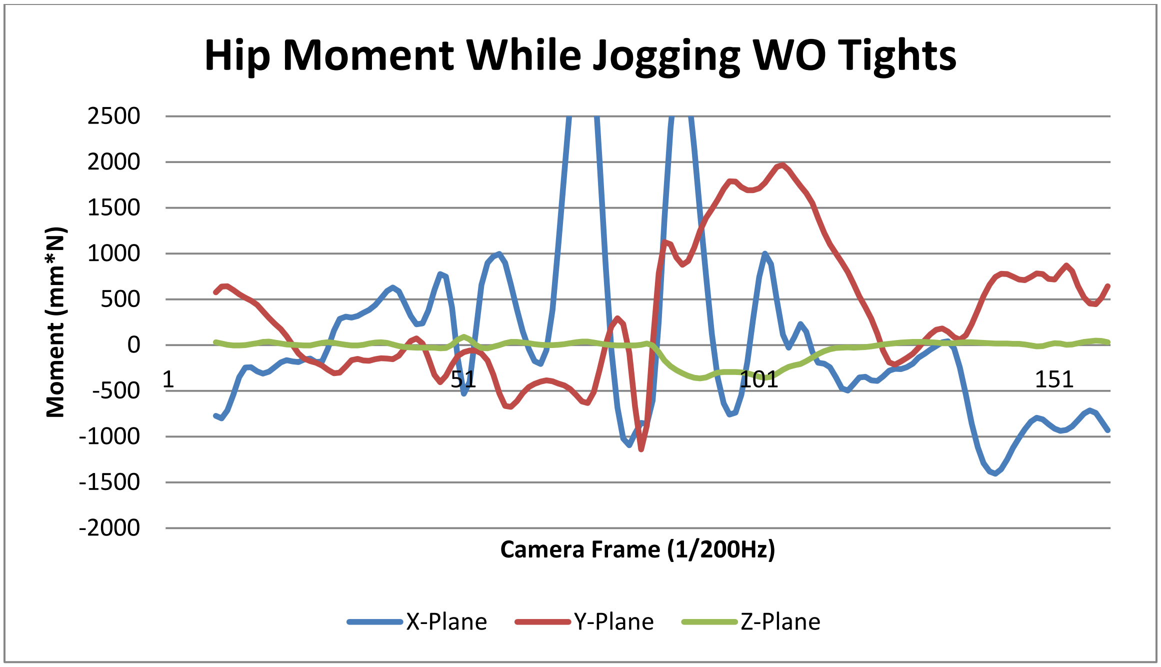


FIGURE 8. Representative Graph of Jogging With & Without Tights: Hip Forces



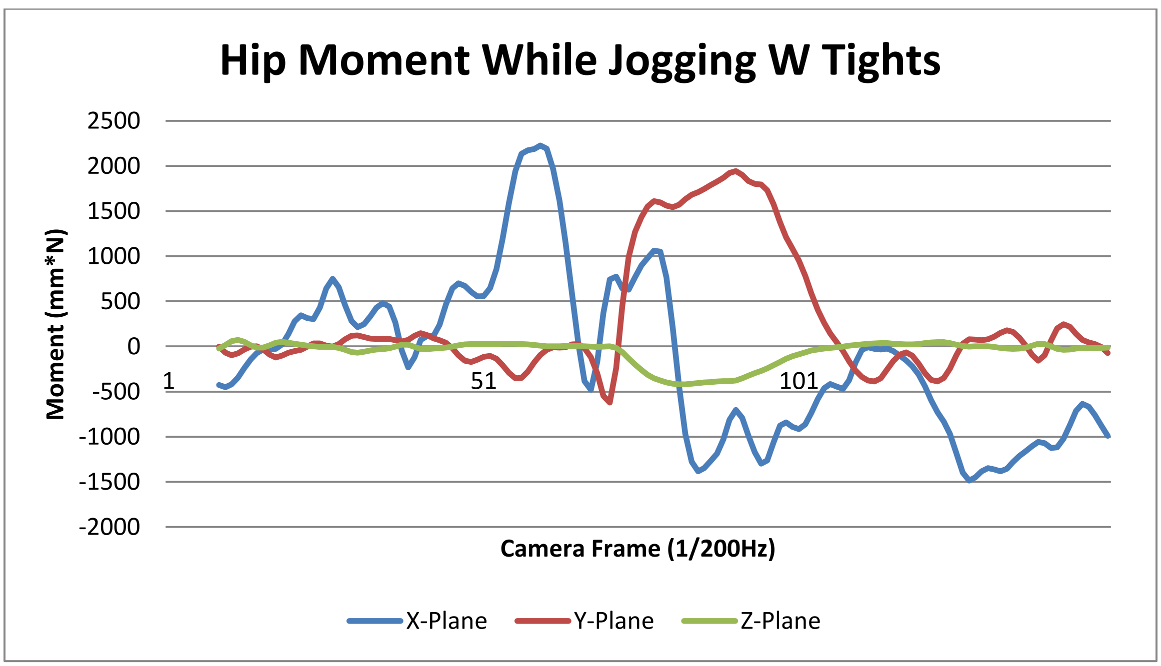


FIGURE 9. Representative Graph of Jogging With & Without Tights: Hip Moments

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