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

Jeremy Zimney
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AN ELECTROMYOGRAPHIC AND
VIDEO MOTION ANALYSIS STUDY OF SPRIERS
AT VARYING SPEEDS AND INCLINES

by

Jeremy Joseph Zimney
Bachelor of Science in Physical Therapy
University of North Dakota, 1999

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

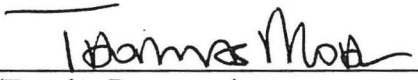
Master of Physical Therapy

Grand Forks, North Dakota

May
2000



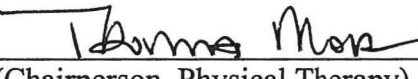
This Independent Study, submitted by Jeremy Joseph Zimney in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done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



(Faculty Preceptor)



(Graduate School Advisor)



(Chairperson, Physical Therapy)

PERMISSION

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

Department Physical Therapy

Degree Master of Physical Therapy

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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	8
CHAPTER 4. RESULTS	16
CHAPTER 5. DISCUSSION	35
APPENDIX	39
REFERENCES	49

LIST OF FIGURES

Figure 1: Electrode Placement.....	12
Figure 2: Average EMG activity during treadmill sprinting expressed as a percent change from treadmill walking	19
Figure 3: ROM for Condition 5 vs. Condition.....	20
Figure 4: EMG Activity for Condition 5 vs. Condition 3.....	21
Figure 5: EMG Activity for Condition 5 vs. Condition 3.....	22
Figure 6: ROM for Condition 4 vs. Condition 2.....	23
Figure 7: EMG Activity for Condition 4 vs. Condition 2.....	24
Figure 8: EMG Activity for Condition 4 vs. Condition 2.....	25
Figure 9: ROM for Condition 2 vs. Condition 3.....	26
Figure 10: EMG Activity for Condition 2 vs. Condition 3.....	27
Figure 11: EMG Activity for Condition 2 vs. Condition 3.....	28
Figure 12: ROM for Condition 4 vs. Condition 5.....	29
Figure 13: EMG Activity for Condition 4 vs. Condition 5.....	30
Figure 14: EMG Activity for Condition 4 vs. Condition 5.....	31
Figure 15: ROM for Conditions 2-5	32
Figure 16: EMG Activity for Conditions 2-5	33
Figure 17: EMG Activity for Conditions 2-5	34

LIST OF TABLES

Table 1: Descriptive Statistics of Subjects	8
Table 2: Origin, Insertion, and Action of Selected Muscles	11

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ABSTRACT

Athletes desire to succeed in their respective sport. Several training programs claim to enhance athletic performance by loading specific muscles and joints needed for increased speed, power, and strength in a sport specific manner. One such training regimen is the Frappier Acceleration[®] program, in which the core element involves sprinting on a treadmill at varying 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.

Eleven males between the ages of eighteen and twenty-two years of age ran on a treadmill at five different conditions at varying speeds and inclines. One of these trials consisted of the subject walking at 2.4 mph and a 0 percent grade in order to obtain a baseline for comparison of the other four trials. Surface electrodes and joint markers were used to analyze electromyographic activity of eight muscles and calculate joint angles while running. A descriptive analysis was then performed comparing the five trials.

From our results we conclude that the sprinter does adopt different strategies and muscle recruitment patterns to compensate for increases in slope. There is an increase in EMG activity in the Vastus Lateralis, Rectus Femoris, Gluteus Maximus, and Tibialis Anterior when running at 8 mph and 25 percent grade when compared to the level condition, and an increase in the EMG activity of all recorded muscles when running at 13 mph and 25 percent grade vs. level running. Examination of range of motion revealed

that there was greater overall motion of the hip on the incline trials while displacements of the knee and ankle were relatively similar.

CHAPTER 1

INTRODUCTION

Many athletes desire to succeed in their respective sport. The increasing technology of human performance enhancement has given athletes an outlet to become bigger, faster, and stronger than conventional methods of training. These athletes yearn for ways to optimize their potential above their competitors. Several programs claim to enhance athletic performance by loading of the specific muscles and joints needed for increased speed, power, and strength within a sport specific manner. One such training regimen is the Frappier Acceleration[®] program, in which the core element involves sprinting on a treadmill at varying speeds and inclines.

Problem Statement

The problem lies in the limited amount of research available to attest to the efficacy of this training technique. Further research is needed to validate the use of this training method in order to endorse its use in training athletes. Although research regarding treadmill training is available, there is a need to evaluate whether differences, if any, exist between level treadmill running and incline treadmill running at speeds above 8mph.

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 level treadmill, and on an

incline causes particular muscles to work harder or the sprinter to change their running technique to accommodate the workload of the varying conditions.

Significance of Study

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

Research Questions

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

Hypothesis

Null: Muscles recruited and joint kinematics do not change while running on an incline compared to level treadmill running.

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

CHAPTER 2

REVIEW OF THE LITERATURE

Numerous articles have been published examining muscle activity in the lower extremity during sprinting. Electromyography (EMG) has been useful in comparing muscular activity among different movements.¹ The activation of different muscles in the lower extremities in sprinting as shown in recordings of EMG activity has been studied by several researchers.²

The ability to time EMG analysis findings with computerized digitization from video data has revolutionized the study of human movement.³ The running cycle is commonly divided into two phases defined by the events of foot contact and takeoff.^{3,4,5} Stance phase occurs when the foot is in contact with the ground, and swing phase occurs when the foot is not contacting the ground.^{3,5,6,7}

Mann et al,⁵ found EMG activity around the hip to increase during the swing phase of sprinting. As velocity increases, swing phase hip flexion increases, resulting in an increased stride length.³ The gluteus maximus (GM) and hamstrings have been found to have an increase in activity at terminal swing. The function of the hip extensor and knee flexors is to decelerate the swinging thigh prior to foot contact by contracting eccentrically.^{2,5,8,9} Mann et al⁵ and Williams⁹ found another increase in GM and hamstring activity during stance phase as hip extension occurs due to concentric

contractions of these muscles. Mann et al⁵ believes that the iliacus and psoas are the prime flexors of the hip joint, and that it is the activity of these muscles that bring about the greatest change in the movement of the lower extremity. The iliacus has an increase in EMG activity that can be observed from toe off to mid swing.^{2,10} The hip flexors appear to be the main muscle group responsible for increased speed during sprinting.⁵ There is a tendency for highly skilled runners to have a greater lifting of the thigh during swing.^{4,10} Hip flexors and extensors are both responsible for increased power generation in sprinting.³

Mero and Komi¹¹ found that the rectus femoris contracted eccentrically at the end of ipsilateral contact due to extension at the hip joint and flexion at the knee joint. They found that during swing the muscle begins concentric contraction when flexing the thigh forwards, and is not very active in extending the leg before initial contact. They concluded that the role of the RF as a hip flexor was more important than as a knee extensor in running. This differs from Williams⁹ who found that high activity in the RF found during support phase, diminishes by late support. Because of the small amount of activity in the RF during late support and early swing, he suggests that the RF did not actively limit hip extension and was not a prime factor in hip flexion.

