1999

An Electromyographic and Video Motion Analysis Study of Elite Sprinters at Varying Speeds and Inclines

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AN ELECTROMYOGRAPHIC AND VIDEO MOTION ANALYSIS STUDY OF ELITE SPRINTERS AT VARYING SPEEDS AND INCLINES

by

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Bachelor of Science in Physical Therapy
University of North Dakota, 1998

An Independent Study

Submitted to the Graduate Faculty of the

Department of Physical Therapy

School of Medicine

University of North Dakota

In partial fulfillment of the requirements

for the degree of

Master of Physical Therapy

Grand Forks, North Dakota
May
1999

This Independent Study, submitted by Anna Hillig in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Faculty Preceptor)

(Graduate School Advisor)

(Chairperson, Physical Therapy)

PERMISSION

Title	An Electromyographic and Video Motion Analysis Study Of Elite Sprinters at Varying Speeds and Inclines
Department	Physical Therapy
Degree	Master of Physical Therapy

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Signature Anna Hillig

Date 12/16/98

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ACKNOWLEDGEMENTS

I would like to sincerely thank Tom Mohr for his assistance and willingness to work extended hours to help complete this study. Thank you to John Frappier for his time and expertise. Thank you to our subjects who were extremely patient, entertaining, and made the long hours worthwhile. Thank you to my parents who were always there when I needed them. Thank you to Carrie Anderson, Sam Gould, and Teri Parker who were not only my fellow researchers but some of my dearest friends. Lastly, thank you to the PT class of 1999 who inspired me, supported me, entertained me and became part of me.

ABSTRACT

Every athlete trains with the hopes of being bigger, stronger or faster than the competitor. Athletes are eager to jump on the “bandwagon” of new training techniques that claim to produce the results the athlete seeks. One such training technique is sprinting on a treadmill at high speeds and inclines. The purpose of this study is to describe muscle activity and joint motion while running on a treadmill at different speeds and inclines.

Six males between the ages of 21 and 27 years of age ran at 20 miles per hour and 0% grade and at 13 miles per hour on a 30% grade. Surface electrodes and joint markers were used to analyze electromyographic activity of six muscles and calculate joint angles while running. A descriptive analysis was then performed comparing the two trials.

From our results we conclude that the sprinter does adopt different strategies and muscle recruitment patterns to compensate for increases in slope. Examination of range of motion revealed that there was greater overall motion of the hip in the incline trial, motion of the knee was greater during level surface running, while ankle motion remained relatively the same. EMG data showed greater overall activity when sprinting at 13 mph on a 30% incline than when sprinting at 20 mph on a 0% incline.

CHAPTER 1

INTRODUCTION

Every athlete trains with the hopes of being bigger, stronger or faster than the competitor. Athletes are eager to jump on the "bandwagon" of new training techniques that claim to produce the results the athlete seeks. One such training technique is sprinting on a treadmill at high speeds and inclines.

Problem Statement

The problem lies in the lack of research available to attest to the efficacy of this training technique. More research is needed to validate the use of this current training method in order to validate its use in training athletes. Although there is research available regarding the biomechanics of running there is a need for more information pertaining to running biomechanics at high speeds and inclines.[1]

Purpose of Study

The purpose of this study is to describe muscle activity and joint motion while running on a treadmill at different speeds and inclines. Elite sprinters were recruited for this study in order to examine whether or not running on a treadmill at high speeds, and on an incline causes particular muscles to work harder or the sprinter to change their running technique to accommodate the increased workload.

Significance of Study

The data collected will provide information concerning muscle activity and joint angles during sprinting. This information will promote the understanding of the biomechanics of elite sprinters and provide a basis for developing protocols specifically designed for training an elite athlete.

Research Questions

1) What muscles are active during sprinting?
2) When during the gait cycle are these muscles active?
3) Are these muscles more highly recruited while sprinting on an incline?
4) What body angles are consistent with elite sprinters at high speeds?
5) How do elite sprinters change their running strategies to adapt to higher speeds?
6) How do elite sprinters change their running strategies to adapt to increased inclines?

Hypotheses

Null: Muscles recruited and joint kinematics do not change while running at increased speed, or on an incline.

Alternate: Muscle recruitment and joint angles increase with increased speed an incline.

CHAPTER 2

REVIEW OF THE LITERATURE

Successful sprinting, like all other sporting activities, is enhanced by proper training methods. Although several studies have investigated various training techniques, muscle activity, and the related kinematics, few, if any, have examined muscle activity and joint motion of running at high speeds and inclines.[2-13,15]

Gait Cycle

Many studies have compared the biomechanics of gait at different velocities.[2-4] As the speed of gait increases, stride length, stride rate, and velocity increase while complete cycle time decreases.[2-6] Initially the velocity changes are due to an increased stride length, but as the velocity continues to increase (as running progresses to sprinting) the changes are due to an increase in stride rate.[4,7,8] Because of these changes, the typical phases of gait are somewhat different in sprinting. As gait speed increases, the relative length of stance phase decreases while swing phase increases compared to slower locomotion.[2-4,7] The factor which distinguishes walking from running is the relative amount of stance time in the gait cycle.[8] As velocity increases (i.e. running and sprinting) the double support phase is eliminated, and there are periods where neither foot is contacting the ground, known as double float.[1-6,8]

The stance phase is divided into the absorption phase, where the knee and ankle joints are flexing, and the propulsion phase, where all joints are extended.[4,8] These two phases are separated by a single moment in time known as midstance or stance phase reversal, as it is the exact time when the flexed joints begin to extend. The swing phase is separated into initial swing, where the joints are flexed, and terminal swing, involving progressive hip and knee extension. Again, these phases are divided by an instant in time termed midswing or swing phase reversal. The stance and swing phases are subsequently divided by initial contact and toe-off.[4,8] As already stated, with increased speed the ground contact time decreases. In progressing from running to sprinting, the absorption phase ultimately decreases while the propulsion phase remains about the same.[8] This results in decreased impact absorption during sprinting as the support leg is used more as a pivot to give quick support and maintain height from the ground than in shock absorption.[2,8]

Joint Kinematics

With increased velocity of gait total ranges of motion (ROM) of the hip, knee, and ankle increase.[2,3] Due to these changes, at initial contact the body's center of gravity is lowered, resulting in a decreased center of gravity during stride.[2,7] This supports a more efficient and quick gait cycle.

During sprinting, the hip reaches its maximum degree of flexion (80°) approximately two-thirds of the way through swing phase as the thigh nearly reaches horizontal.[3-5] Minimal hip flexion is achieved after toe-off where the hip reaches 15° of flexion.[2,3] Knee flexion reaches 130° at midswing and progressively extends to approximately 30° to 40° of flexion during stance phase.[2,3]

Minimal ankle plantar flexion of 8° occurs halfway through stance phase, immediately before the plantar flexion moment begins. At toe-off the ankle reaches maximum plantar flexion of 35°.[3] It is important to point out that in sprinting, initial contact does not occur at the heel, but on the forefoot.[2-5] Initial contact takes place in plantar flexion, but once the foot contacts the ground, it rapidly dorsiflexes.[2,3]

Muscle Activity

Various muscles are active throughout each phase of the sprinting cycle. Depending on which phase is considered and whether the muscle is accelerating or decelerating a joint, the contraction may be concentric or eccentric. In general, electromyographic activity increases with increased velocity, although there may be a relative decrease in activity during the stance phase (latter one-third) of sprinting.[3,7,8] Simonsen et al.[5] found that most muscle activity to occurred in the terminal swing and early stance phases of the gait cycle.

The gluteus maximus is active in the latter part of terminal swing and in the early stance phase of sprinting.[5,9,10] Its main function is to decelerate the thigh during swing phase (before foot contact) and to stabilize the pelvis and hip joint in the early stance phase when impact occurs.[3,5,6,10]

The biceps femoris has been found to be active in terminal swing and early stance phases of the sprinting cycle.[3,5,8,10] During late swing phase it acts, along with the other hamstring muscles, to decelerate the thigh and leg (two joint muscle).[2,3,6,8,10] It is active throughout early stance phase to stabilize the knee joint, flex the knee, and to increase hip extension to propel the body over the stance limb.[3,8] It is interesting to note that the biceps femoris, primarily a knee flexor, is not active during late stance (propulsion) or early swing phases when the knee is experiencing its greatest amount of flexion. Most of this flexion is not due to muscle activity but rather to the quick acceleration of the thigh in early swing phase.[5]

The gastrocnemius is active during the late stages of terminal swing where it acts to stabilize the ankle prior to heel contact.[2,3] It remains active after heel strike and throughout the stance phase to control the rapid dorsiflexing that occurs and to maintain ankle stability.[2,3,8,9] There is some discrepancy in the literature as to the function of the gastrocnemius in the propulsion phase. Mann et al.[3] and Simonsen et al.[5] concluded that the gastrocnemius was not active in toe-off where as Jonhagen et al.[9] and Ounpuu[8] found the highest activity of the muscle to occur at toe-off.

The activity of the anterior tibialis is seen immediately after toe-off and continues into swing and throughout the absorption phase of stance. The muscle primarily acts to dorsiflex the foot in swing phase for foot clearance and to stabilize and control the lowering of the foot during absorption.[2,3,9] It has also been proposed to actively accelerate the tibia over the stance foot.[5]

The rectus femoris, a two joint muscle, has been considered to be more important as a hip flexor than a knee extensor in sprinting.[7] It is activated during absorption of stance phase and at midswing.[5,8,9,10] It has also been shown to be active in early swing phase to control hip extension.[2,10] In the absorption phase the muscle is acting to stabilize and control the knee flexion that is occurring at heel strike and throughout stance phase.[2,3,8,10] The rectus femoris is then activated once more in midswing to flex the thigh forward to help clear the limb during swing and to begin extending the leg in preparation for foot contact.[8-10] Montgomery et al.[10] has found that peak activity occurs during this time.

