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

Erica Fretland
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AN ELECTROMYOGRAPHIC AND VIDEO MOTION ANALYSIS STUDY OF
ELITE SPINTERS AT VARYING SPEEDS AND INCLINES

by

Erica Fretland
Bachelor of Science in Physical Therapy
University of North Dakota, (1997)

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

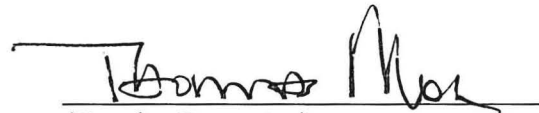
Grand Forks, North Dakota

May

1998



This Independent Study, submitted by Erica D. Fretland 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 Erica J. Jettland
Date 12/18/97

TABLE OF CONTENTS

List of Figures	v
List of Tables	vi
Acknowledgements	vii
Abstract	viii
Chapter 1: Introduction	1
Chapter 2: Review of the Literature	3
Chapter 3: Methods	7
Chapter 4: Results	14
Chapter 5: Discussion	25
Appendices	30
References	40

LIST OF FIGURES

Figure		Page
1.	Electromyographic Electrode Placement on the Lower Extremities.....	10
2.	Kinematic and Electromyographic Data for Subject 5 at 20 mph and 0%...	17
3.	Kinematic and Electromyographic Data for Subject 5 at 13 mph and 10%..	18
4.	Ensemble Averaged Curve for Electromyographic Activity.....	19
5.	Electromyographic Activity During Sprinting.....	20
6.	Ensemble Averaged Curve for Range of Motion.....	21
7.	Muscle Activation for Sprinting at 20 mph and 0% grade.....	23
8.	Muscle Activation for Sprinting at 13 mph and 30% grade.....	24

LIST OF TABLES

Table		Page
1.	Physical Characteristics of Subjects.....	7
2.	Origin, Insertion and Action of Selected Muscles for Sprinting.....	11
3.	Muscle Activation Patterns.....	22

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ABSTRACT

Background and Purpose: The purpose of this study is twofold 1) to describe muscle activity and joint motion while running on a treadmill at different speeds and inclines and 2) to examine whether or not running on a treadmill at high speeds and on an inline causes particular muscles to work harder or the sprinter to change their running technique to accommodate the increased workload. Subjects and Methods: EMG and motion analysis data was collected from six subjects while they were running on a treadmill, first at twenty miles per hour at zero percent grade and then at thirteen miles per hour and thirty percent grade. Results: This study shows that there is a greater amount of EMG activity during sprinting at twenty miles per hour at zero percent grade than there is on the incline at thirteen miles per hour and thirty percent grade. The gastrocnemius, anterior tibialis, and rectus femoris had the greatest increases in activity between the two trials. The range of motion for both trials was similar with the exception of hip flexion. On the incline, the subjects showed greater amounts of hip flexion. Conclusion and Discussion: Incline training appears to be useful in helping athletes increase their overall hip range of motion to assist in increasing their overall velocity. Training at either level increased EMG activity, but apparently, velocity has a greater influence on the amplitude of EMG activity than running on the incline.

CHAPTER 1 INTRODUCTION

Every athlete trains with the hopes of being bigger, stronger or faster than their 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 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.

Purpose of Study

The purpose of this study is twofold 1) to describe muscle activity and joint motion while running on a treadmill at different speeds and inclines and 2) to examine whether or not running on a treadmill at high speeds and on an inline 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 and incline.

CHAPTER 2

REVIEW OF THE LITERATURE

There have been many studies focusing on the biomechanics of running. These studies centered around a comparison of different training methods, different speeds, differences of training on a treadmill versus on ground, and the analysis of different muscle timing during locomotion. However, there have been few studies to date on the analysis of electromyography or kinematics during incline sprint training.

Training Methods

When an athlete is running at a constant speed, they can be running at a submaximal, maximal, or supramaximal effort. In order to run faster, a sprinter can increase their velocity by increasing their stride length and/or the stride rate. However, at high speeds, an increase velocity must come from an increase in stride rate rather than an increase in stride length.¹ To train at a supramaximal level, there are two methods, overspeed training and overload training.^{1,2}

The overspeed training method can be accomplished in different ways. The athlete can either train on a high speed treadmill, downhill running or some method of towing.² This will result in an increase in stride rate, but only at the expense of stride length.² Mero¹ found that horizontal towing resulted in increases of: 1) velocity (8.4%), 2) stride rate (6.9%), and 3) stride length (1.5%) when compared to running at a maximal level.

The overload method utilizes running uphill or towing of various sizes of parachutes to accomplish its training effects. Delecluse² suggests that a slope of $\leq 3^\circ$ is optimal when running uphill. This slope results in an increased stride length and a faster velocity. In the one unpublished study by Swanson et al³, there was a significant training

effect in sprinters who trained using a super treadmill on inclines at 30% incline. It resulted in an average sixteen centimeters increase in stride length, a 1.3 mph increase in treadmill speed, a seven degree increase in hip range of motion, and an increase in maximum hip flexion angle. Swanson³ also found that there wasn't a significant change in electromyographic activity as a result of the overload training.

Kinematics

Mann et al⁴ reviewed the range of motion of the lower extremity during jogging, running, and sprinting and found that the hip flexes to a maximum of 80° during sprinting and extends from 50° to about 15° at toe off. The knee joint never fully extends during stance and only reaches about 30°, but reaches a maximum of 130° during middle swing. Lastly, the ankle joint dorsiflexes to about 8° at foot contact and reaches a maximum of plantarflexion of about 25° during toe off.

Dal Monte et al⁵ investigated the use of the treadmill for training with middle and long distance runners. They compared the running styles of the athletes while on the treadmill versus the track. The results revealed that the similarity, in energy cost and movement, increases as the speed increases, but this is only achieved after significant amount of training on the treadmill.⁵

One study concentrated on the effects of altered slope and speed on running biomechanics. The authors measured fourteen variables, but only presented four. The results of their study showed that stride length decreased as slope increased, stride rate increased with speed, period of support decreased as speed increased, and period of non-support decreased as slope increased.⁶

Electromyography

The rectus abdominus (RA) is consistently active during the toe-off and early swing phases of gait. This activity correlates with the action of the abdominals which is to stabilize the pelvis.⁴ This stability is needed since the pelvis has more movement in the sagittal plane with running than with walking.⁴

The gluteus maximus (GM) demonstrates only one period of activity during running. This occurs during the late swing and early stance phases of gait.⁷⁻⁹ The function is to stabilize the pelvis on the supporting lower extremity while the momentum of the body carries it over that supporting leg.⁸

The rectus femoris (RF) muscle has two periods of activity during running. One during stance and the other during middle swing.⁷⁻⁹ The eccentric activity during stance is to stabilize the knee joint as flexion occurs and help absorb some of the impact from heel strike.^{1,4} The period of activity during middle swing is a concentric contraction to extend the knee joint, flex the thigh and advance the leg during this phase of gait. This activity is occurring while the gluteus maximus and hamstrings are relaxed to allow this forward propulsion.⁷ Mero¹ believes that the rectus femoris is more important as a hip flexor than as a knee extensor. But one must also keep in mind that the quadriceps, along with the gluteus maximus, are the key muscles in the initial acceleration phase of sprinting.²

The long head of the biceps femoris (BF) has a period of activity during stance and also during late swing.⁷⁻⁹ The concentric activity during stance phase is to help extend the hip and begin knee flexion.⁴ During late swing phase of gait, it undergoes eccentric activity to help control the rapid knee extension associated with this period of the gait cycle. The hamstrings play the biggest role in forward propulsion and developing high levels of speed once full sprinting has been achieved, although the gluteus maximus and adductor magnus are also important.²

The gastrocnemius (GS) is active during late swing to stabilize the ankle joint just prior to heel strike.^{4,7,9} It continues to be active through mid stance through eccentric contractions in order to control the amount of dorsiflexion occurring. Immediately following this period of activity, it undergoes concentric contraction in toe off in order to initiate the plantarflexion for push off.