During running, the quadriceps contracts both eccentrically and concentrically; to absorb and generate power.³ Activity can be found in both the vastus lateralis (VL) and the vastus medialis (VM) at the end of swing as they contract in preparation for initial contact.^{2,9} During single limb support, the knee extensors show their greatest activity. The activity of the quadriceps diminishes toward the end of the support phase.^{2,9,10} The semitendinosus (ST) and biceps femoris (BF), are active during the end of swing phase

and at the beginning of stance phase.^{2,5} The hamstring muscles work eccentrically at the end of swing to limit extension of the knee and prepare for loading.^{2,5,9,10} The hamstring activity continues into the single limb support phase serving to propel the thigh backwards into extension.^{5,12}

The tibialis anterior (TA) has a two-peak activity.^{2,5} Mann et al⁵ found the TA to be active during swing phase to bring about dorsiflexion at the ankle joint. The TA is also active during a cocontraction with the gastrocnemius during footstrike to help establish a stable base of support and control movements of the ankle.^{2,5,9} The gastrocnemius (GA) have been found to demonstrate activity during foot descent, providing stability to the ankle joint in preparation for initial contact.^{2,5,9} Jonhagen et al² found the GA to have high activity throughout the support phase including toe-off, playing a primary role in the push-off of sprinting. This contradicts the findings of Mann et al⁵ where no activity was observed just before and during push-off. They postulated that the majority of forward propulsion during sprinting is brought about by the rapid hip flexion of the swing limb, rather than by push-off of the stance limb.

Delecluse¹³ has divided training into three categories: hypertrophy training, neuronal activation training, and speed-strength training. The primary goal of hypertrophy training is to increase the cross-sectional area of the muscle fibers. Most athletes perform hypertrophy training in their preparatory period as a method to improve the quantity of the muscle mass prior to training for speed of neuromuscular activation and/or muscle contraction. Hypertrophy training is characterized by a large number of sets of repetitions with submaximal loads of 60 to 80% of one rep maximum.¹³ To improve resistance against gravitational forces, the athlete should improve lower

extremity strength by utilizing squats and semisquats.⁸ If fast twitch fibers are recruited and overloaded, they tend to undergo hypertrophy very readily, however it is evident that the use of hypertrophy training for sprinters must be limited and combined with other strength training methods.¹³

Methods to improve neuronal activation make use of short term, fast actions against near maximal loads or supramaximal loads in the case of eccentric actions. The near maximal loading compels the motor neurons to fire high frequency impulses for comparatively long times. These training methods should be practiced in a rested state with each action being executed as fast as possible; the number of consecutive repetitions is limited to a maximum of three.¹³

Delecluse¹³ divides speed-strength training into stretch-shortening cycle exercises and sprint-associated exercises. Stretch-shortening cycle exercises (plyometrics) reduce the deceleration phase found at the end of concentric movement in traditional lifting.¹³ Chu and Korchemny⁸ recommend applying a variety of plyometric jumps with ankle rebounds to improve recruiting and firing abilities of muscles. McFarlane¹⁴ recommends power speed exercises utilizing resistance such as sandbags, weight vests, or wrist weights while stressing perfection of technique. The purposes of power speed exercises are to isolate and combine a series of joints to the specificity of sprinting, and to maintain and improve these skills with a continuous development in speed, flexibility, and strength.¹⁴ Delecluse¹³ recommends that speed-strength training should always be performed using a time check to assess the quality of training.

Specific sprint exercises that reproduce fast running and include a strength component are needed to establish an efficient transfer between strength training and fast

running. Overload and overspeed running are examples of such exercises.¹³ Uphill running is a classic overload training technique. Nelson and Osterhoudt¹⁵ found uphill running at a 10% grade to produce a decrease in stride length and periods of support and non-support while causing an increase in stride rate when compared to horizontal. Another method of overload running is pulling parachutes while sprinting. Resistance is varied depending on the size of the chute. High resistances are used to improve the acceleration phase, medium resistances to increase speed endurance, and the smallest chute is used in the phase of maximal running speed. All methods of overload running aim at increasing stride length.¹³

In overspeed training, the athlete is made to run faster than he/she normally can by artificial means.¹³ Examples of overspeed techniques include downhill running, downwind running, towing, and high-speed treadmill running.^{10,13} It is possible to achieve a higher stride rate in supramaximal running as compared with normal maximal running, supporting the idea that it could have benefits in sprint training by adapting neuromuscular performance to a higher stride rate level.^{13,16}

The Frappier Acceleration™ Program is a training regimen that includes the use of a high speed running treadmill and consistently utilizes grades over 25% and speeds over 10mph.^{1,17} A main goal of their training protocols is to develop muscular power during both stance and recovery phases of the sprinting cycle.¹ Swanson et al¹ found that as a training tool, high speed incline running is effective in increasing the activity levels in some, but not all lower extremity muscles. The fact that the runner's pace can be controlled externally points to some interesting possibilities for training the athlete, whether at submaximal, maximal, or supramaximal speeds.¹⁸

CHAPTER 3

METHODS

Subjects

Twelve, healthy males gave their informed written consent to serve as subjects in this study (See Table 1). Two subjects were eliminated from this study due to faulty electrodes and irregular EMG data. 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	19.1 (years)	18-22	1.60
Height	70.6 (inches)	69-74	1.87
Weight	164.2 (pounds)	150-195	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 transmitted 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 placed in the subject's shoe. Another switch composed of three piezo-resistive sensors was mounted under the bed of the treadmill and allowed the investigators an additional means to identify when initial contact was occurring. Upon contact of the left foot with the treadmill, an LED light was illuminated in the video image via the footswitch, and a small lamp was activated via the treadmill switch. A switch controlled by the investigator allowed the footswitch circuit to be closed only during the EMG collection period.

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 videocassette recorder (JVC of America, 41 Slater Drive, Elmood Park, MF 07407). The videotape 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) videocassette recorder for the purpose of digitization.