Activity in the rectus abdominus was found to occur in the latter portion of the propulsion phase of stance continuing into early swing. It controls the backward and forward motion of the pelvis and appears to correlate with the flexion and extension of the hip (i.e. hip and pelvis flexion occur at the same time).[2]

Training Techniques

Delecluse[11] has proposed several training techniques including neuronal activation, hypertrophy training, and speed-strength training. Both neuronal activation and hypertrophy training use resistive exercises to stimulate the fast-twitch muscle fibers. The author recommends that speed-strength training, which is divided into stretch-shortening exercises (e.g. plyometrics) and sprint-associated exercises, follow these methods. The sprint-associated exercises consist of overload training and overspeed training.

Overload training usually involves sprinting while pulling a parachute of various sizes or uphill sprinting, where an incline of less than or equal to 3^{o} is recommended. This technique is utilized to improve acceleration, speed endurance, and increase stride length.[11] Swanson et al.[12] trained a group of athletes on a high-speed treadmill with a 30% incline and found an increase in stride length, treadmill speed, and hip range of motion as well as possible improved neuromuscular function in the gastrocnemius and soleus. It has also been documented that uphill training at a 10% slope will not only increase stride rate but decrease the period of support as compared to horizontal or downhill training.[1]

Overspeed training consists of downhill sprinting, towing, or high-speed treadmill sprinting. All are done at a supramaximal pace, are aimed at stimulating increased neuromuscular activation, and result in increased stride rate and length and decreased ground contact time as compared to maximal running.[7,11]

It has been found that after adequate training, the treadmill is a good simulator of running since there are no significant differences in the kinematics or energy costs compared to track running.[13]

CHAPTER 3

METHODS

Subjects

Six healthy males gave their informed written consent to serve as subjects in this study (See Table 1). The study was conducted at Orthopedic Associates in Fargo, North Dakota. The study was approved by the Institutional Review Boards at the University of North Dakota and Orthopedic Associates (See appendix).

Table 1. Descriptive Statistics of Subjects

	Mean	Range	Standard Deviation
Age	22.67 (years)	21 – 27	2.21
Height	72.33 (inches)	67 – 78	3.86
Weight	191.67 (pounds)	173 – 215	14.44

Instrumentation

Electromyography

The electromyographic information was collected by a Noraxon Telemyo 8 telemetry unit (Noraxon USA, 13430 North Scottsdale Rd., Scottsdale, AZ 85254). This information was then sent to a Noraxon Telemyo 8 receiver and then digitized by an analog digital interface board in the Peak Analog Module (Peak Performance

Technologies, 7388 S. Revere Parkway, Suite 601, Englewood, CO 80112-9765). The video data and the electromyographic data were synchronized using the Peak Event Synchronization Unit. To start the EMG data collection, the synchronization unit was triggered by a footswitch.

Video

Eight reflective markers were placed on each subject to represent various joint centers in the sagittal plane. The exact placement of each marker is detailed below. The camera used to film the sprinting activity was a Peak High Speed Video 60/120 Hz camera (Peak Performance Technologies, 7388 S. Revere Parkway, Suite 601, Englewood, CO 80112-9765). A camera frequency of 60 Hz was utilized during the trials with a shutter speed of 1/250 of a second. The trials were taped on a JVC model BR-S378U video cassette recorder (JVC of America, 41 Slater Drive, Elmood Park, MF 07407). The video tape was encoded with a SMPTE time code generator.

After recording all of the trials, the subjects movements were digitized using the Peak Motus Software package. The tapes were played back on a Sanyo Model GVR-S955 (Sanyo, 1200 W. Artesia Boulevard, Campton, CA 90220) video cassette recorder for the purpose of digitization.

Protocol

The skin on the lower extremity was prepared by cleansing it with alcohol and shaving away any excess body hair for the placement of the six (6) surface EMG electrodes over the chosen muscles. These muscles were chosen because they have been shown in previous studies to be active during sprinting (See Table 2).

Table 2. Origin, Insertion, and Action of Selected Muscles for Sprinting

Muscle	Origin	Insertion	Action
Rectus Abdominus	Pubic Symphasis Pubic Crest	Xiphoid process 5^{th} to 7^{th} Intercostal cartilage	Flex trunk Stabilize pelvis during walking
Gluteus Maximus	Posterior Crest of Ilium Sacrotuberous ligament	Iliotibial Tract Gluteal Tuberosity	Extend thigh Laterally rotate thigh Extend trunk
Rectus Femoris	Anterior inferior iliac spine	Base of the patella Tibial Tuberosity	Extend leg Flex thigh
Biceps Femoris	Ischial Tuberosity	Head of Fibula	Flex Knee Extend thigh Extend trunk
Gastrocnemius	Condyles of femur	Calcaneal tuberosity	Plantarflexion
Anterior Tibialis	Upper ½ lateral surface of tibia Interosseous membrane	1^{st} metatarsal 1^{st} cuneiform	Dorsiflexion Inversion

The placement of the electrodes was determined by finding each muscle by a previously identified measurement from anatomical landmarks.[14] Figure 1 displays these points anatomically along with a descriptive measurement for each one. The ground, or reference, electrode was placed on the iliac crest.

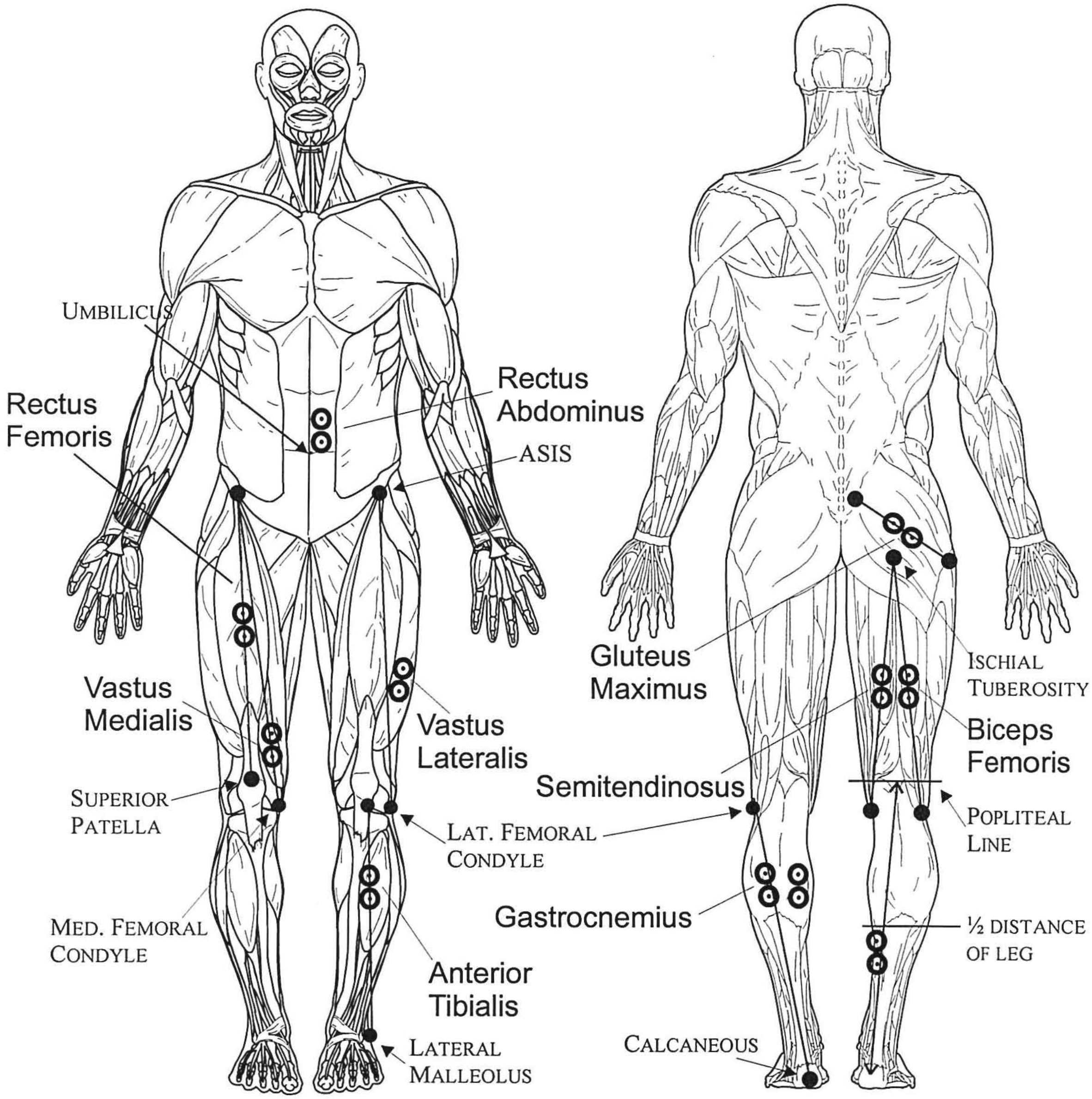
The electromyographic signals from the electrodes were transmitted to a receiver, which sent the signals into a computer for display and recording of the data. This information was stored on the computer hard drive for future analysis.

Eight reflective markers were placed on each subject to represent the joint centers of the upper and lower extremity. The markers were placed at the TMJ, acromion, lateral epicondyle of the humerus, dorsal aspect of the wrist, greater trochanter, lateral femoral condyle, lateral malleolus, and the fifth metatarsal head on the left side of each subject. These markers were videotaped and digitized to allow the sagittal motion of the neck, trunk, arm, forearm, thigh, leg, and foot to be analyzed.

Each athlete completed a total of two trials on the treadmill with a duration of six seconds for each trial. The athlete sprinted at 20 mph at 0% grade and 13 mph at 30% grade. Each subject was given a rest period between each trial.