Lastly, the anterior tibialis (AT) demonstrates activity just after toe off all the way through early stance.⁴ It functions to dorsiflex the foot during swing and to stabilize the ankle after heel strike. It once again initiates dorsiflexion after foot flat until mid stance.

CHAPTER 3 METHODS

Subjects

Six healthy males gave their informed written consent to serve as subjects in this study (Table 2). All the subjects were trained athletes who had successfully completed the Frappier Acceleration program. 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	24.67 (years)	22-26	1.51
Height	69.58 (inches)	68-72.5	1.91
Weight	178.67 (pounds)	152-201	20.63

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 Sampling Module (Peak Performance Technologies, 7388 S. Revere Parkway, Suite 601, Engelwood, 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, Engelwood, 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, NJ 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

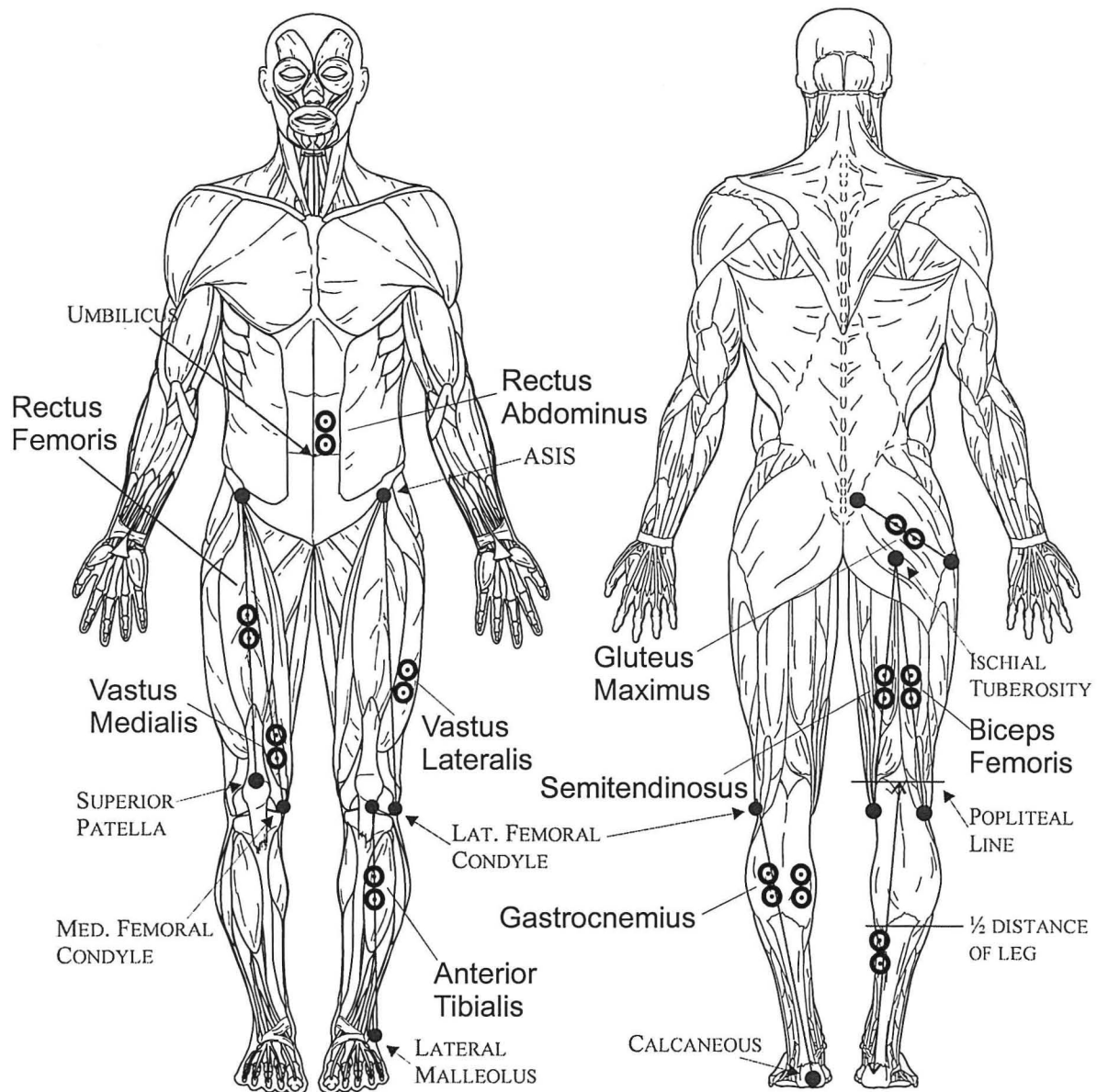
The skin on the lower extremity was prepared by cleansing it with alcohol and shaving away any excess body hair for the placement of the six (6) surface EMG electrodes over the chosen muscles. These muscles were chosen because they have been shown in previous studies to be active during sprinting. (See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

The placement of the electrodes was determined by finding each muscle by a previously identified measurement from anatomical landmarks.¹² Figure 1 graphically displays these points 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 then 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 four trials on the treadmill with a duration of six seconds for each trial. Each subject began by walking at 3.4 miles per hour and zero percent grade to get a baseline for the EMG activity. The athlete then sprinted at twenty miles per hour at zero percent grade and thirteen miles per hour at thirty percent grade. Each subject was given a rest period between each trial.



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 calcaneus)

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 for Lower Extremity Muscles

Table 2. Origin, Insertion, and Action of Selected Muscles for Sprinting^{10,11}

Muscle	Origin	Insertion	Action
Rectus Abdominus	Pubic Symphysis 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

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

The integrated EMG data was quantitatively processed using the DATAPAC III software program. In order to normalize the data within subjects, a baseline of muscle activity was utilized. The baseline of muscle activity, for each muscle, was obtained by analyzing the integrated EMG from two complete sprinting cycles while walking at 3.4 miles per hour and 0% grade. An ensemble average was computed for two complete stride lengths for each subject.¹³ The ensemble average was computed by sampling the EMG activity of an entire sprinting cycle at 2% intervals. The ensemble average was computed for two sprinting cycles, 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 percent of the sprinting cycle. Maximal activation was defined as 66.6 percent to 100 percent of peak activity, moderate activity was between 33.3 percent

and 66.6 percent of the peak level, and minimal activation was from 0 to 33.3 percent of the peak.