Electrode and Marker Placement

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 eight (8) 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).

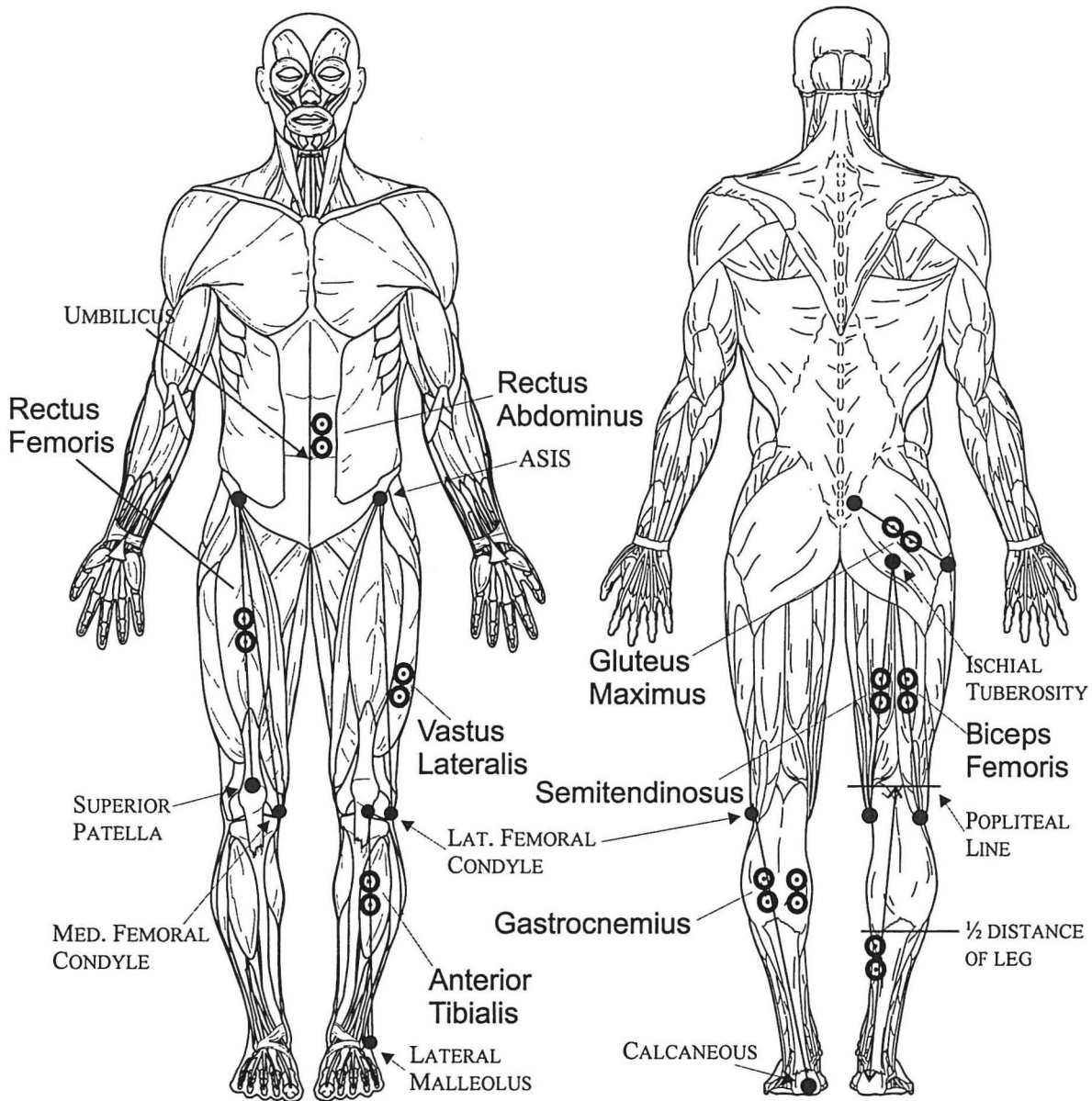
The placement of the electrodes was determined by finding each muscle by a previously identified measurement from anatomical landmarks.¹⁹ Figure 1 displays these points anatomically along with a descriptive measurement for each one. The ground electrode was placed on the iliac crest.

The electromyographic signals from the electrodes were input directly to a receiver, which then transmitted 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 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 illuminated during the trials and captured on tape. The marker locations were digitized to allow the sagittal motion of the neck, trunk, arm, forearm, thigh, leg and foot to be analyzed.

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

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 Interosseus membrane	1 st Metatarsal 1 st Cuneiform	Dorsiflexion Inversion
Vastus Medialis	Medial lip of linea aspera Intertrochanteric line	Medial surface, top of patella Tibial tuberosity	Extends knee (leg)
Erector Spinae	Posterior iliac crest and sacrum Sacral and inferior lumbar spinous processes, and supraspinous ligament	Fibers run superiorly to angles of lower ribs and cervical transverse processes	Maintain posture Extend trunk, bilaterally Rotates trunk, unilaterally



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

Semitendinosus - midpoint of a line from the ischial tuberosity to the medial femoral condyle

Rectus Femoris - midpoint of a line from the ASIS to superior pole of patella (minimum of 10 cm above the patella)

Vastus Lateralis - along a line $\frac{1}{4}$ the distance from the lateral knee joint line to the ASIS and over the belly of the vastus lateralis

Gastrocnemius - over the muscle belly $\frac{1}{3}$ the distance of the leg (fibular head to calcaneus)

Anterior Tibialis - over the muscle belly $\frac{1}{3}$ the distance of a line running from the lower margin of the patella to the lateral malleolus

Figure 1. Electrode Placement.

Protocol

Conditions

Table 3. Description of Protocol Conditions

	Speed	Grade
Condition 1	Walking at 2.4 mph	0% grade
Condition 2	8 mph	25% grade
Condition 3	PSF of 8 mph/25% grade	0% grade
Condition 4	13 mph	25% grade
Condition 5	PSF of 13 mph/25% grade	0 % grade

Calculation of Preferred Stride Frequency

Subjects were allowed to warm-up on the treadmill for 1-2 minutes prior to beginning their trials. Following the completion of the warm-up, the subjects were required to perform 3-4 bouts of exercise on the treadmill at the same speed and incline of condition 2 (8 mph and +25% grade). During each exercise bout, the investigator recorded with a stopwatch the time it took the subject to complete five complete stride cycles. The subjects were allowed to take as much rest as needed between each of the bouts of exercise. The investigator then ran the subject on a 0% grade for condition 3 at a speed that would allow the same preferred stride frequency (PSF) as in condition 2. For condition 3, the investigator timed how long it took the subject to complete five complete stride cycles. The speed for condition 3 at 0% grade was adjusted up or down until the time it took to complete 5 stride cycles for condition 3 was within .2 seconds of the time it took the subject to complete 5 stride cycles for condition 2. Once this was established,

the speed was recorded as the speed that would be utilized for condition 3 in the trials. The subjects then ran 3-4 five second bouts of exercise on the treadmill at the same speed and incline of condition 4 (13 mph and +25% grade) in order to determine the PSF estimation used to dictate the speed that was used in condition 5 on a 0% grade using the same procedure.