Data Analysis

Prior to videotaping, the camera was calibrated by videotaping a meter stick. Then the video footage for each sprinting trial was calibrated in meters, cropped to the first three completed sprinting trials, and digitized using the Peak system. The software calculated the joint angles and segmental motion. The raw analog data was scaled and matched to the video. Reports were then generated to show anthropometric



Gluteus Maximus - midpoint of a line running from the inferior lateral angle of the sacrum to the greater trochanter
Rectus Abdominus - 2 cm superior and 2 cm lateral to umbilicus
Biceps Femoris - midpoint of a line from the ischial tuberosity to the lateral femoral condyle
Rectus Femoris - midpoint of a line from the ASIS to superior pole of patella (minimum of 10 cm above the patella)
Gastrocnemius - over the muscle belly 1/3 the distance of the leg (fibular head to calcaneous)
Anterior Tibialis - over the muscle belly 1/3 the distance of a line running from the lower margin of the patella to the lateral malleolus

Figure 1. Electrode Placement.

representation of the motion, joint motion, and integrated EMG data of the sprinting cycles for each trial.

The integrated EMG data was quantitatively processed using the Peak Motus software program. An ensemble average was computed for one complete stride length for each subject. The ensemble average was computed by sampling the EMG activity of an entire sprinting cycle at 0.5 percent intervals. The ensemble average was computed for one sprinting cycle, for each subject, with the averaged curves for each subject added together to yield a grand mean curve representative of all the subjects. The qualitative analysis and timing of the muscle activity was determined from the grand mean, ensemble average curves for each muscle. The muscle activation was graded as maximal, moderate, or minimal in relation to the peak level of averaged EMG activity that occurred during 100% of the sprinting cycle. Maximal activation was defined as 66.6-100% of peak muscle activity, moderate activity fell between 33.3 and 66.6% of peak level, and minimal activation was from 0-33.3%.

The hip, knee and ankle range of motion was processed similar to the EMG data. That is, an ensemble average was computed for one sprinting cycle for each subject, and then averaged to compute a grand mean ensemble average for all of the subjects. Due to the small sample size, statistical testing was not performed.

CHAPTER 4

RESULTS

All electromyographic and kinematic figures were created from a combined average of the six subjects performing at 20 mph on a 0% incline and 13 mph on a 30% incline. The percent time displayed on each figure represents a single sprint cycle. At 20 mph, initial contact occurred at 0% and toe-off at 21% stance phase. The remaining 79% represents swing phase of the cycle. During the 13 mph trial, stance phase occurred from 0-29% and swing phase continued from 29-100% of the sprint cycle.

Kinematics

Twenty miles per hour

Ensemble average curves for hip, knee, and ankle ranges of motion (ROM) are represented in Figure 2. At 20 mph, maximal hip flexion occurred at 76% of the sprint cycle reaching 59°. The hip extended to 7° at 32% of the cycle. The knee flexed to a maximum of 136° at approximately 61% of the sprint cycle and a minimum of 24° at 0% of the sprint cycle. Maximal plantar flexion occurred at 38% of the cycle and reached 60°, while the minimum of 17° of plantar flexion occurred at 13% of the sprint cycle.

Thirteen miles per hour

At 13 mph and 30% incline, maximal hip flexion was 84° at 80% of the cycle and decreased to 10° of flexion at 35% of the cycle. At any given point in the stride, the degree of hip flexion is greater at 13 mph as compared to 20 mph. Knee flexion peaked at 131° at 68% and minimal flexion occurred at 31% of the cycle reaching 25°. Maximal plantar flexion was 57° occurring at 43% of the sprint cycle. Minimal ROM occurred at 14% of the cycle with 13° of plantar flexion.

Quantitatively, hip flexion was always greater at 13 mph than at 20 mph throughout the sprint cycle. ROM patterns between the two were congruent. At the knee, maximal flexion was greater and occurred earlier in the stride at 20 mph. The knee extension movement was greater at 20 mph during late swing/early stance. ROM at the ankle displayed very similar patterns, but there was generally a greater amount of dorsiflexion during stance and mid to late swing at 13 mph than 20 mph. Also, at 20 mph, the dorsiflexion moment decreased more quickly during stance as compared to 13 mph.

EMG

Ensemble averaged EMG activity for all six muscles at 20 mph and 13 mph is shown in Figure 3 and compared in Figure 4. Figure 4 shows that greater muscle activity was only evident in the biceps femoris and gluteus maximus at 20 mph and 0% incline. The gastrocnemius, anterior tibialis, rectus femoris, and rectus abdominus showed more activity at 13 mph and 30% incline. The largest muscle activity level difference between the two speeds was in the gluteus maximus and the least was in the rectus abdominus.

Figures 5 and 6 display ensemble averaged EMG activity for individual muscles at 20 and 13 mph relative to joint motion. Table 3 shows muscle activity as a percentage of the sprint cycle and Figures 7 and 8 graphically display the same information. The gastrocnemius activity showed the most activity at 20 mph during stance phase (See

Figures 5 and 6). However, at 13 mph there were two periods of peak activity, once during stance and once during mid to late swing. The anterior tibialis displayed activity throughout both the 13 and 20 mph trials. However, at 13 mph, it displayed greater average activity with two peaks, one during stance and one during early swing.

The rectus femoris at 20 mph showed peak activity during late stance/early swing and remained active until mid-swing where it began a gradual decrease. At 13 mph, activity in the rectus femoris remained steady until mid-swing where activity showed a significant increase, but again steadily declined during late swing.

The biceps femoris activity was greatest at 20 mph during the stance phase. The activity then declined from early to mid-swing, and rose again peaking just prior to initial contact. The biceps femoris at 13 mph remained relatively steady throughout the sprint cycle, displaying it's peak activity in late swing.

At 20 mph, the gluteus maximus attained it's greatest activity during stance, then decreased during early swing, and began to rise again during late swing. In comparison, the gluteus maximus activity at 13 mph was smaller in amplitude but followed the approximate activity timing seen at 20 mph. The rectus abdominus had greater maximal activity during the incline sprint at 13 mph, but the timing of its activity was approximately the same in both trials.

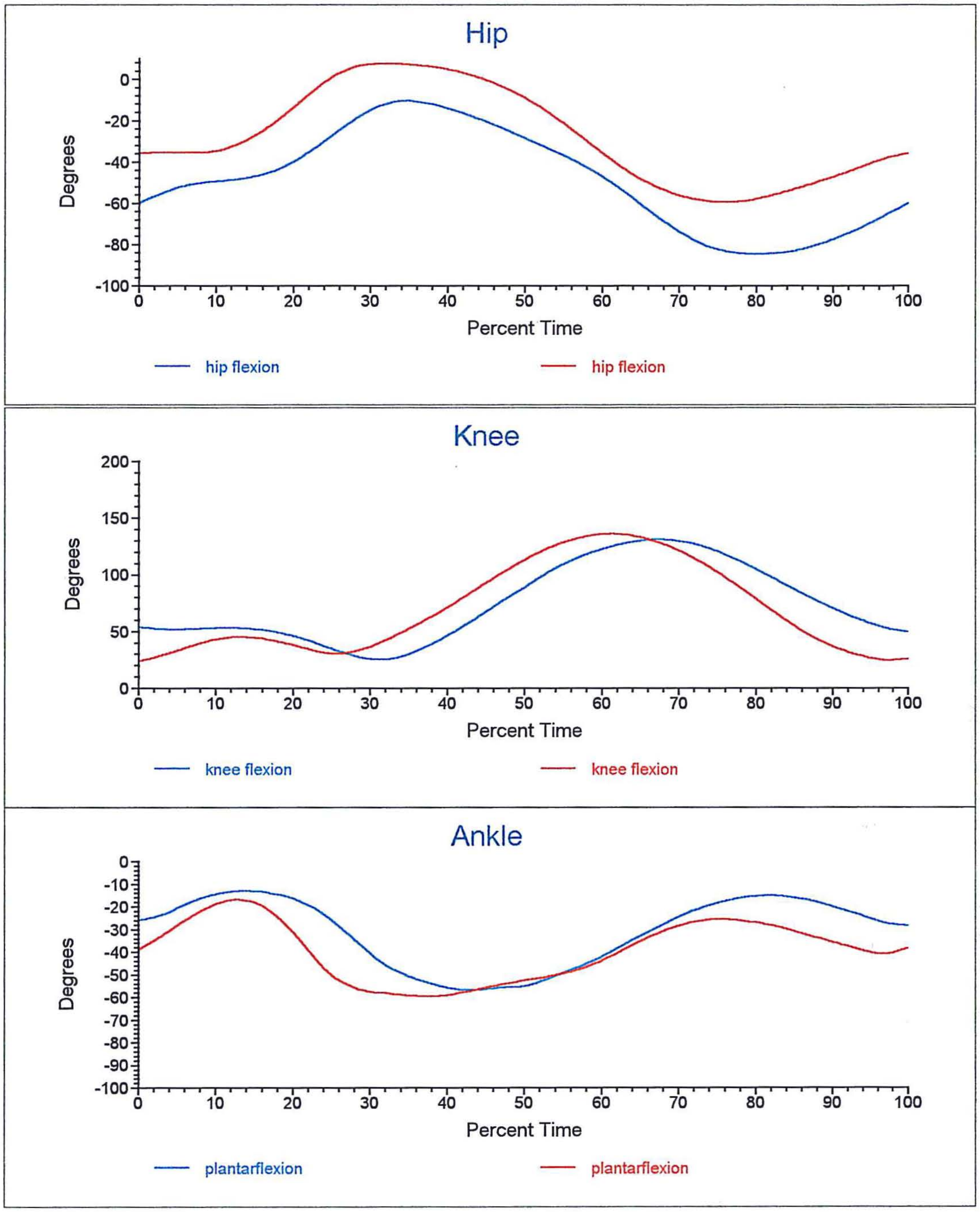


Figure 2. Ensemble averaged curves for range of motion. Red line is sprinting at 20 mph and 0%. Blue line is sprinting at 13 mph and 30%.