The hip, knee and ankle range of motion data was processed similar to the EMG data. That is, an ensemble average was computed for two sprinting cycles, for each subject, and then averaged to compute a grand mean ensemble average for all of the subjects.

Due to computer error, one subject's data was dropped from the study. Statistical analysis was not performed on the trials due to the small sample size.

CHAPTER 4 RESULTS

Figures 2 and 3 show the stickman figures, kinematic data, and integrated electromyographic activity for a representative subject performing each trial. Initial contact occurred at approximately zero percent of the running cycle and push off occurred at approximately twenty one percent. Twenty one to fifty percent is considered early swing, fifty percent to seventy two percent was mid-swing and seventy two to one hundred percent of the running cycle is terminal swing.⁷

Quantitative Analysis

The ensemble averaged curves for the electromyographic activity are shown in Figure 4. The ensemble averaged curve shows the quantity of muscle activity during one sprinting stride length. This average curve is a composite of two stride lengths for each subject. There was missing data for the biceps femoris (subject 3 in trials 3 and 4) and the rectus abdominus (from subjects 4 and 6 in trial 3). Each curve in the other trials represents the averaged activity over ten stride lengths.

Figure 5 compares the average activity in each muscle for both trials. There was an increase in the muscle activity in all muscles when sprinting at twenty miles per hour and zero percent grade compared to sprinting on an incline at thirteen miles per hour and thirty percent grade. The greatest increases were seen in the rectus femoris, anterior tibialis, and gastrocnemius. There was greater than a 337 percent change in EMG activity

in those muscles. The rectus abdominus had the least amount of change in muscle activity, with less than an 81 percent increase.

The ensemble averaged data for the hip, knee and ankle range of motion is shown in Figure 6. At twenty miles per hour, the maximum amount of hip flexion was 44 degrees, occurring at 72 percent of the stride length. The hip was hyperextended to 8 degrees at 30 percent of the running cycle. For the knee joint at twenty miles per hour, the range of motion was from 20 degrees (0% and 92%) to 120 degrees (58%) of flexion. The ankle moved from 28 degrees of plantarflexion (at 10%) to 62 degrees (at 40%) during the twenty mile per hour sprint.

When running at thirteen miles per hour on a thirty percent grade the hip flexed to a maximum of 75 degrees at 82 percent of the cycle. The hip joint reached neutral at 34 percent of the stride length. The knee joint moved from 20 degrees of flexion at 26 percent of the running cycle to 120 degrees at 67 percent. The ankle moved from 17 degrees (at 10%) to 56 degrees (at 40%) of plantarflexion.

Qualitative Analysis

Table 3 shows the activation times for each muscle, during both trials, given in percent of the total running cycle. This same information is graphically displayed in Figures 7 and 8. In general, there was a longer activation period for all of the muscles when sprinting at twenty miles per hour on the level surface versus sprinting at thirteen miles per hour at thirty percent grade. The one exception to this was the rectus abdominus, which was active for a longer period of time during the incline trial.

The gastrocnemius showed an earlier peak activation during the incline trial, but there was only one period of maximal activity, whereas the twenty mile per hour trial had

two periods of maximal activity. During the incline trial, there was a later activation for the anterior tibialis. Conversely, the rectus femoris and rectus abdominus were activated earlier in the incline trial than in the level trial. The biceps femoris showed a longer period of maximal activity on the incline than on the level surface, but there were two periods of maximal activity during the level trial as compared to one on the incline.

The range of motion in the hip between trials was very similar with periods of flexion and extension occurring at approximately the same points in the sprint cycle. The amount of knee flexion was consistent during both trials, but the cyclic motion between flexion and extension was different. In the level trial, the knee underwent progressive flexion beginning at stance until it peaked at middle swing; at which point it began to extend. On the incline, the knee cyclically extended, flexed and then extended again. The range of motion at the ankle was very similar in both trials until terminal swing. During terminal swing, the ankle had a small amount of plantarflexion in the twenty mile per hour trial, but in the other trial, it continued to dorsiflex.

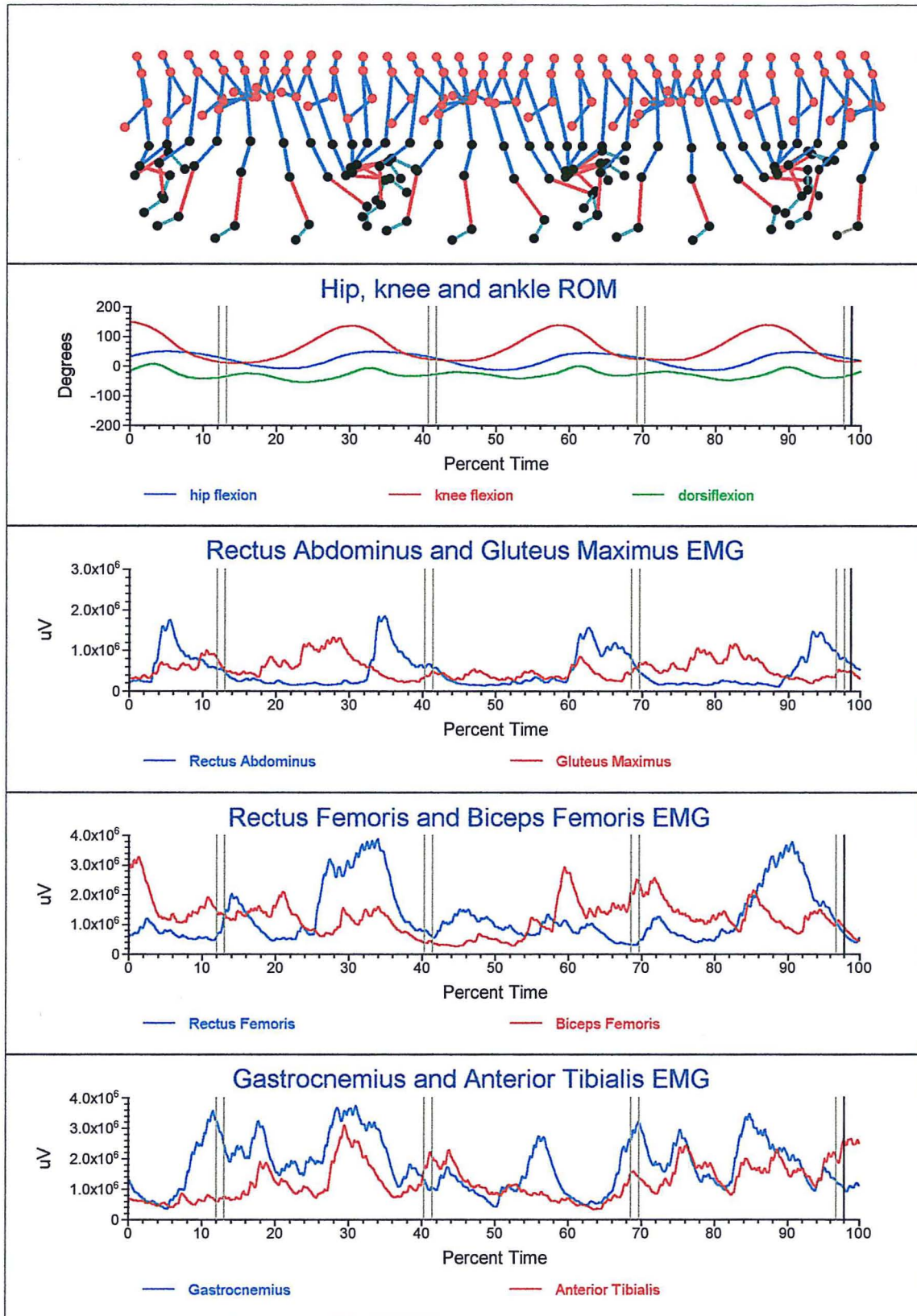


Figure 2. Kinematic and electromyographic data for subject 5 during sprinting at 20 mph at 0 percent grade. Vertical lines indicate initial contact of foot.