Trials

After successful completion of the pre-testing bouts of exercise, each subject completed a total of 5 trials of EMG and kinematic data in only one trial of each condition (C1, C2, C3, C4, C5). Each trial consisted of a six-second bout of exercise on the treadmill. Kinematic and EMG data were collected throughout the trial. The subjects were allowed to take as much rest as needed between trials to minimize any effect of fatigue. Walking was the first trial recorded for all subjects. The four running conditions were performed in a random order determined by blindly drawing out of a hat.

Data Analysis

Prior to videotaping, the camera field was calibrated by videotaping a meter stick. The video footage for each sprinting trial was cropped down to five completed strides 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 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 data was transferred into the Microsoft Excel program to determine the percent change from walking of each muscle from the ensemble averages of each sprinting condition.

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

For each psf/0% grade condition, the speed of the treadmill is increased in an effort to replicate stride frequency of the incline conditions. In Condition 3, the speeds range from 12mph to 13.5mph. In Condition 5, the speeds range from 17mph to 18.5mph. Also, two subjects are eliminated from this study due to faulty electrodes and poor recording of EMG activity. Therefore, nine subjects are used to evaluate EMG and motion analysis.

13psf/0% grade (Condition 5) vs. 8psf/0% grade (Condition 3)

Figure 3 shows the ensemble average curves for hip, knee, and ankle ROM during these two conditions. At the hip joint, Condition 5 has greater total ROM than Condition 3. Differences in total knee and ankle ROM are smaller. At the ankle, Condition 5 elicits the highest degree of plantarflexion peak whereas Condition 3 causes the greatest dorsiflexion.

Figure 4 and 5 show the ensemble average curves for EMG activity of the eight muscles selected. Condition 5 exhibits a higher EMG activity total for all muscles selected compared to Condition 3. In Figure 2, the four muscles showing the largest difference in percent change from walking are RF (340%), RA (288%), VL (221%), GM (219%). The muscle showing the least difference is the GA (91%).

13mph/25% grade (Condition 4) vs. 8mph/25% grade (Condition 2)

Figure 6 shows the ensemble average curves for hip, knee, ankle, ROM during these two conditions. Little difference is noted in hip and knee ROM. At the ankle, Condition 6 displays a greater degree of plantarflexion throughout the entire stride length when compared to Condition 2.

In Figure 7 and 8, the GM, GA, and VL elicit a higher peak in EMG activity during Condition 4 than in Condition 2. However, Condition 4 displays a higher average EMG activity for all muscles selected. The four muscles showing the largest difference in percent change from walking are the RF (654%), RA (522%), BF (371%), and ST (318%), as shown in Figure 2. The muscle showing the least difference is the GA (96%).

8mph/25%grade (Condition 2) vs. 8psf/0%grade (Condition 3)

Figure 9 shows the ensemble average curves for hip, knee, ankle ROM during these two conditions. At the hip, Condition 2 exhibits a greater degree of hip flexion throughout the entire stride when compared to its counterpart. Condition 3, however, attains a higher peak of ROM in both knee flexion and extension. At the ankle, Condition 2 achieves the highest peak of ROM for dorsiflexion.

Figure 10 and 11 show EMG activity for these two conditions. During Condition 2, the VL, RF, GM, GA, and TA exhibit a greater average EMG activity when compared to the level condition. During Condition 3, the RA, BF, and ST are higher in average EMG activity. The muscles that show the largest difference in percent change from walking are the VL (186%), RF (133%), and GM (121%). The muscle showing the least percent change is the TA (13%).

13mph/25%grade (Condition 4) vs. 13psf/0%grade (Condition 5)

Figure 12 shows the ensemble average curves for hip, knee, and ankle ROM during these two conditions. At the hip, Condition 4 exhibits a greater degree of hip flexion throughout the entire stride cycle when compared to Condition 5. However, the level condition elicits the highest peak in ROM for both knee flexion and extension. At the ankle, Condition 5 achieves the highest peak of ROM for dorsiflexion.

In Figure 13 and 14, Condition 5 elicits a higher peak in EMG activity for the GM, VL, BF, ST, GA, and TA when compared to this incline condition. However, Condition 4 shows higher average EMG activity for all eight muscles examined compared to the level condition. The four muscles showing the largest difference in percent change from walking are RF (447%), VL (222%), RA (152%), and GM (136%) as shown in Figure 2. The muscle showing the least is the GA (33%). In addition, Condition 4 displays the greatest average EMG activity for all the muscles tested when compared with the other conditions.