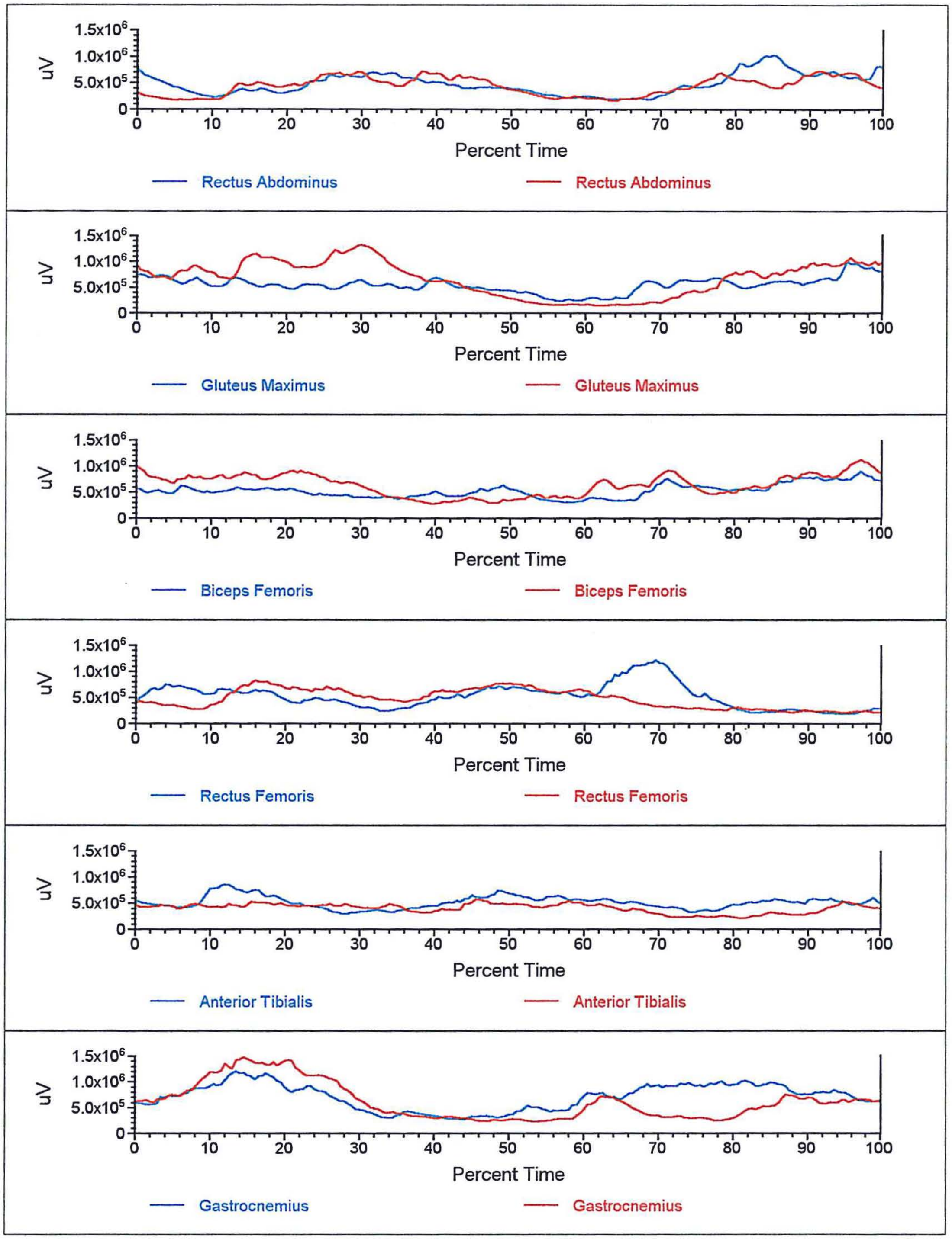


Figure 3. Averaged EMG activity for 13 and 20 mph. Thirteen mph is shown in blue and 20 mph is shown in red.

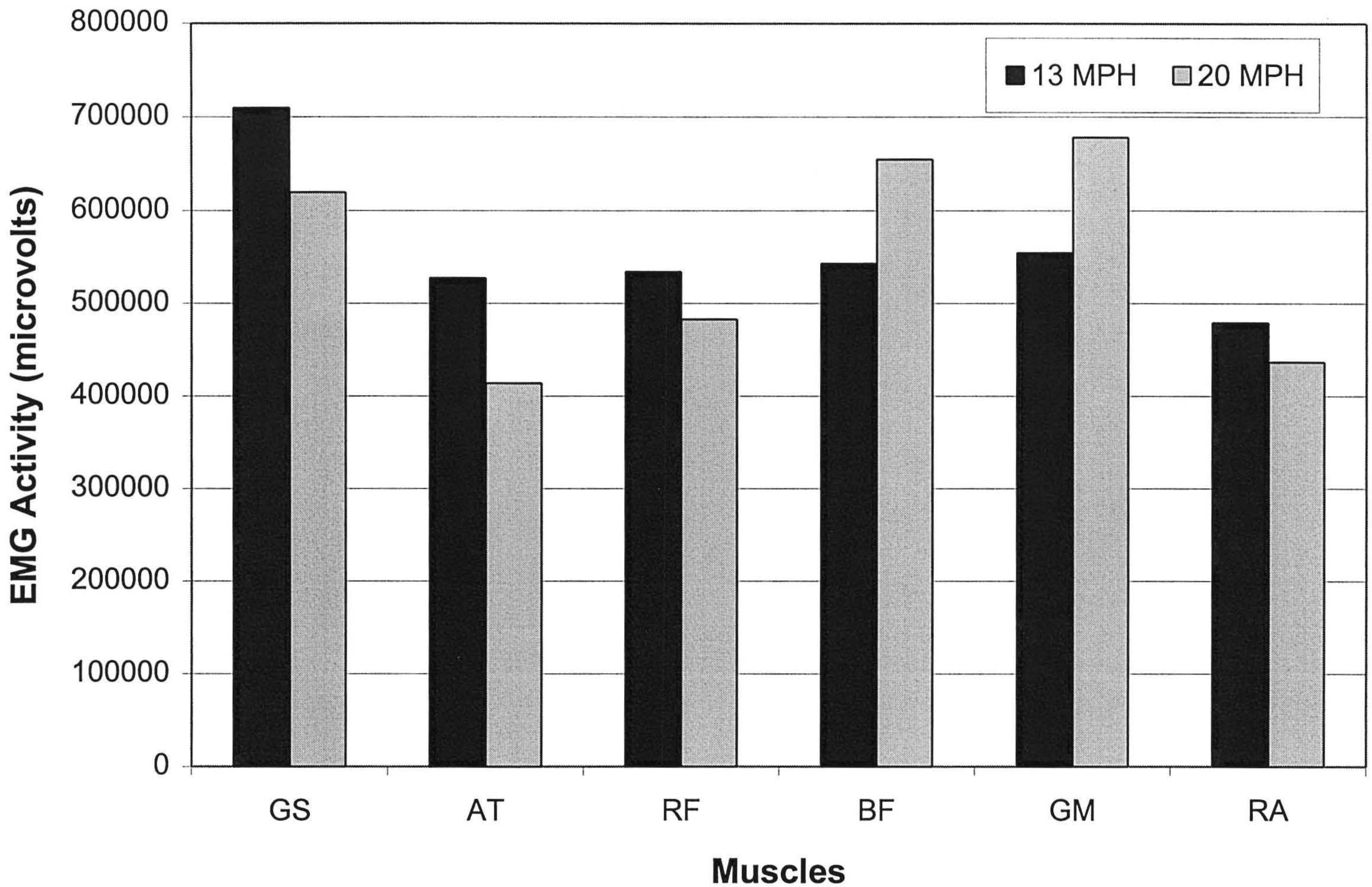


Figure 4. EMG activity during sprinting.