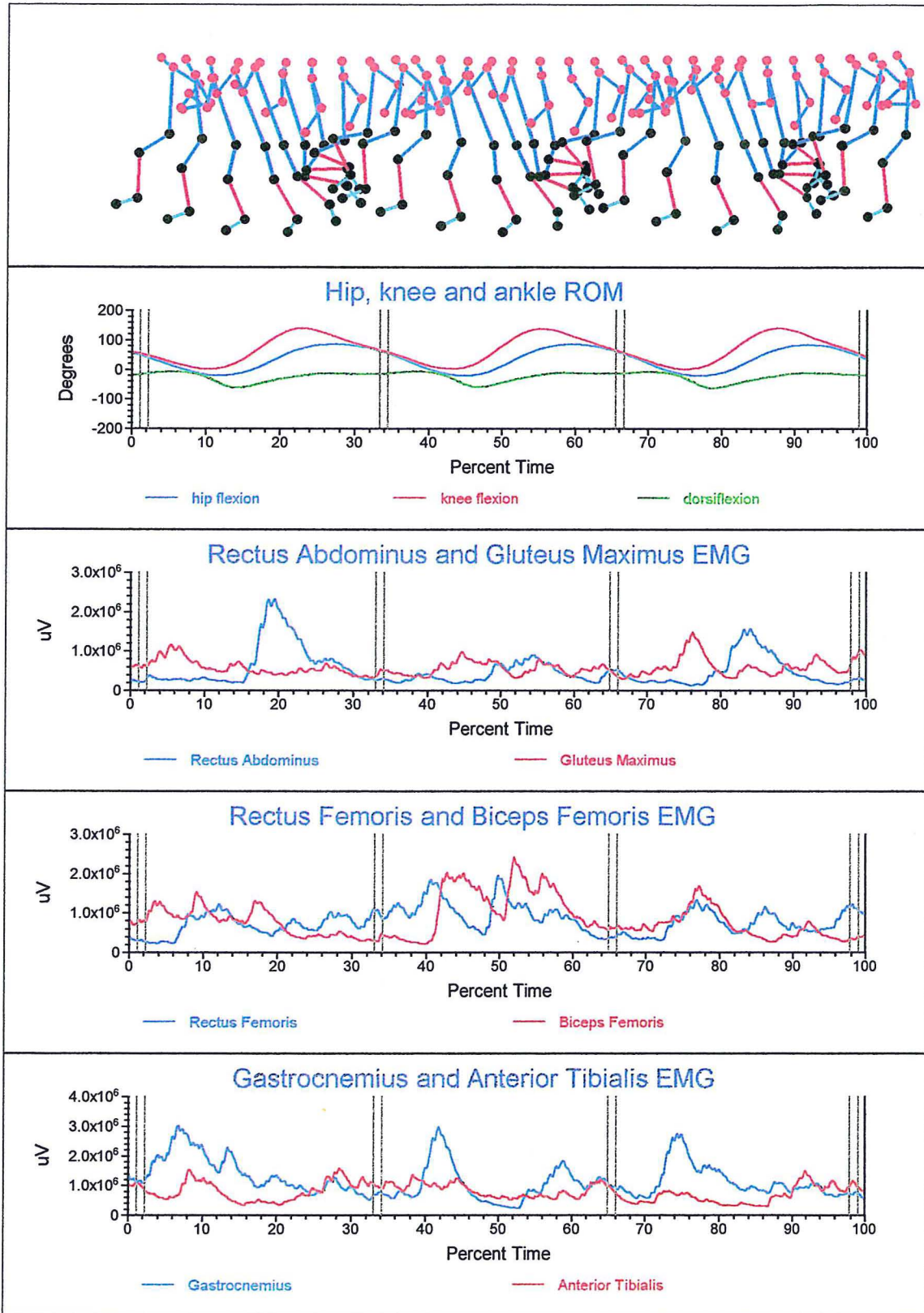


Figure 3. Kinematic and electromyographic data for subject 5 during sprinting at 13 mph at 30 percent grade. Vertical lines indicate initial contact of foot.