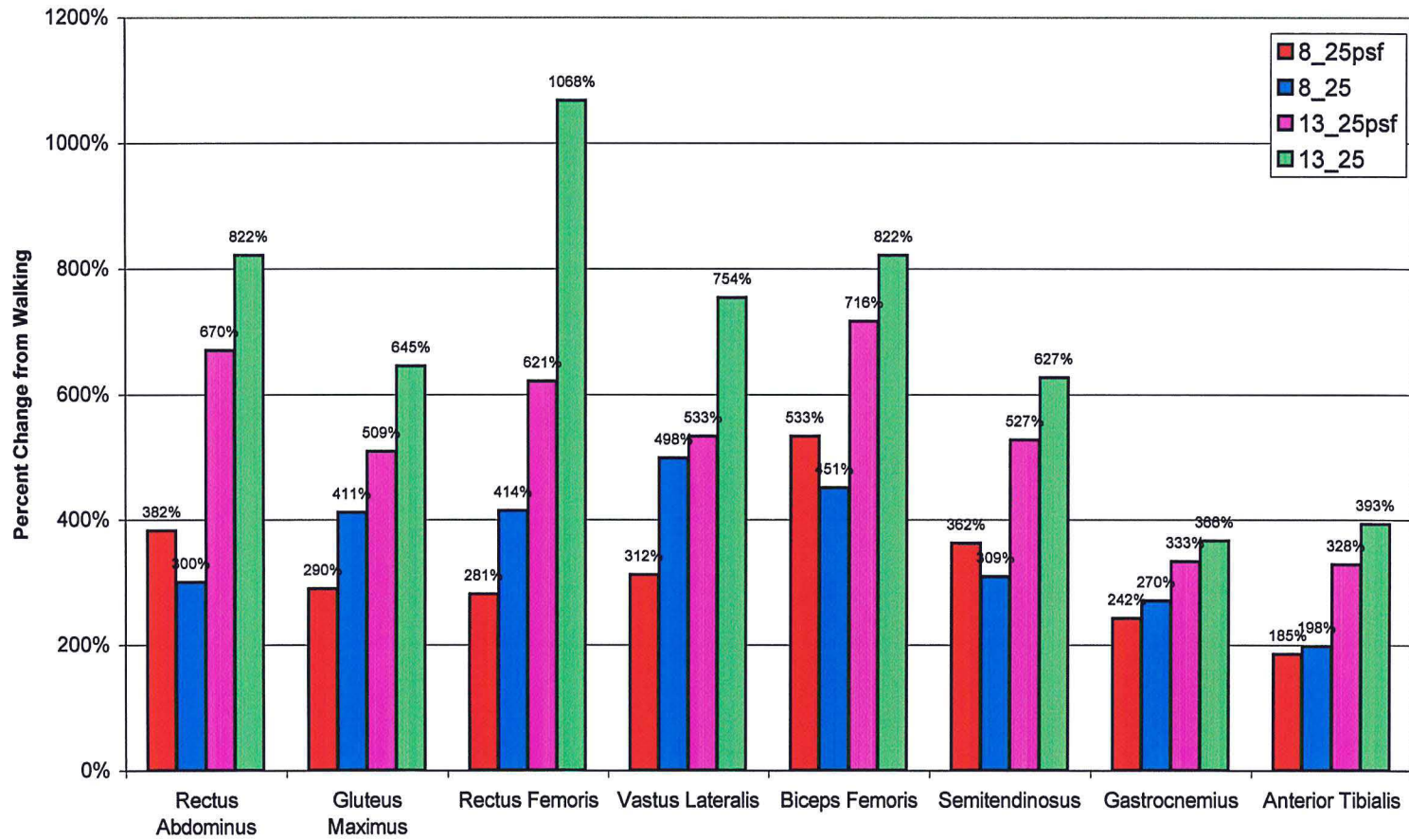


Figure 2. Average EMG activity during treadmill sprinting expressed as a percent change from treadmill walking.

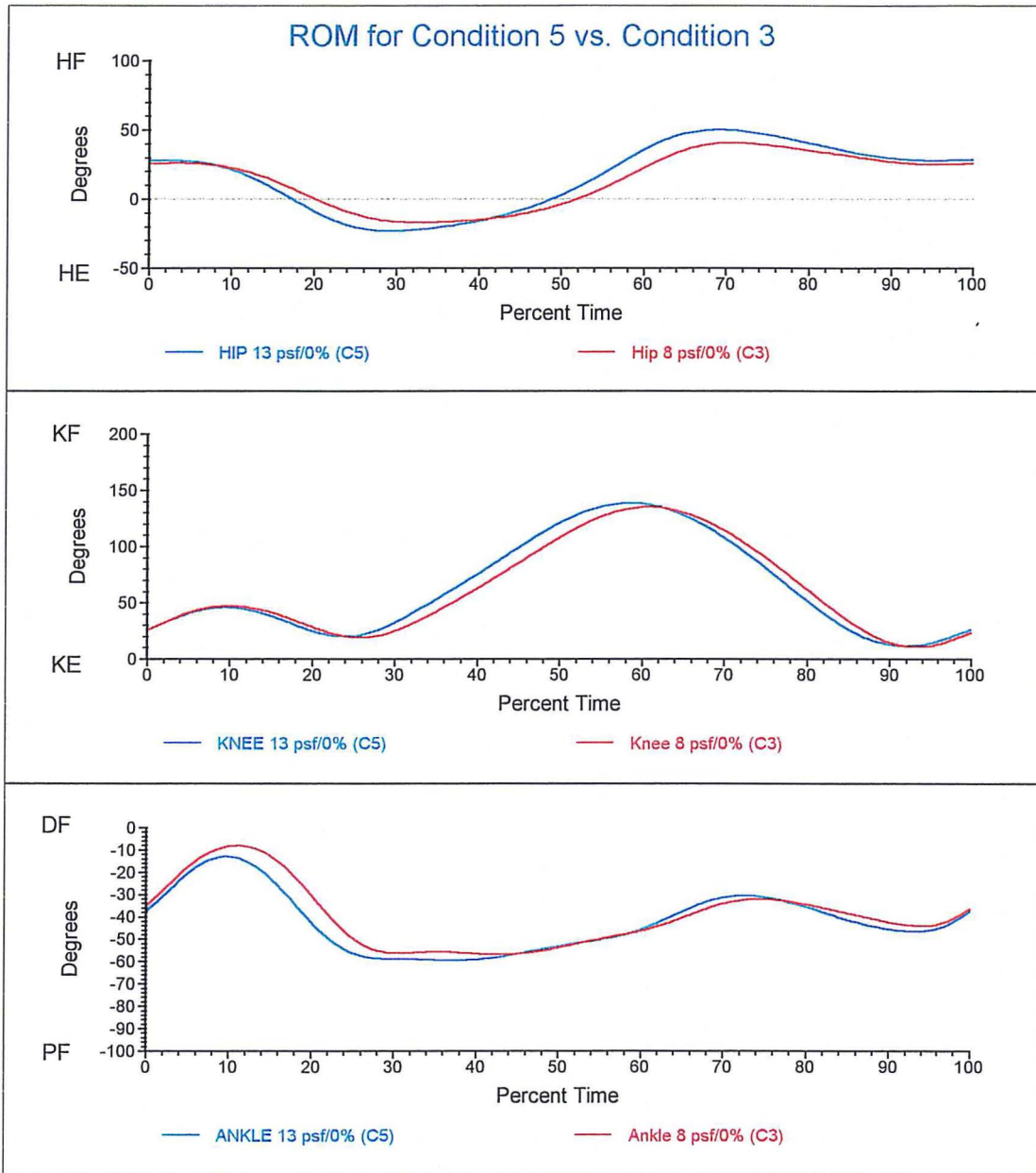


Figure 3.