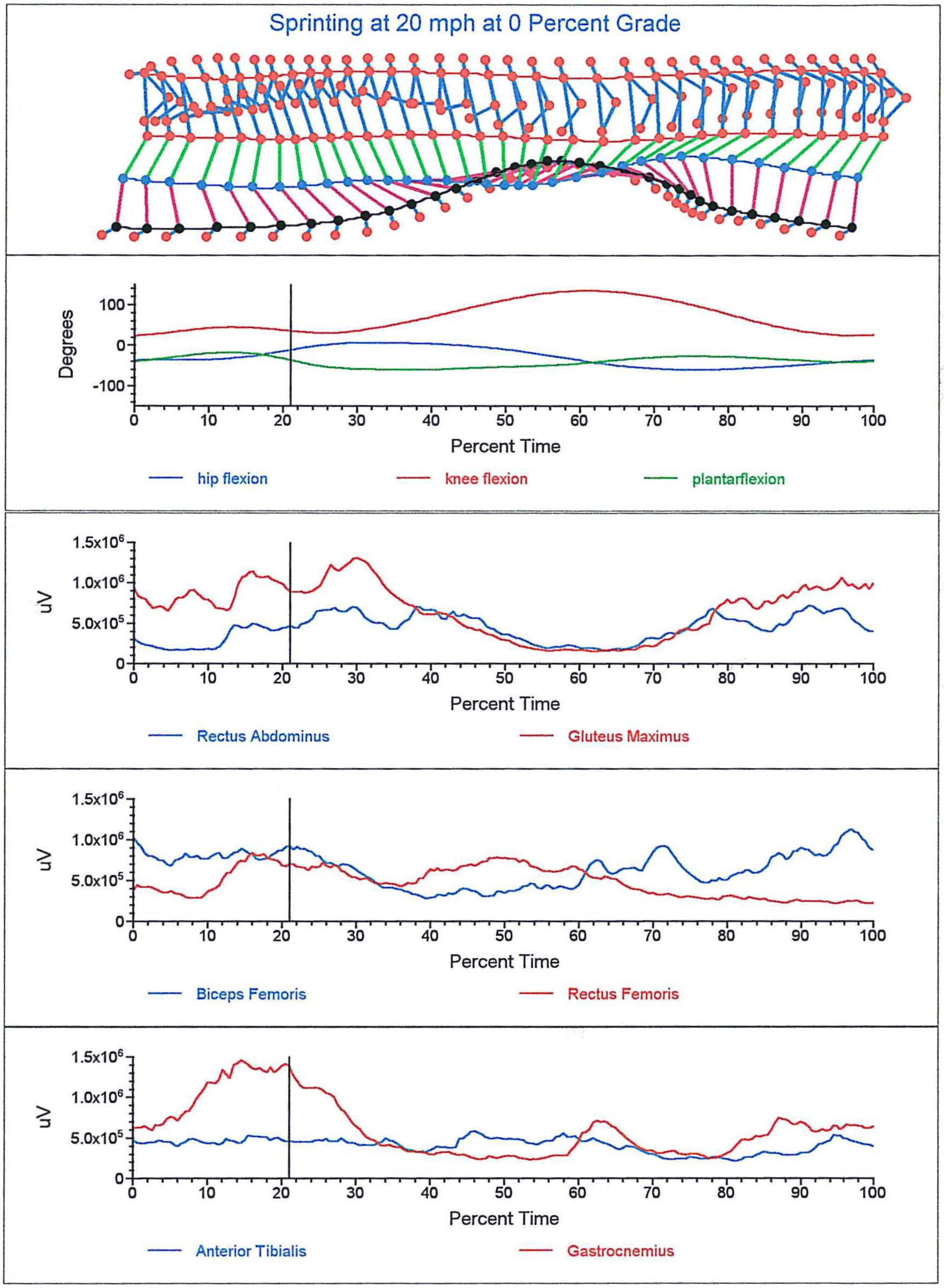


Figure 5. Ensemble averaged kinematic and electromyographic data for all subjects sprinting at 20 mph and 0% grade. The vertical line represents toe off.

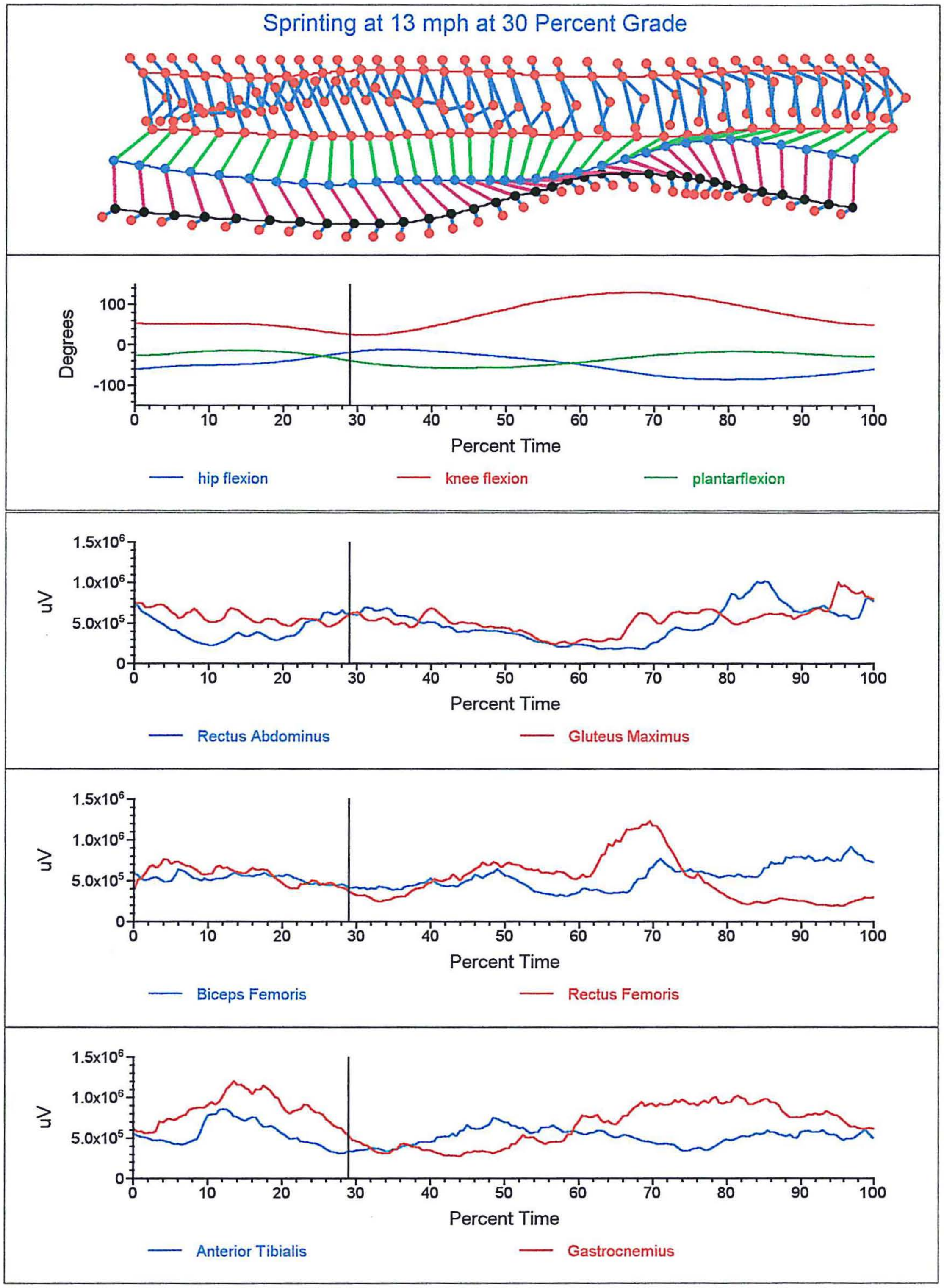


Figure 6. Ensemble averaged kinematic and electromyographic data for all subjects sprinting at 13 mph and 30% grade. The vertical line repressents toe off.

Table 3. Muscle Activation Patterns.

	Sprinting at 20 mph and 0% grade			Sprinting at 13 mph and 30% grade		
	Maximal Activation	Moderate Activation	Minimal Activation	Maximal Activation	Moderate Activation	Minimal Activation
Gastrocnemius	10-29%	0-10% 29-34% 63-69% 86-100%	34-63% 69-86%	10-26% 69-89%	0-10% 26-33% 53-69% 89-100%	33-53%
Anterior Tibialis	0-66% 94-100%	66-94%		11-22% 46-55%	0-11% 22-46% 55-100%	
Rectus Femoris	15-31% 41-63%	0-15% 31-41% 63-79%	79-100%	66-74%	0-30% 41-66% 74-80%	30-41% 80-100%
Biceps Femoris	0-27% 88-100%	27-38% 54-88%	38-54%	71-77% 86-100%	0-71% 77-86%	
Gluteus Maximus	16-37% 91-100%	0-16% 37-48% 79-91%	48-79%	0-6% 96-100%	6-56% 68-96%	56-68%
Rectus Abdominus	24-49% 78-100%	14-24% 49-55% 71-78%	0-14% 55-71%	82-90%	0-8% 23-55% 74-82% 90-100%	8-23% 55-74%

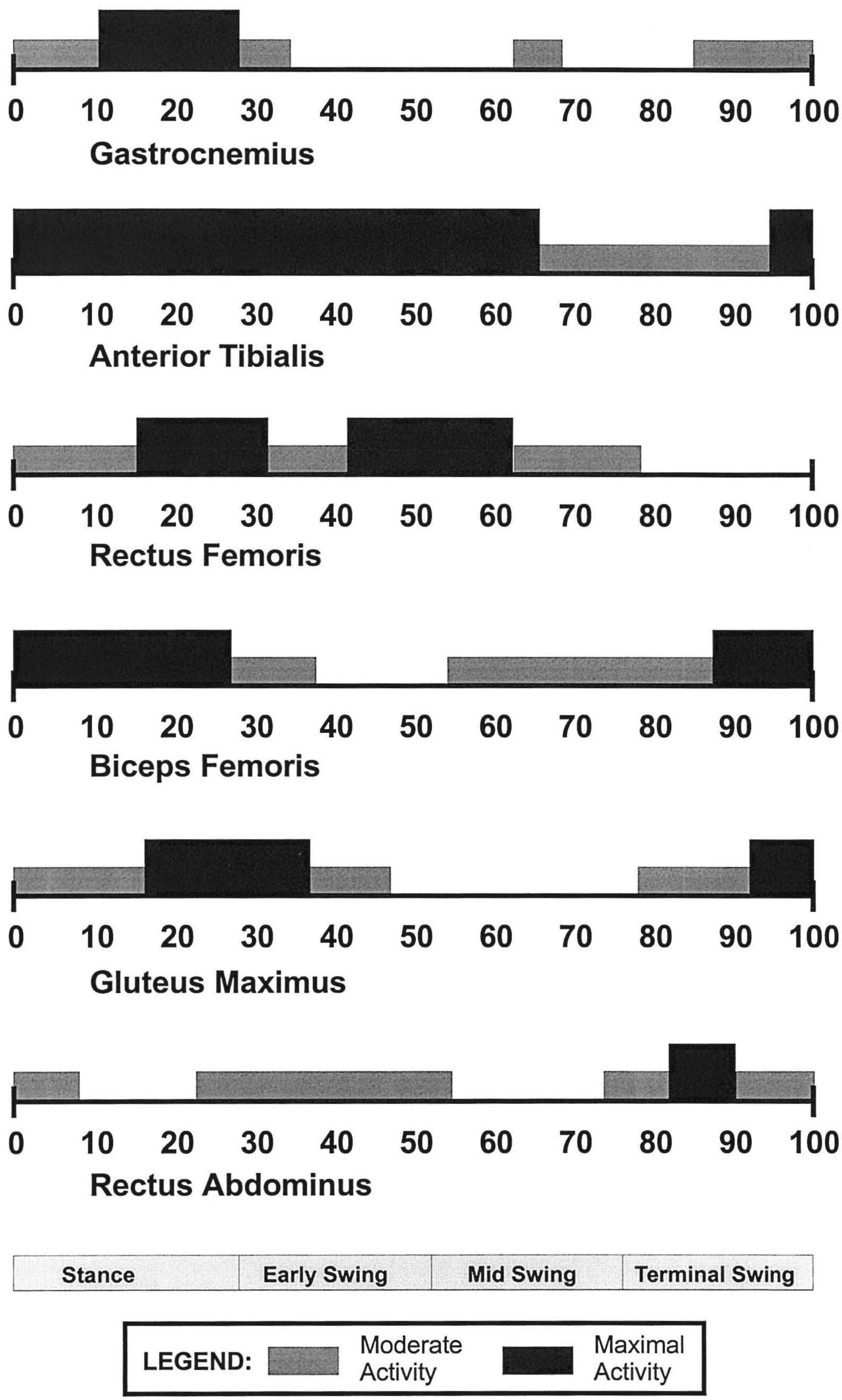


Figure 7. Muscle activation for sprinting at 20 mph and 0 percent grade.