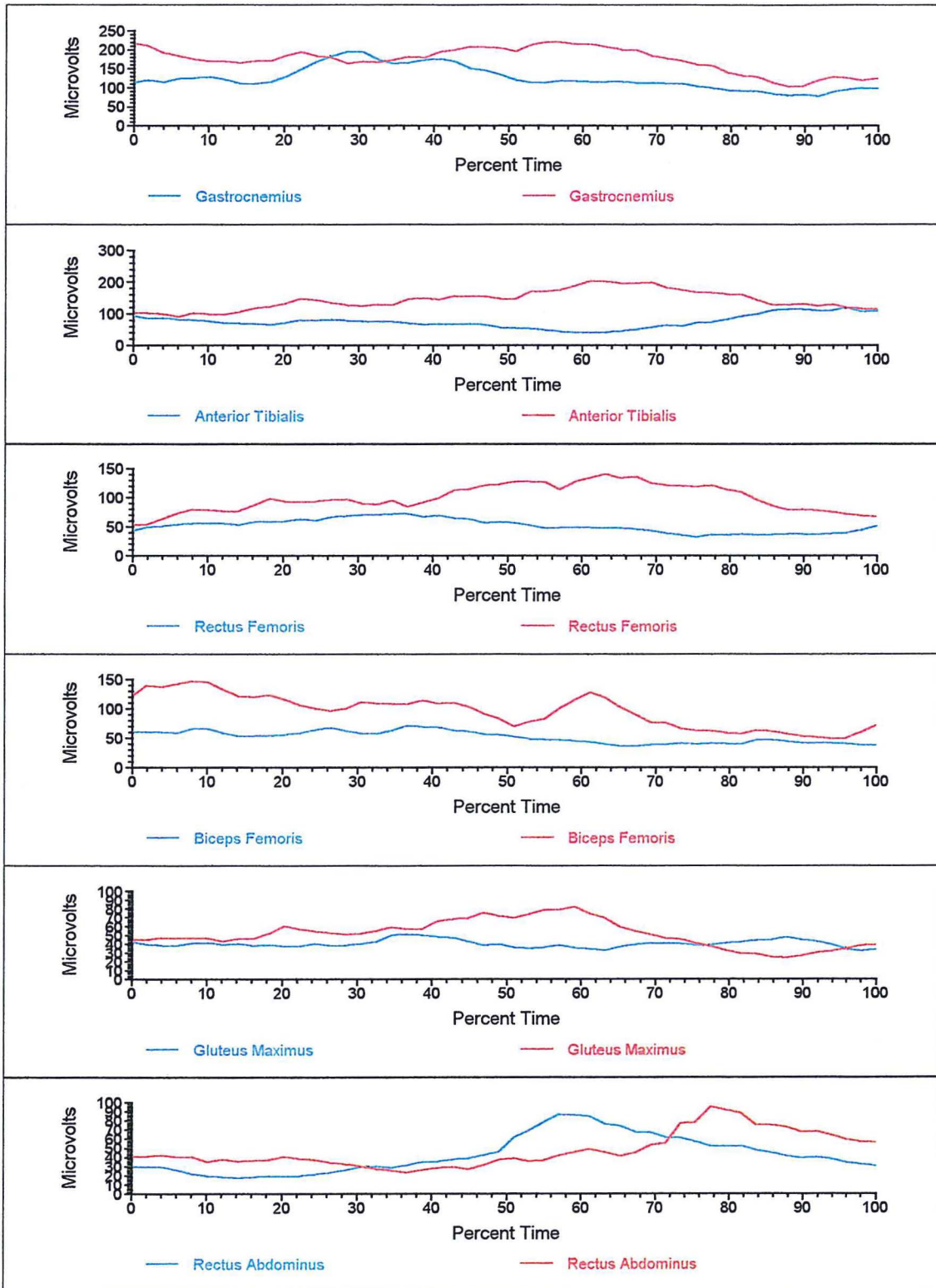


Figure 4. Ensemble averaged curve for EMG activity. Red line is sprinting at 20 mph and 0%. Blue line is sprinting at 13 mph and 30%.

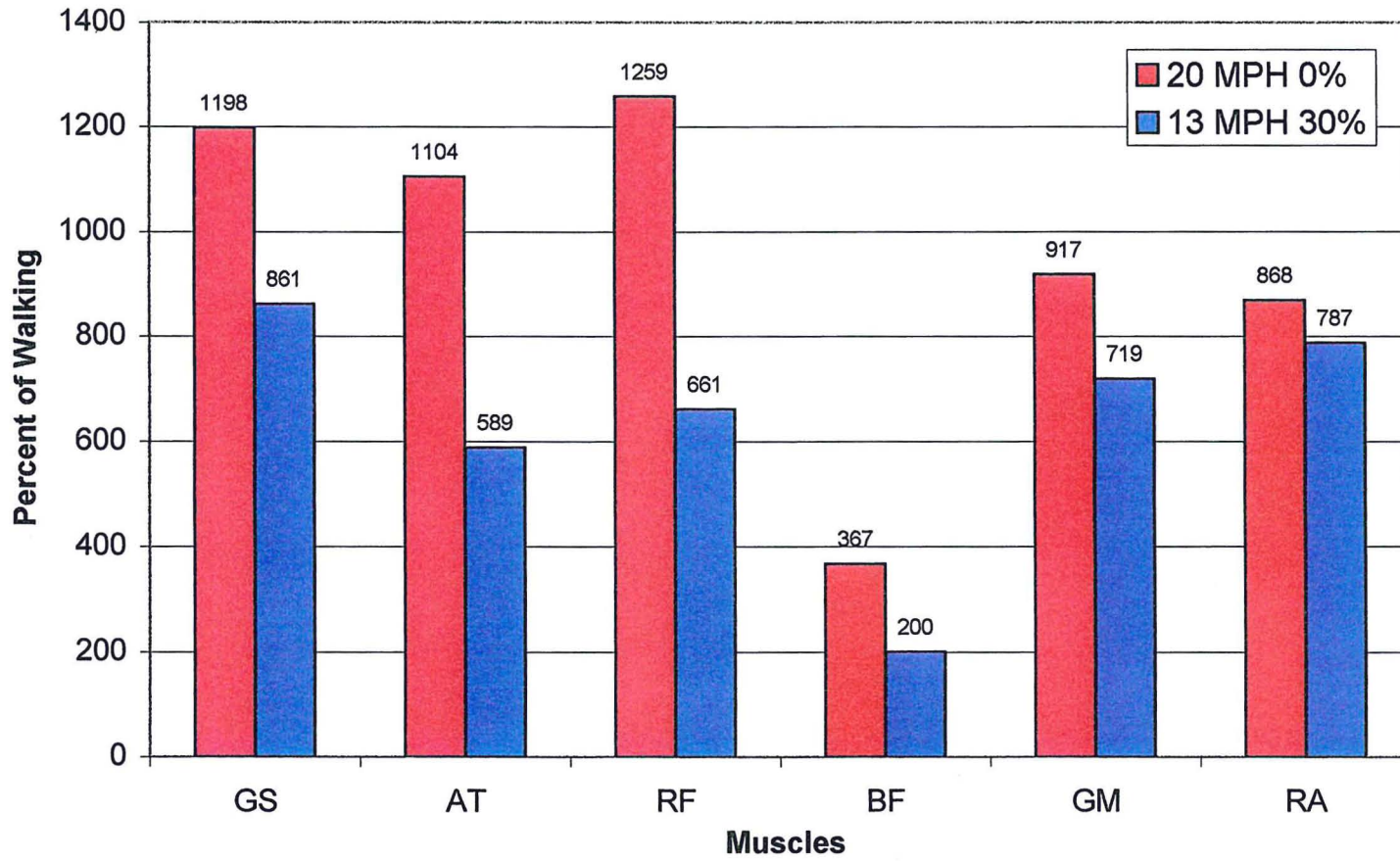


Figure 5. EMG activity during sprinting.