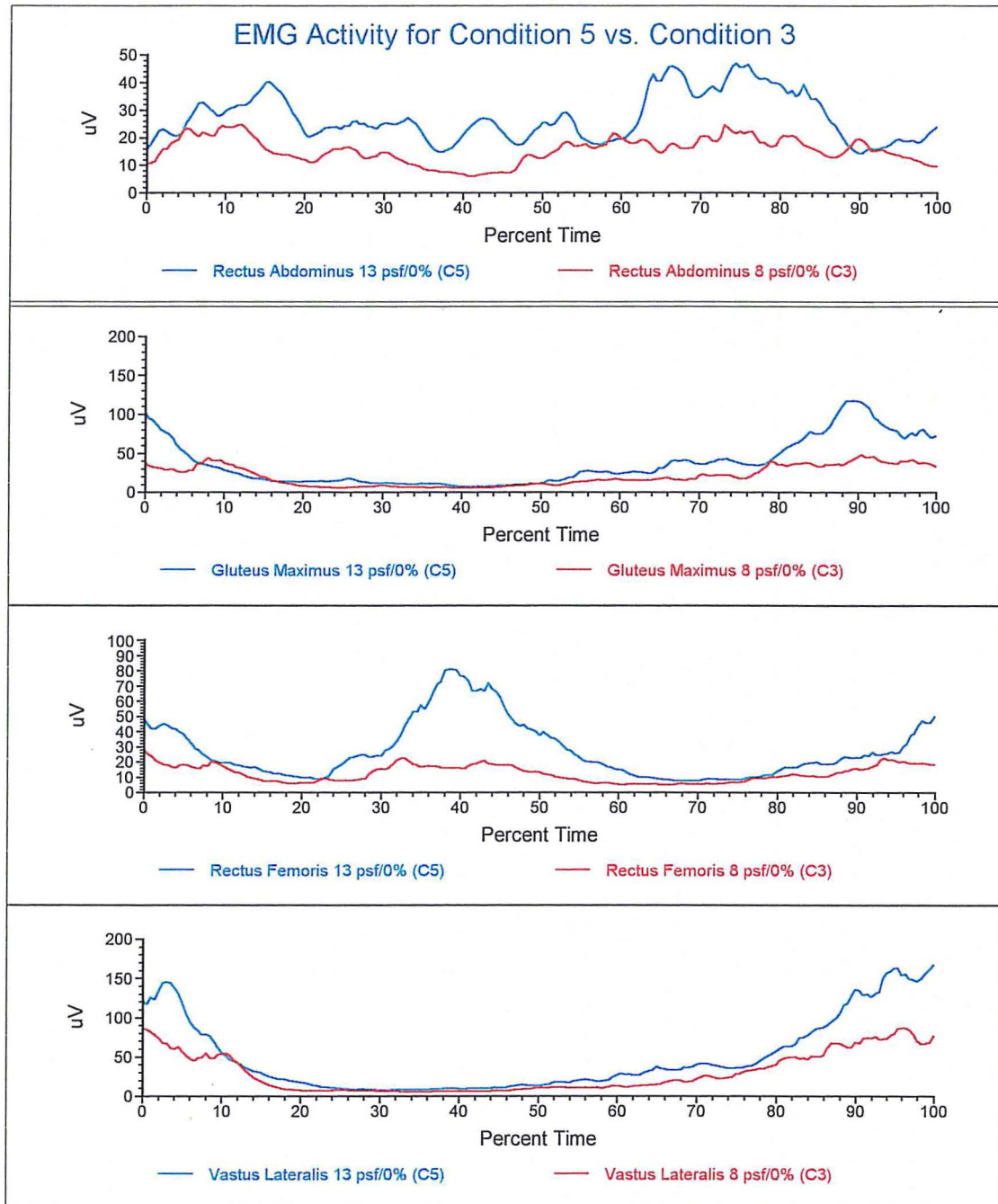


Figure 4.