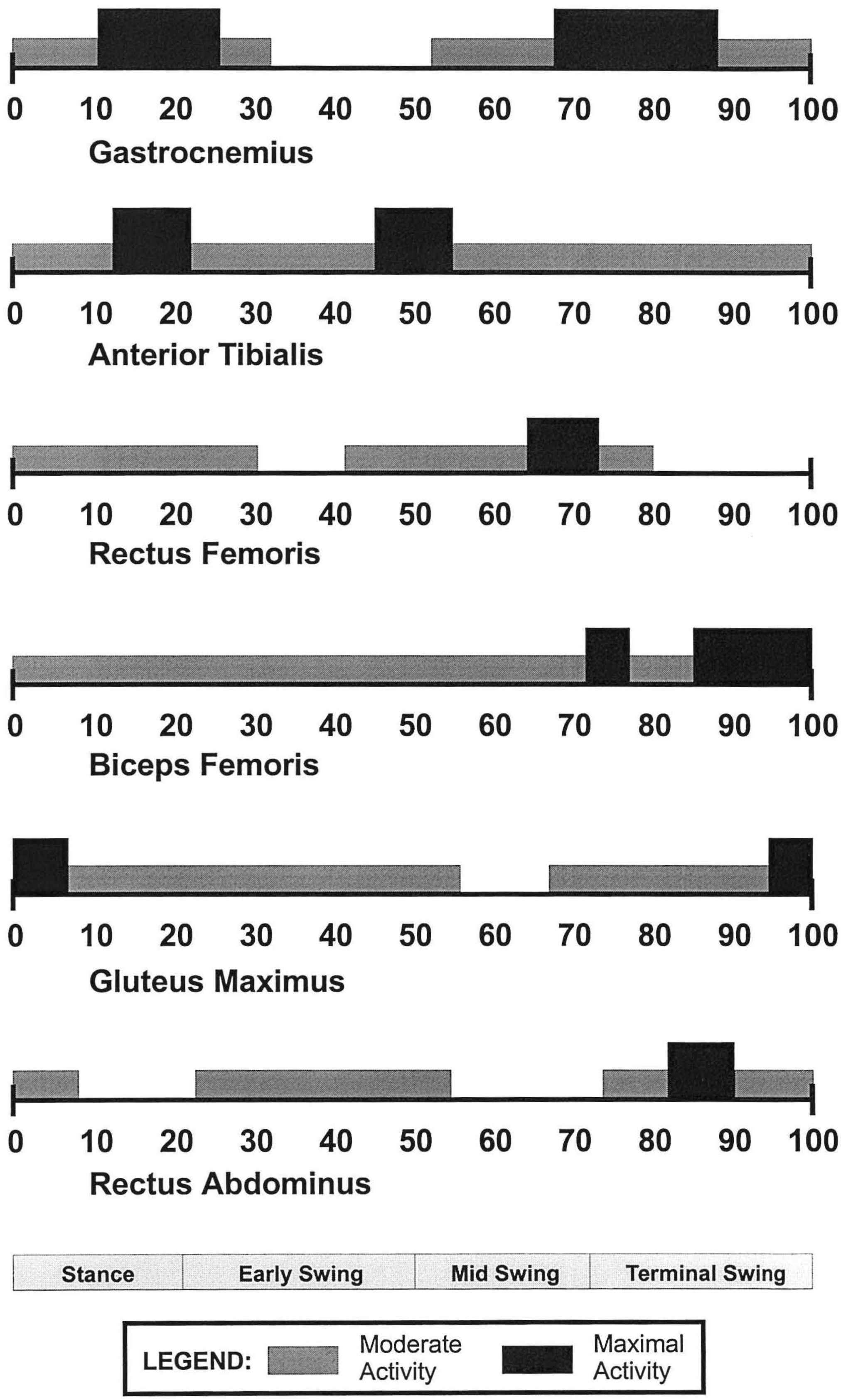


Figure 8. Muscle activation for sprinting at 13 mph and 30 percent grade.

CHAPTER 5

DISCUSSION

Joint Kinematics

The ensemble averaged curves for ROM showed that total hip ROM increased 12° during the 13 mph trial while total knee ROM decreased 6° during the same trial, as compared to the 20 mph trial. Ankle ROM remained relatively the same between the two trials (1° difference).

At 20 mph, total hip excursion was 66°, from 59° of flexion to 7° of extension. Mann et al.[3] found a similar amount of excursion of 65° (80° to 15° of flexion) during level sprinting. However, Owens[15] reported an excursion of only 36° (44° to 8°). The differences in our study compared to the latter study are thought to evolve from the variability in athletic build and performance between subjects in the studies. At 13 mph, total hip excursion increased to 74° (84° to 10° of flexion). Only one study was found to compare joint ROM during incline sprinting.[15] It reported similar results with total hip excursion at 75° (75° to 0°). Although increased speed usually increases hip ROM, we suggest that increased ROM occurred during the 13 mph trial to allow adequate clearance of the limb from the incline. When taking into account that the knee was actually extended more during the 13 mph trial, the need for increased hip flexion became even more apparent.

At 20 mph, total knee excursion was 112° (136° to 24°). Other studies reported an excursion of 90°-100°.[2,15] These discrepancies are hypothesized to occur due to differences in sprinting speed and variability of athletes between studies. At 13 mph, knee excursion decreased to 106° (131° to 24°). Owens[15] reported a total of 100° of knee ROM. In our study, total knee ROM decreased between the 20 mph and the 13 mph trials. Generally, with increased speed the knee flexes more to increase the velocity of the lower limb. We suggest that the knee is flexed less during the 13 mph trial because of the decreased speed.

At 20 mph, the total ankle ROM was 43° (60° to 17°). Mann et al.[3] and Owens[15] reported varying results, 27° and 34° respectively. Again, speed of sprinting and difference in athletic build and performance are suspected causes for the variable results. At 13 mph, ankle ROM was 44° (57° to 13°). Owens[15] reported a total excursion of 39°. Although the total ankle excursion is almost identical in the 20 mph and the 13 mph trials, there was less plantar flexion in the 13 mph trial. Therefore, we concluded that more dorsiflexion was needed for foot clearance on the incline.

Muscle Activity

Sprinting at 13 mph with a 30% incline produced more overall average activity in all muscles except the gluteus maximus and biceps femoris than sprinting at 20 mph. Swanson et al.[16] reported similar results with the exception of the anterior tibialis and gluteus maximus which produced less and more activity, respectively, during incline sprinting.

Mann and Hagy[2] and Mann et al.[3] reported that the gastrocnemius was active during late terminal swing phase and throughout stance phase. Although we found moderate activity in those phases, the greatest activity at 20 mph occurred only during mid to late stance phase. We agree with Ounpuu[8] and Jonhagen et al.[9] that the activity increased in mid to late stance for power generation to propel the body forward during push-off. At 13 mph, there were two phases of maximal activity in the gastrocnemius, However, the activity during late stance was of lesser magnitude than that occurring at 20 mph. The decreased magnitude is speculated to occur because of the increased hip flexion occurring during the 13 mph trial. Increased hip flexion is related to increased power generation in sprinting.[3] Therefore, less power generation was needed by the gastrocnemius at push-off as compared to the 20 mph trial. The increased activity during mid swing was suggested to eccentrically control the knee extension and dorsiflexion moments.

At 20 mph, the anterior tibialis had maximal activity throughout most of the sprint cycle, which is similar to results reported by previous studies.[2,3,9] In agreement with these studies, we suggest that the anterior tibialis was acting concentrically to dorsiflex the foot for clearance during swing and eccentrically for stabilization during stance. The muscle exhibited two periods of shorter maximal activation with the incline trial. We suggest that it once again acted eccentrically during stance for stabilization and concentrically during mid-swing for foot clearance.

At 20 mph, the rectus femoris was activated from stance phase to the end of mid-swing with peak activity occurring during late stance/early swing and again during the end of early swing into mid-swing. These findings are similar to those found in previous studies.[2,5,8-10] We agree with several authors that the muscle was acting eccentrically during stance phase to stabilize and control knee flexion as well as to control hip extension in early swing.[2,3,8,10] It was activated during mid-swing to flex the thigh forward for limb clearance and extend the leg for contact. At 13 mph, maximal muscle activity occurred during mid-swing, and we postulated that it performed similar to its activation during swing at 20 mph.

Mann et al.[3] and Jonhagen et al.[9] found most of the bicep femoris activity to occur from mid to terminal swing lasting into stance phase. At 20 mph, our results of maximal muscle activity showed nearly identical patterns. We agree with Jonhagen et al.[9] that the muscle was working eccentrically during mid to terminal swing to control hip flexion and leg extension and to stabilize in early stance. It then contracted concentrically toward the end of stance phase and into early swing to help extend the thigh. At 13 mph, the muscle was active throughout the entire cycle with maximal activity occurring in terminal swing. This activity pattern was thought to be an eccentric contraction to control the hip flexion moment as well as extension of the knee.

We found maximal gluteus maximus activity to occur at the end of terminal swing and again at the end of stance into early swing during the 20 mph trial. During terminal swing, the activity was suggested to occur to control hip flexion and to decelerate the thigh. Other studies have supported these findings.[5,9,10] The second period of maximal activation occurred to help pull the thigh into extension. At 13 mph, maximal activity occurred during the end of terminal swing into early stance similar to that occurring during 20 mph.