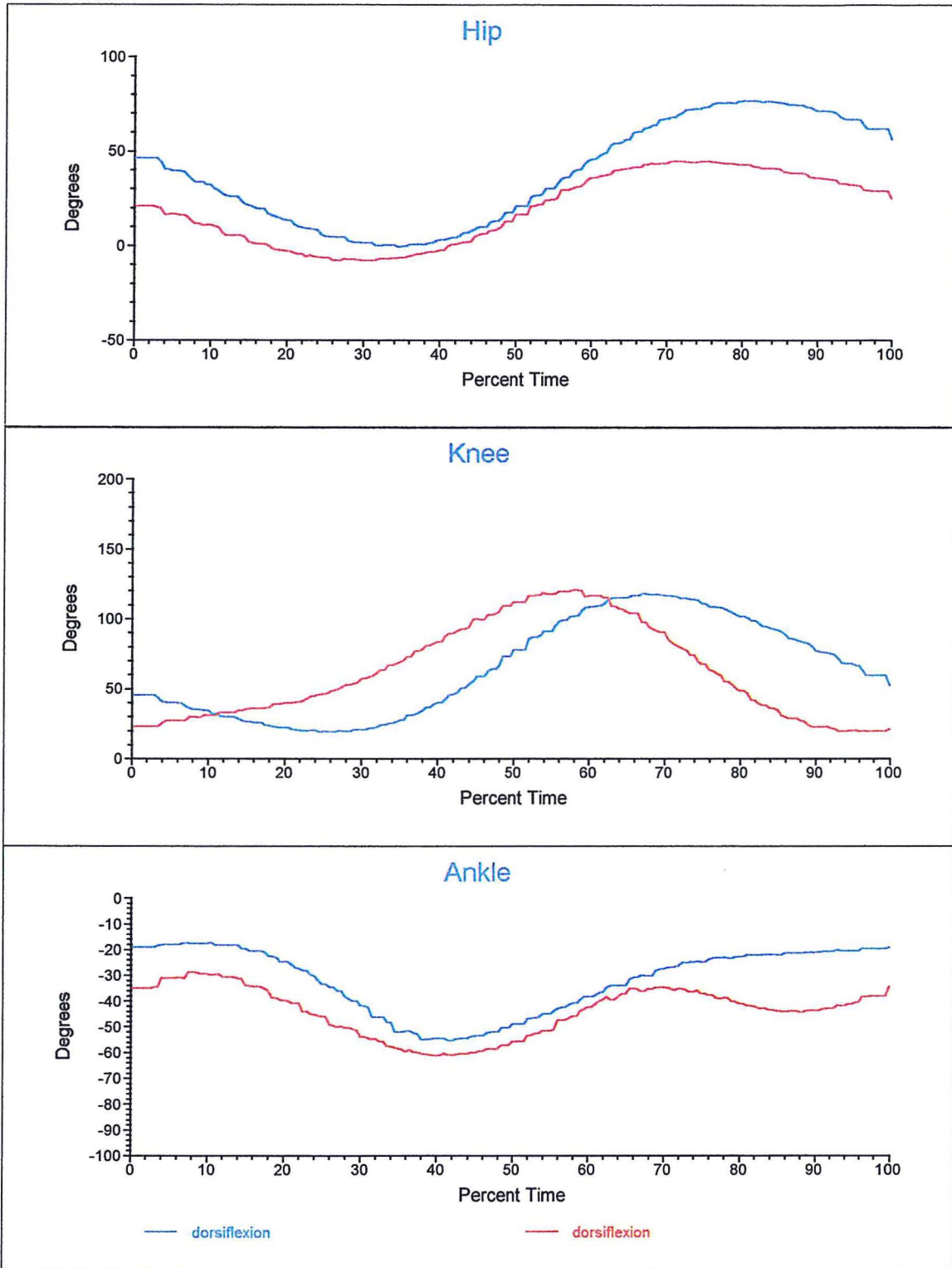
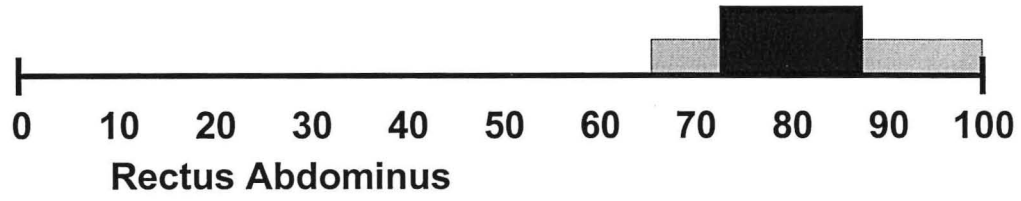
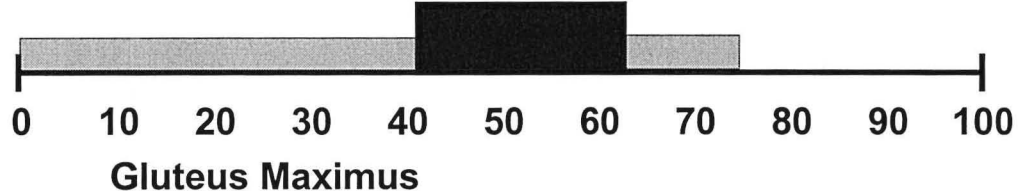
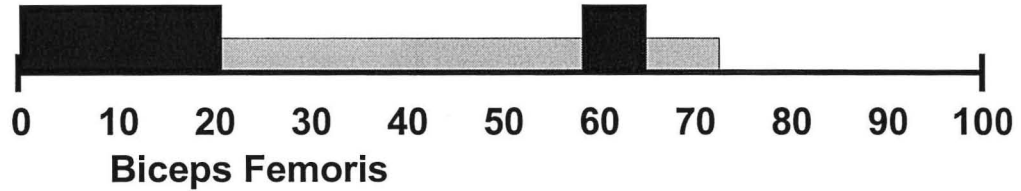
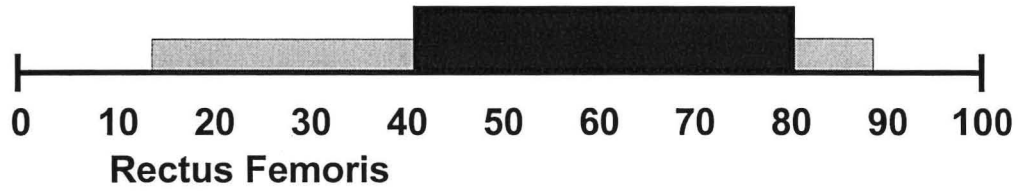
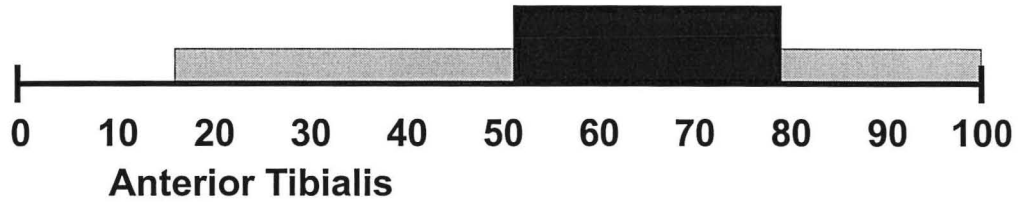
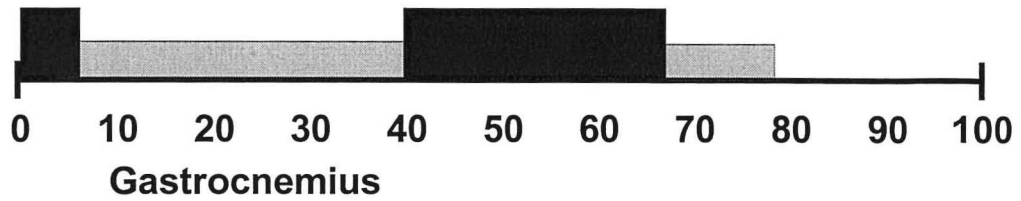


Figure 6. Ensemble averaged curve for range of motion. Red line is sprinting at 20 mph and 0%. Blue line is sprinting at 13 mph and 30%.