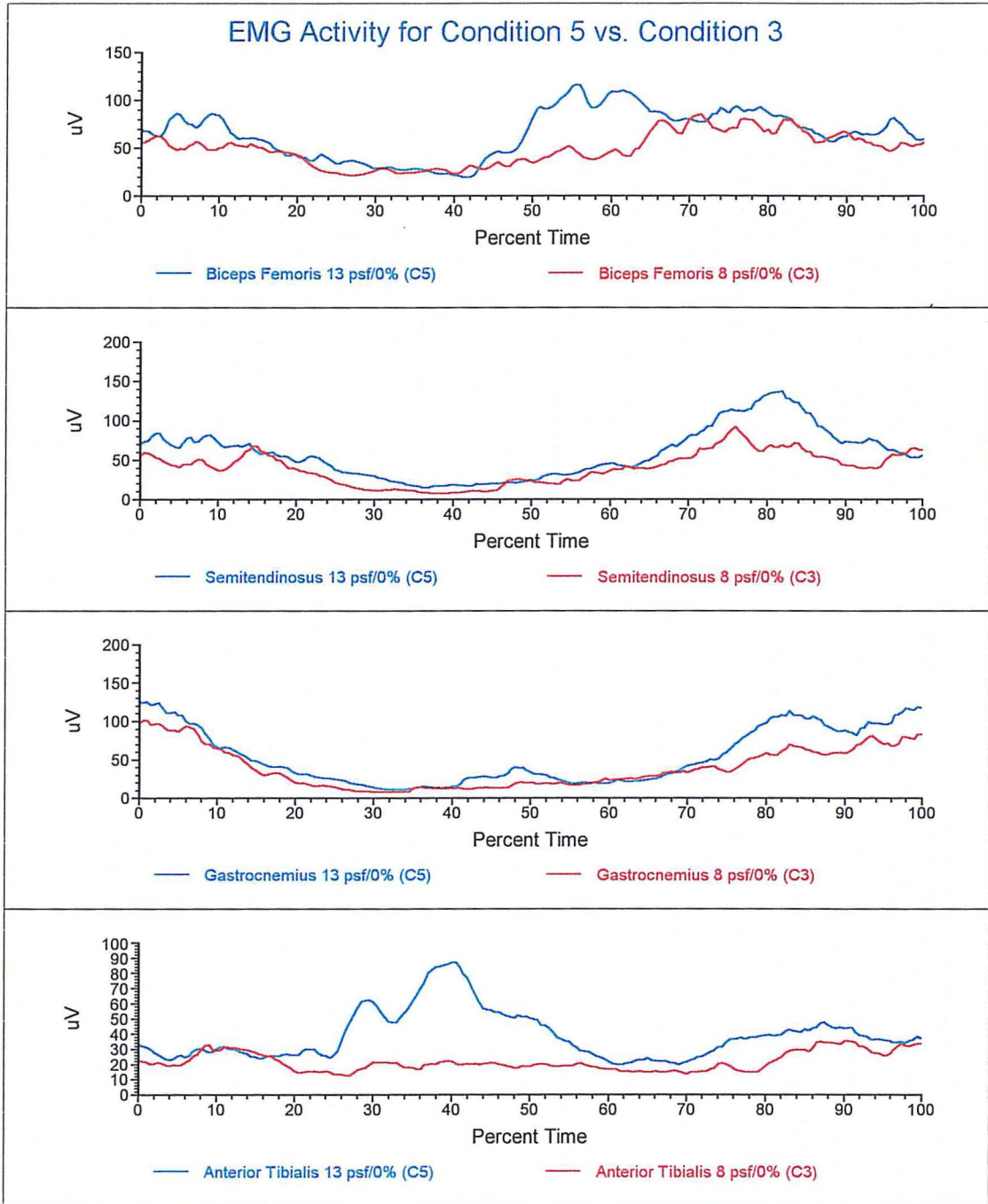


Figure 5.

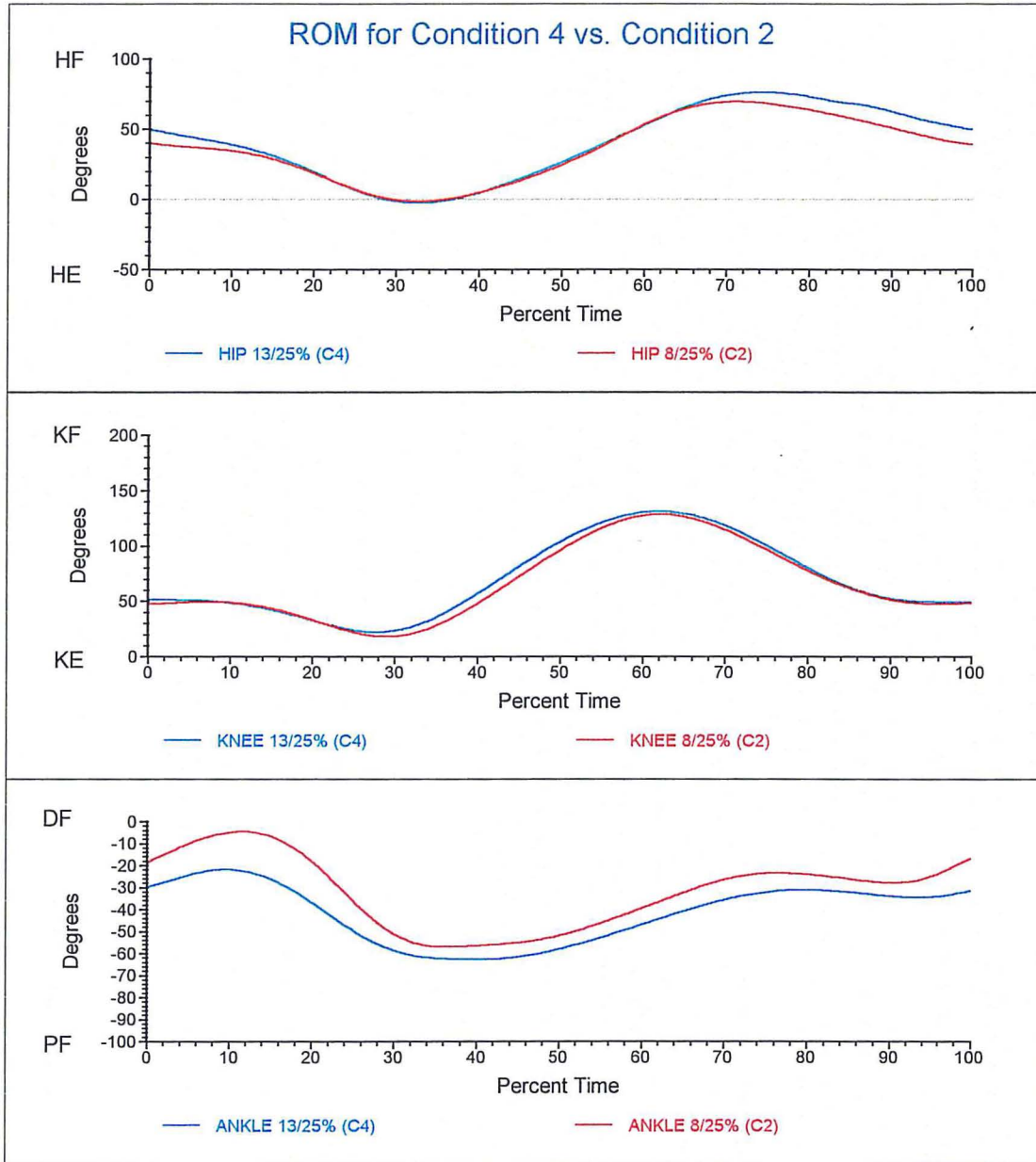


Figure 6.