The rectus abdominus had two periods of maximal activation during the 20 mph trial. During early swing, it may have acted to eccentrically control the amount of anterior pelvic tilt occurring with hip extension while during terminal swing, it may have been acting concentrically to pull the pelvis into a posterior tilt to allow proper hip flexion. Mann[2] supports these findings. At 13 mph, there is one period of maximal activity of greater amplitude than at 20 mph. It occurred during terminal swing suggesting it was concentrically contracting to pull the pelvis into a posterior tilt.

Limitations

Our study exhibited several limitations. The sprinters were at various training levels, including several who had not previously run on a high-speed treadmill. Our EMG data may have been skewed as the more poorly trained individuals were straining all muscles in order to maintain their position on the treadmill. Also, the subjects were not accustomed to the equipment attached to their bodies which may have altered their sprinting technique. Finally, the sample size was not adequate to represent a population of elite sprinters.

Clinical Implications

Incline training appears to be useful in increasing hip ROM and muscle activity of the gastrocnemius, anterior tibialis, rectus femoris, and rectus abdominus. Therefore, it may be beneficial for athletes to include incline training in their treatment protocols to improve power generation and speed in sprinting.

Conclusion

Sprinting at 13 mph and a 30% incline produced increased muscle activity in the gastrocnemius, anterior tibialis, rectus femoris, and rectus abdominus and produced greater hip flexion and ankle dorsiflexion ranges of motion to accommodate for the increase in slope.

APPENDIX

REPORT OF ACTION: EXEMPT/EXPEDITED REVIEW
University of North Dakota Institutional Review Board

DATE: September 16, 1998 **PROJECT NUMBER:** IRB-9706-285

NAME: Thomas Mohr, Carrie Anderson, Samantha Gould, Anna Hillig, Teri Parker **DEPARTMENT/COLLEGE:** Physical Therapy

PROJECT TITLE: An Electromyographic and Video Motion Analysis Study of Elite Sprinters at Varying Speeds and Inclines (Protocol Change)

The above referenced project was reviewed by a designated member for the University's Institutional Review Board on September 17, 1998 and the following action was taken:

☒ Project approved. **EXPEDITED REVIEW** No. 3.
Next scheduled review is on April 1999.

☐ Project approved. **EXEMPT CATEGORY** No. ________. No periodic review scheduled unless so stated in the Remarks Section.

☐ Project approved **PENDING** receipt of corrections/additions. These corrections/additions should be submitted to ORPD for review and approval. **This study may NOT be started UNTIL final IRB approval has been received**. (See Remarks Section for further information.)

☐ Project approval **deferred. This study may not be started until final IRB approval has been received**. (See Remarks Section for further information.)

☐ Project **denied.** (See Remarks Section for further information.)

REMARKS: Any changes in protocol or adverse occurrences in the course of the research project must be reported immediately to the IRB Chairperson or ORPD.

PLEASE NOTE: **Requested revisions for student proposals MUST include adviser's signature**.

Richard Ferraro 9-17-98

Signature of Designated IRB Member
UND's Institutional Review Board

Date

cc: Chair, Physical Therapy
Dean, Medical School

If the proposed project (clinical medical) is to be part of a research activity funded by a Federal Agency, a special assurance statement or a completed 310 Form may be required. Contact ORPD to obtain the required documents.

(1/98)

_X_ EXPEDITED REVIEW REQUESTED UNDER ITEM _3_ (NUMBER[S]) OF HHS REGULATIONS
___ EXEMPT REVIEW REQUESTED UNDER ITEM ____ (NUMBER[S]) OF HHS REGULATIONS

UNIVERSITY OF NORTH DAKOTA HUMAN SUBJECTS REVIEW FORM FOR NEW PROJECTS OR PROCEDURAL REVISIONS TO APPROVED PROJECTS INVOLVING HUMAN SUBJECTS

PRINCIPAL INVESTIGATOR: Thomas Mohr, Carrie Anderson, Samantha Gould, Anna Hillig, Teri Parker **TELEPHONE:** 777-2813 **DATE:** 4/15/98

ADDRESS TO WHICH NOTICE OF APPROVAL SHOULD BE SENT: PO Box 9037, Dept. Of Physical Therapy, UND

SCHOOL/COLLEGE: Medicine & Health Sciences **DEPARTMENT:** Physical Therapy **PROPOSED PROJECT DATES:** 5/1/98 to 5/1/99
(Month/Day/Year)

PROJECT TITLE: An Electromyographic and Video Motion Analysis Study of Elite Sprinters at Varying Speeds and Inclines

FUNDING AGENCIES (IF APPLICABLE): None

TYPE OF PROJECT (Check ALL that apply):

___ NEW PROJECT _X_ CONTINUATION ___ RENEWAL ___ DISSERTATION OR THESIS RESEARCH _X_ STUDENT RESEARCH PROJECT

___ CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT

DISSERTATION/THESIS ADVISER, OR STUDENT ADVISER: Thomas Mohr, PT, Phd

PROPOSED PROJECT: ____ INVOLVES NEW DRUGS (IND) ____ INVOLVES NON-APPROVED USE OF DRUG _X_ INVOLVES A COOPERATING INSTITUTION

IF ANY OF YOUR SUBJECTS FALL IN ANY OF THE FOLLOWING CLASSIFICATIONS, PLEASE INDICATE THE CLASSIFICATION(S):

___ MINORS (<18 YEARS) ___ PREGNANT WOMEN ___ MENTALLY DISABLED ___ FETUSES ___ MENTALLY RETARDED

___ PRISONERS ___ ABORTUSES ___ UND STUDENTS (>18 YEARS)

IF YOUR PROJECT INVOLVES ANY HUMAN TISSUE, BODY FLUIDS, PATHOLOGICAL SPECIMENS, DONATED ORGANS, FETAL MATERIAL, OR PLACENTAL MATERIALS, CHECK HERE ______

IF YOUR PROJECT HAS BEEN\WILL BE SUBMITTED TO ANOTHER INSTITUTIONAL REVIEW BOARD(S),PLEASE LIST NAME OF BOARD(S): Red River Sports Medicine, Fargo, ND

Status: ________ Submitted; Date 6/11/97 Approved; Date 6/12/97 Pending______

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1. **ABSTRACT:** (LIMIT TO 200 WORDS OR LESS AND INCLUDE JUSTIFICATION OR NECESSITY FOR USING HUMAN SUBJECTS.

Sports training facilities are inundated every year with athletes who want to enhance performance. The challenge is to develop training techniques to meet these performance goals. One technique that is being utilized clinically is training athletes on high quality treadmills. These treadmills allow the athlete to run at high speeds and various grades of incline that simulate functional activities.

The purpose of this research project is to describe muscle activity and joint motion while running on a treadmill at different speeds and inclines. The muscle activity will be collected via electromyographic procedures using surface electrodes. Motion analysis video equipment will be utilized simultaneously to film the subject. This will allow us to analyze the EMG data along with joint movement. The data from this study will be used to describe normal patterns of muscle activity and joint motion which will be used in developing training protocols for athletes.

Normal, trained, healthy subjects will be used in this research project. Human subjects are needed for this EMG research study in order to determine when the selected muscles are active when running at high speeds and at various grades of incline.

PLEASE NOTE: Only information pertinent to your request to utilize human subjects in your project or activity should be included on this form. Where appropriate attach sections from your proposal (if seeking outside funding).

2. **PROTOCOL:** (Describe procedures to which humans will be subjected. Use additional pages if necessary.)

Subjects:
It is anticipated that we will recruit 10 male subjects between ages 18 and 28. These subjects will participate voluntarily. These subjects will be chosen due to their elite athletic abilities since they will be required to run at high speeds and various inclines. They will also have participated in a previous training program. The project will be completed at Orthopedic Associates in Fargo, ND.

Methods:
Prior to the running trials, each subject's age, height, and weight will be recorded. During the trial, we will measure electromygraphic (EMG) activity in selected trunk and lower extremity muscles. We will measure activity in the following muscles while the athletes are running on the treadmill: 1) rectus abdominus, 2) gluteus maximus, 3) rectus femoris, 4) biceps femoris, 5) anterior tibialis, and 6) gastrocnemius.

To record EMG activity, the motor points of the above muscles will be located using a small electrical stimulator. The skin of the lower extremity of each subject will be prepared by cleansing the skin with alcohol before attachment of the EMG adhesive electrodes over the motor point. Adhesive surface electrodes will be placed on the subject's skin over the motor point. The EMG signals will be transmitted to a receiver unit and then fed into a computer for display and recording of data. Prior to beginning the experimental trial, the researcher will apply manual resistance to the subject's lower extremity in order to elicit a maximal voluntary contraction from each muscle being monitored in this study. The muscle activity recorded during the maximal voluntary contraction will be considered as a 100% EMG activity level to which the EMG activity during exercise on the treadmill can be compared. This procedure is done to normalize the EMG data for later analysis.

Video analysis will be used to measure upper extremity, lower extremity and trunk range of motion during the activity. Reflective markers will be attached to the trunk and lower extremity using double-sided adhesive tape. We anticipate placing markers on the shoulder, elbow, wrist, hip, knee and ankle. Video cameras will be placed on the side of the subject and will film the subject's trunk and lower extremity markers and motion during the experimental trial. This will be recorded on videotape and will be transferred to a computer for analysis.

The athlete will run at 20 mph with 0%, 10%, 20% 30% and 40% grade of the treadmill incline. At each incline the athlete will run for a total of six seconds in order to obtain the necessary data for analysis. The subjects will be given a three minute rest period between trials.

Data analysis:
Descriptive statistics describing the subjects' anthropometric profiles will be provided. The mean activity of each monitored muscle will be calculated. The EMG data collected during the experimental trials will be expressed as a percentage of the EMG activity recorded during the maximal contraction prior to the experimental trials (i.e. normalized). The video image will be converted to a stickman-like figure, from which we can determine joint angles and limb velocity. The EMG data is synchronized with the video data to determine the level of EMG activity during the various running trials.