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	0-6% 40-68%	6-40% 68-79%	79-100%	19-47%	47-52%	0-19% 52-100%
Anterior Tibialis	53-80%	17-53% 80-100%	0-17%	83-100%	0-38% 76-83%	38-76%
Rectus Femoris	43-83%	15-43% 83-88%	0-15% 88-100%	20-50%	0-20% 50-70%	70-100%
Biceps Femoris	0-21% 59-64%	21-59% 64-72%	72-100%	0-47%	47-61%	61-100%
Gluteus Maximus	41-64%	0-41% 64-75%	75-100%	33-44% 83-91%	0-33% 44-51% 65-83%	51-65% 91-100%
Rectus Abdominus	73-88%	67-73% 88-100%	0-67%	51-72%	44-51% 72-100%	0-44%



Stance	Early Swing	Mid Swing	Terminal Swing
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Figure 7. Muscle activation for sprinting at 20 mph and 0 percent grade.

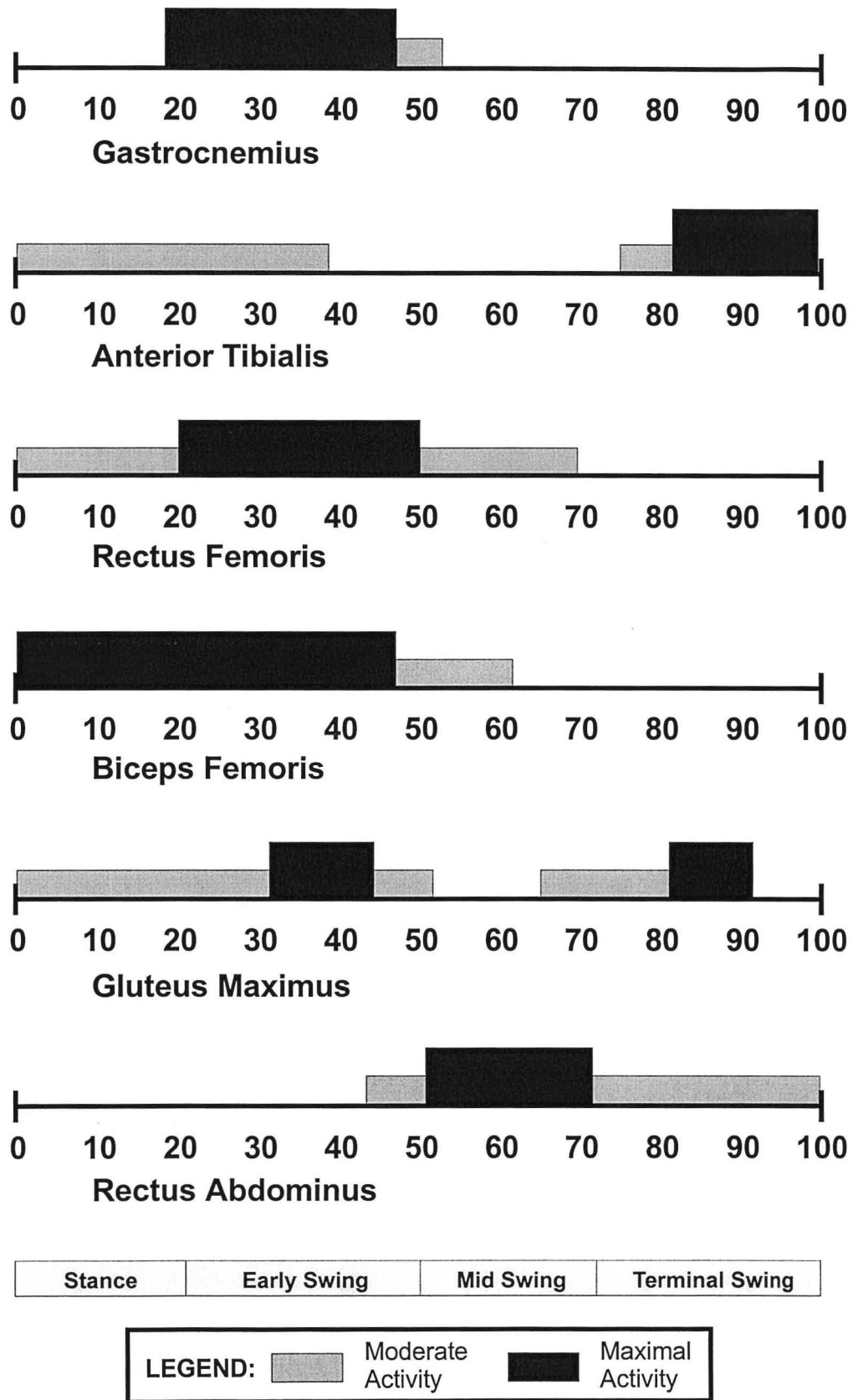


Figure 8. Muscle activation for sprinting at 13 mph and 30 percent grade.

CHAPTER 5 DISCUSSION

Discussion

Quantitative

In this study, running at twenty miles per hour produced a greater amount of electromyographic activity than running on the incline. Craik and Oatis¹⁴ reported that there was a general trend towards an increase in amplitude with increasing velocity. This appears to be consistent with our study where there was a greater amplitude in the electromyographic activity in the sprinters when they ran at twenty miles per hour compared to when they ran at thirteen miles per hour on the incline. So, it appears that speed had a greater impact on the EMG activity than the incline.

There was a greater range of movement in the hip during the incline trial than the level trial, but the overall range of movement was similar for the knee and ankle in both trials. Because the knee is approaching its functional limit of flexion at 120 degrees during swing, we suggest that as a compensation for running on the incline, there is less plantarflexion at the ankle. Therefore, we hypothesize that the increased amount of hip flexion seen with incline running is to compensate for 1) the knee motion that could not increase due to the functional limitations, and 2) the ankle that was in more dorsiflexion. This compensation may allow for adequate clearance of the foot during swing while maintaining the high velocity of the sprint.

Qualitative

Mann⁴ reports that the gastrocnemius is active from terminal stance all the way to push off, however our subjects did not reflect his findings. On incline sprinting, the GS was active in early swing, just after toe off, and was probably actively plantarflexing the ankle to the point where it reaches its maximum level. On level sprinting, the GS was most active in mid-swing most likely to control the amount of dorsiflexion.

At twenty miles per hour, the anterior tibialis is most active during mid-swing when active dorsiflexion is occurring. The AT has only minimal activity during stance, because dorsiflexion during stance is passive and is a result of the trunk advancing over a fixed extremity. These findings agree with Mann⁴ who found activity from toe off to early stance. The greatest activity in our study was from toe off until the middle of terminal swing, with the peak activity at the point where there is the most dorsiflexion. The incline trial was again different, since the peak activity occurred in late swing and gradually decreased through early swing. During this time, the AT is functioning to dorsiflex the foot just prior to initial contact.

Mero¹ states that the rectus femoris is more important as a hip flexor than a knee extensor. This was apparent in the 20 mph trial when the peak activity occurred during middle swing when there was maximum amount of hip flexion. This also agrees with the findings of Jönhagen⁷, Montgomery⁸ and Simonson⁹ who found activity during middle swing and stance. The incline trial showed the peak activity of the RF during early swing apparently contracting eccentrically over both joints to control the amount of hip extension and knee flexion.

The biceps femoris was active in stance during both trials, and contracting concentrically to initiate hip extension. However, at 40% of the gait the BF may eccentrically control the amount of hip flexion that is occurring. There is a longer period of maximal BF activity during the incline trial. We hypothesize that this is needed in order to pull the body weight up the incline during late stance and early swing. Towards the end of the running cycle, the BF was not active when there is both hip flexion and knee extension occurring. During this time, the BF is most likely inhibited by the antagonists that are controlling hip flexion and knee extension. This is comparable to the findings of Jönhagen⁷, Montgomery⁸ and Simonson⁹.

The gluteus maximus should be active during late swing and early stance according to Jonhagen⁷, Montgomery⁸ and Simonson⁹. This was not the case in either trial in our study. The GM was active during the first half of the gait cycle in both trials and is concentrically contracting to extend the hip. At the end of the cycle, it is relatively inactive at twenty miles per hour, but is active in the incline trial and may be contracting eccentrically to control the amount of hip flexion.

The rectus abdominus activity in this study does not correlate with the study by Mann⁴. He proposed that this muscle is active during toe off and early swing. However, these subjects showed periods of maximal activity during late swing in both trials. This is occurring at the time in the running cycle when there is the greatest amount of hip flexion which would result in an anterior pelvic tilt. The RA is probably controlling the amount of pelvic motion that is occurring at this time. It has a longer period of activity during the incline trial, possibly due to the greater amount of hip flexion that is occurring during this trial.

Limitations of Study

There were many limitations in this study. First of all, we tried to synchronize the EMG collection with the motion analysis by the use of a footswitch. However, at the time of analysis, we found that the switch had malfunctioned and made it more difficult to analyze the data. Second, the placement of the joint markers may have lead to incorrect measurement of the joint angles. In this study, we chose goniometric landmarks to place our markers, but at the ankle, this will result in some degree of plantarflexion even if the ankle is in neutral. Our subjects were at a different level in their training, some were more advanced than others. This may account for some of the differences in EMG activity, since the less experienced runners may recruit muscles differently than advanced runners. This leads us into the next limitation. Because of the small sample size, any deviation in the EMG in one subject may result in drastic changes in the overall average. We also lost some data due to movement artifact so the sample is even smaller. Therefore, care must be taken when trying to apply the results from this study due to the small sample size.

Conclusion

This study shows that there is a greater amount of EMG activity during sprinting at twenty miles per hour at zero percent grade than there is on the incline at thirteen miles per hour and thirty percent grade. The gastrocnemius, anterior tibialis, and rectus femoris had the greatest increases in activity between the two trials. The range of motion for both trials was similar with the exception of hip flexion. On the incline, the subjects showed greater amounts of hip flexion.

Clinical Implications

Since there are so many athletes who are trying to enhance their performance in their respective sports, this study may help develop safe training programs to assist them. Incline training appears to be useful in helping athletes increase their overall hip range of motion, however range of motion in other areas is similar in both the high speed sprinting and the incline sprinting. The gastrocnemius, anterior tibialis, and rectus femoris had the greatest increases in EMG activity during the level trial, therefore, training programs should emphasize the strengthening of these muscles.

APPENDIX

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

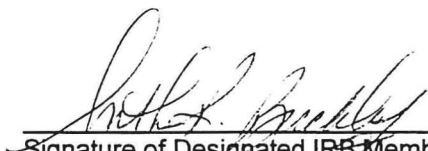
DATE: June 12, 1997 **PROJECT NUMBER:** IRB-9706-285
Thomas Mohr, Shannon Owens,
NAME: Erica Fretland **DEPARTMENT/COLLEGE:** Physical Therapy
PROJECT TITLE: An Electromyographic and Video Motion Analysis Study of Elite Sprinters
at Varying Speeds and Inclines

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

- Project approved. **EXPEDITED REVIEW NO.** 3.
Next scheduled review is on _____.
- 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.

cc: T. Mohr, Adviser
Dean, Medical School



Signature of Designated IRB Member
UND's Institutional Review Board

6/20/97

Date

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.



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

PRESIDENT:
John Frappier, M.S.

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

BUSINESS MANAGER:
Brad Holm

ACCOUNT EXECUTIVES:
Brad Gorder
Andy Becker

M.I.S.
Rich Johnson

CONSULTANTS:
Don Chu, RPT, Ph.D., ATC
President NSCA

Tim Krumrie
12 Year NFL Player
Cincinnati Bengals Coach

Curt Giles
14 Year NHL Player
Canadian Olympic Team

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





September 17, 1997

Orthopaedic Surgeons

R. Mark Askew, M.D.
Philip Q. Johnson, M.D.
Mark A. Lundeen, M.D.
Jeffrey P. Stavenger, M.D.

Orthopaedic Hand Surgeon

J. Donald Opgrande, M.D.

Spine Care

Scott E. Turner, D.O.

Physical Therapists

Sheryl Aslakson, PT
Jason Burud, PT
Justin Feeser, PT
Nicole Hewitt, PT
Ron L. Kaser, PT, L/ATC
Denise Kroke, PT
Mike Kroke, PT
Jeff Larson, PT, L/ATC
Jody Maluski, PT
Scott Nice, M, PT
Brian Skjerseth, PT
Kathy Woken, PT, L/ATC
Jeff Wold, PT

Athletic Trainers

Leo Dougherty, L/ATC
Head Athletic Trainer
Dave Bucholz, L/ATC
Don Bruenjes, L/ATC
Kelly Burns, L/ATC
Jon Darling, L/ATC
Sonva Drechsel, L/ATC
Debra Hill, L/ATC
Jodi Ingebretson, L/ATC
Al Kraft, L/ATC
Ronda Peterson, MS, L/ATC
Tom Peterson, L/ATC
Brenda Potter, L/ATC
Hugh Snaoro, L/ATC
Stacy Stoner-Dockter, M.A. L/ATC
Mark vanBeek, L/ATC
Chris Young, L/ATC

Occupational Therapists

Tom Baumgartner, OTR/L
Bob Dahl, OTR/L
Ralph Fisk, OTR/L
Pat Lucas, OTR/L
Daron Redinger, OTR/L
Sharon Westohal, OTR/L

Exercise Physiology

John P. Frappier, M.S.
Jon Hinrichs, M.S.

Business Manager

Tim Haugen, CPA
Bill Cox
Scott Marquardt

Marketing and Public Relations

Paul Smith

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

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, Shannon Owens and Erica Fretland TELEPHONE: 777-2813 DATE: 6/10/97

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 PROJECT DATES: 7/15/97 to 7/15/98
(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 CONTINUATION RENEWAL DISSERTATION OR THESIS RESEARCH 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 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 _____ Pending

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 electromyographic (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 psychological, 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 2 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 May _____ 6/11/97
Principal Investigator Date

Project Director or Student Adviser Date

Training or Center Grant Director Date

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 Shannon Owens, Erica Fretland 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 by 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.

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

References

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2. Delecluse C. Influence of strength training on sprint running performance: current findings and implications for training. *Sports Med.* 1997;24:147-156.
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4. Mann RA, Moran GT, Dougherty SE. Comparative electromyography of the lower extremity in jogging, running, and sprinting. *Am J Sports Med.* 1986;14:501-510.
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