3. **BENEFITS:** (Describe the benefits to the individual or society.)

The data collected throughout this research study will be analyzed to determine which muscles are active when the athlete is running at high speeds and various inclines. The body angles will also be analyzed to examine the running strategies at these various speeds and inclines. The data should provide information on which muscles are active during running, and this information will provide the basis for developing protocols specifically for training athletes. It will also further the available knowledge base of research in this area.

4. **RISKS:** (Describe the risks to the subject and precautions that will be taken to minimize them. The concept of risk goes beyond physical risk and includes risks to the subject's dignity and self-respect, as well as psycho-logical, emotional or behavioral risk. If data are collected which could prove harmful or embarrassing to the subject if associated with him or her, then describe the methods to be used to insure the confidentiality of data obtained, including plans for final disposition or destruction, debriefing procedures, etc.)

The risks involved in this research project are minimal. The subjects may experience a tingling discomfort while the investigator is using the electrical stimulator to elicit a muscle contraction in order to locate the motor point of the muscle to be monitored. The EMG and video analysis equipment causes no discomfort to the subject, since they are both monitoring devices. Because the video information is converted to stickman-like diagrams, the actual subject's video is not used in data reporting. Therefore, the subject is not recognizable.

The process of physical performance testing does impose a potential risk of injury to the muscle. The testing will occur in a controlled setting , and because only subjects who have already been trained on the treadmill at the proposed speeds and inclines, the risk of injury is minimal. The participant will be closely observed throughout the activity on the treadmill to decrease the potential of harm. However, the activity that this athlete will be performing carries with it the same amount of risk as running at the elite levels to which the participant is accustomed The investigator or participant may stop the experiment at any time if the participant is experiencing discomfort, pain, fatigue, or any other symptoms that may be detrimental to his/her health.

The subjects' names will not be used in any reports of the results of this study. Any information that is obtained in connection with this study and that can be identified with the subject will remain confidential and will be disclosed only with the subject's permission. The data will be identified by a number known only by the investigator.

5. **CONSENT FORM:** A copy of the **CONSENT FORM** to be signed by the subject (if applicable) and/or any statement to be read to the subject should be attached to this form. If no **CONSENT FORM** is to be used, document the procedures to be used to assure that infringement upon the subject's rights will not occur.

Describe where signed consent forms will be kept and for what period of time.

Consent forms will be kept in the Physical Therapy Department at the University of North Dakota for a period of 3 years.

6. For **FULL IRB REVIEW** forward a signed original and thirteen (13) copies of this completed form, and where applicable, thirteen (13) copies of the proposed consent form, questionnaires, etc. and any supporting documentation to:

Office of Research & Program Development
University of North Dakota
Grand Forks, North Dakota 58202-7134

On campus, mail to: Office of Research & Program Development, Box 7134, or drop it off at Room 105 Twamley Hall.

For **EXEMPT** or **EXPEDITED REVIEW** forward a signed original and a copy of the consent form, questionnaires, etc. and any supporting documentation to one of the addresses above.

The policies and procedures on Use of Human Subjects of the University of North Dakota apply to all activities involving use of Human Subjects performed by personnel conducting such activities under the auspices of the University. No activities are to be initiated without prior review and approval as prescribed by the University's policies and procedures governing the use of human subjects.

SIGNATURES:

Thomas Mohr Carrie Anderson Anna Hellig Tami Arnold Jeli Parker 4/5/98

Principal Investigator Date

Project Director or Student Adviser Date

Training or Center Grant Director Date

(Revised 3/1996)

INFORMATION AND CONSENT FORM

TITLE: An Electromyographic and Video Motion Analysis Study of Elite Sprinters at Varying Speeds and Inclines_

You are being invited to participate in a study conducted by Carrie Anderson, Samantha Gould, Anna Hillig, Teri Parker and Thomas Mohr from the physical therapy department at the University of North Dakota. The purpose of this study is to study muscle activity in your trunk and lower extremity while you are running at different speeds and inclines on the treadmill. We will also be measuring the angles of the joints of the upper extremity, lower extremity and trunk while you are exercising. We hope to describe the muscle activity and the different angles that you employ during this bout of exercise. Only trained, normal, healthy subjects will be asked to participate in this study.

You will be asked to run on the treadmill for a total of five(5) trials consisting of the following: 1)Running on the treadmill at 20 miles per hour with 0% grade. 2) Running on the treadmill at 10% grade. 3) Running on the treadmill at 20% grade. 4) Running on the treadmill at 30% grade. 5) running on the treadmill at 40 % grade. Each trial will last approximately six seconds. You will be given a rest period between trials.

The study will take approximately one hour of your time. You will be asked to report to the Acceleration Training Department at Orthopedic Associates in Fargo, ND, at an assigned time. You will then be asked to change into gym shorts for the experiment. We will first record your age, gender, height and weight. During the experiment, we will be recording the amount of muscle activity and the angles of your joints that is present when you run on the treadmills on the five different settings.

Although the process of physical performance testing always involves some degree of risk, the investigator in this study feels that, because of your prior training, the risk of injury or discomfort is minimal. In order for us to record the muscle activity, we will be placing nine electrodes on your trunk and lower extremity. Before we can apply the electrodes, we will use a small stimulator to electrically stimulate the muscles to locate the best spot to place the electrodes. The stimulator will cause a mild tingling sensation. The recording electrodes are attached to the surface of the skin with an adhesive material. We will also attach reflective markers at various points on your arm, leg and trunk. These devices only record information from your muscles and joints, they do not stimulate the skin. After we get the electrodes attached, we will give you a brief training session to refamiliarize you on the treadmill. The amount of exercise you will be asked to perform will be moderate.

Your name will not be used in any reports of the results of this study. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. The data will be identified by a number known only be the investigator. The investigator or participant may stop the experiment at any time if the participant is experiencing discomfort, pain, fatigue, or any other symptoms that may be detrimental to his/her health. Your decision whether or not to participate will not prejudice your future relationship with the Physical Therapy Department or the University of North Dakota. If you decide to participate, you are free to discontinue participation at any time without prejudice.

The investigator involved is available to answer any questions you have concerning this study. In addition, you are encouraged to ask any questions concerning this study that you may have in the future. Questions may be asked by calling Dr. Thomas Mohr at (701) 777-2831. A copy of this consent form is available to all participants in the study. A copy of the consent form will be retained in the Physical Therapy Department for a period of three years.

In the event that this research activity (which will be conducted at Orthopedic Associates) results in a physical injury, medical treatment will be available, including first aid, emergency treatment and follow up care as it is to a member of the general public in similar circumstances. Payment for any such treatment must be provided by you and your third party payment, if any.

ALL OF MY QUESTIONS HAVE BEEN ANSWERED AND I AM ENCOURAGED TO ASK ANY QUESTIONS THAT I MAY HAVE CONCERNING THIS STUDY IN THE FUTURE. MY SIGNATURE INDICATES THAT, HAVING READ THE ABOVE INFORMATION, I HAVE DECIDED TO PARTICIPATE IN THE RESEARCH PROJECT.

I have read all of the above and willingly agree to participate in this study explained to me by Shannon Owens or Erica Fretland

____
Participant's Signature Date

____
Witness (not the scientist) Date

UNIVERSITY OF UND NORTH DAKOTA

SCHOOL OF MEDICINE & HEALTH SCIENCES
DEPARTMENT OF PHYSICAL THERAPY
501 NORTH COLUMBIA ROAD
P.O. BOX 9037
GRAND FORKS, NORTH DAKOTA 58202-9037
(701) 777-2831
FAX (701) 777-4199

MEMO

DATE: April 9, 1998

TO: IRB, University of North Dakota

FROM: Thomas Mohr, PT, PhD
Chairman, UND Physical Therapy

RE: Sprinting Study

I am writing to request a continuation of the study entitled "An Electromyographic and Video Motion Analysis Study of Elite Sprinters at Varying Speeds and Inclines". The study had been approved last year (project " IRB-9706-285). We were able to collect data on 5 subjects, but we would like to run additional subjects this year to strengthen the data. With the flood last summer, we did not have enough time to complete the study as we had intended. The data we did collect was fine and we did not have any problems that would have presented a risk to the subjects. We have received verbal approval to continue the study from John Frappier of Acceleration Products.

I am resubmitting the same IRB and Consent forms as last year with the following changes:

> **The student researchers will change this year (the two from last year will graduate this year).**
>
> **I have added the required information regarding retention of the consent forms to the consent form.**
>
> **We anticipate that we would collect data from 10 subjects this year.**

If you have any questions, please do not hesitate to contact me.

ACCELERATION PRODUCTS, INC.

2301 25th Street South, Suite E, Fargo, North Dakota 58103
(701) 241-9018 Fax: (701) 232-0119 E-mail: accelr8@corpcomm.net

June 12, 1997

Thomas Mohr Phd.
UND School of Medicine
PT Dept. Box 9037
Grand Forks, ND 58202

Dear Mr. Mohr,

I have had the opportunity to review the research proposal "An Electromyographic and Video Motion Analysis Study of Elite Sprinters at Various Speeds and Inclines". I am in agreement and approve of this study. The Red River Valley Sports Medicine Institute has also approved of this study. We look forward to working with you.

Sincerely,

John Frappier
President

JF/jlh

Red River Valley
Sports Medicine Institute

September 17, 1997

Dr. Tom Mohr, Chairman
UND School of Medicine
PT Dept. Box 9037
Grand Forks, ND 58202

Dear Dr. Mohr,

I have had the opportunity to review the research proposal "An Electromyographic and Video Motion Analysis Study of Elite Sprinters at Various Speeds and Inclines". As Medical Director of the Red River Valley Sports Medicine Institute, I approve and support this research endeavor. We look forward to working together with you.

Sincerely,

Mark A. Lundeen, MD
Medical Director RRVSMI

2301 25th Street South • Suite C
Fargo, North Dakota 58103
Tel 701-280-2406
Fax 701-237-0922

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