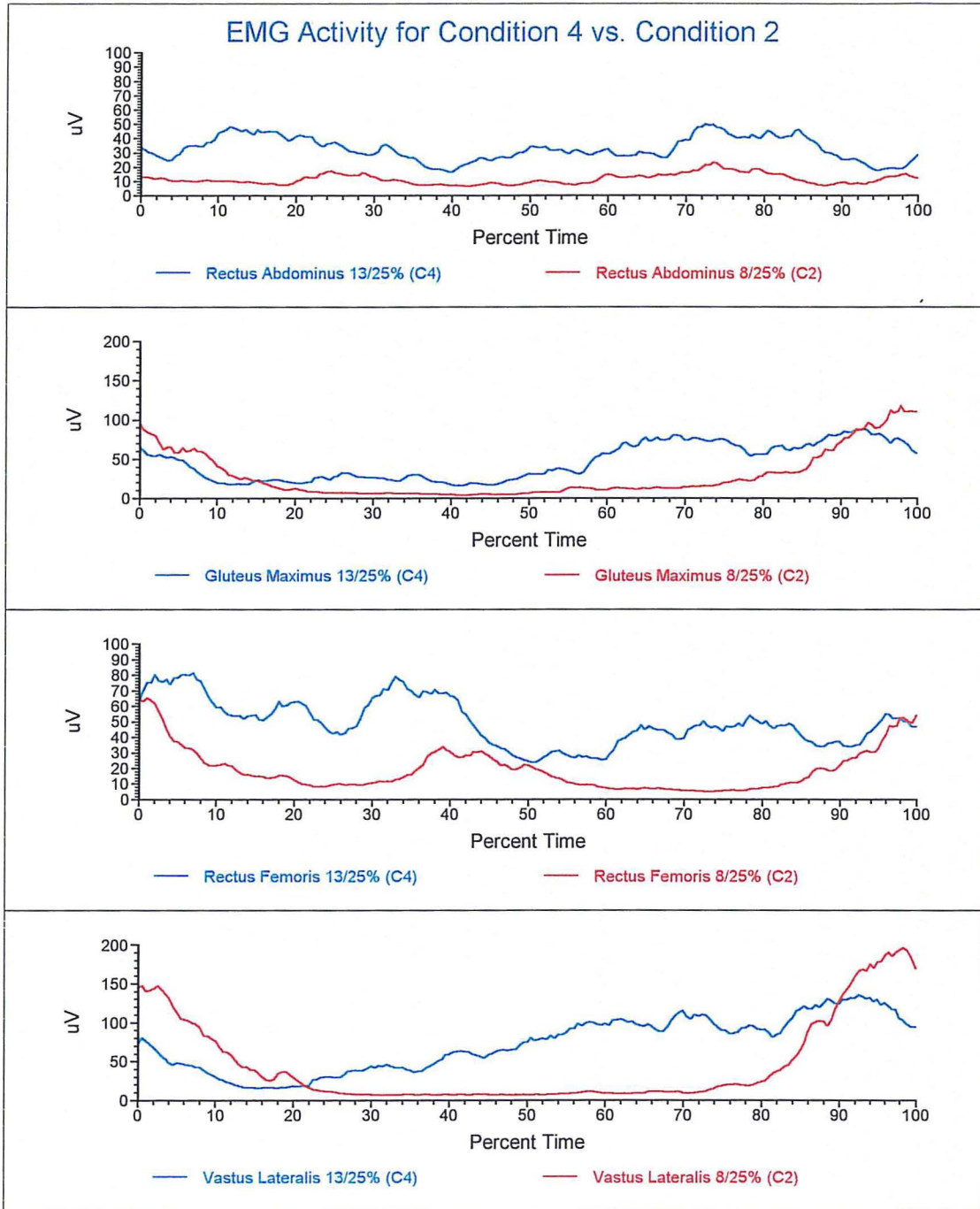


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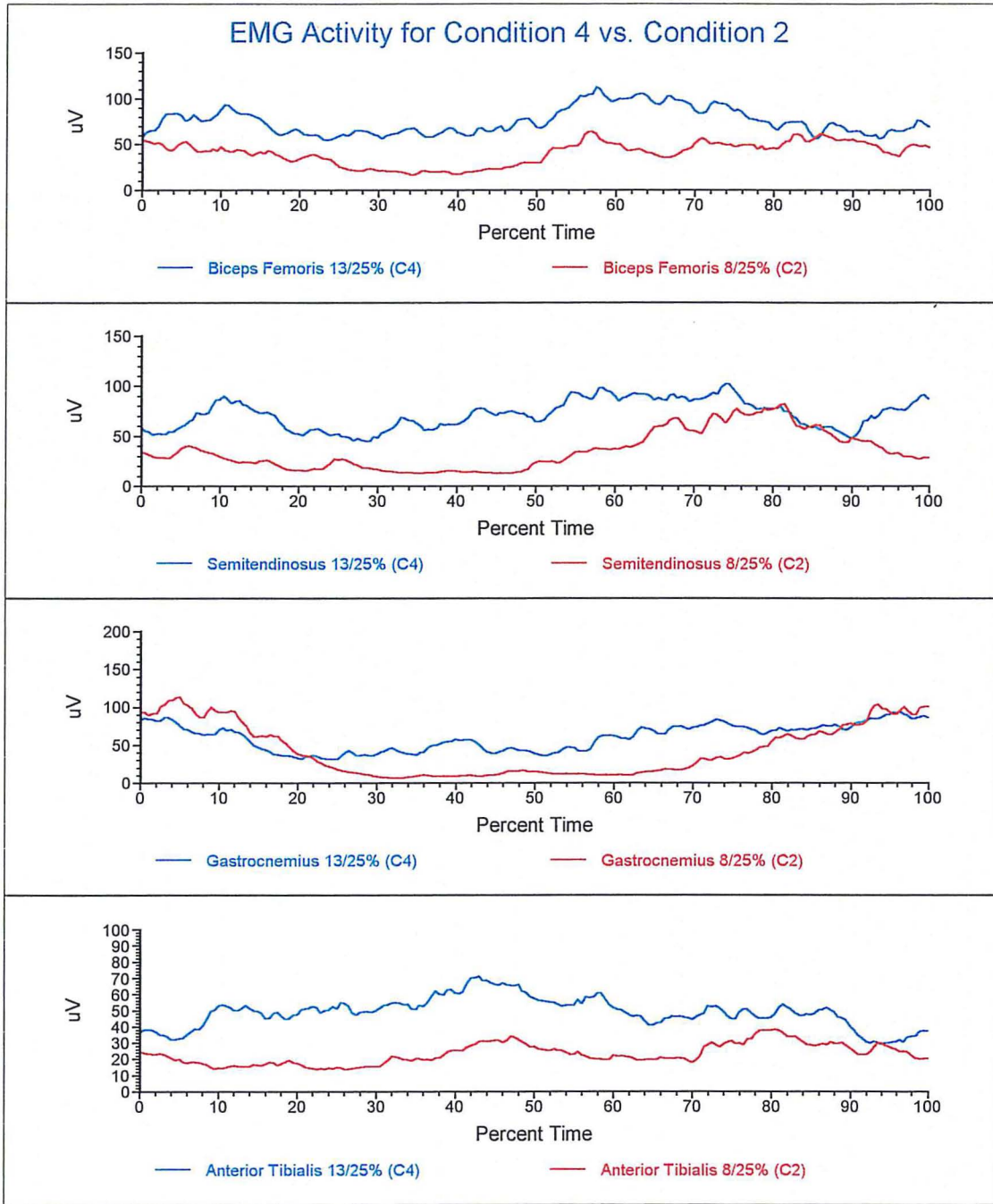


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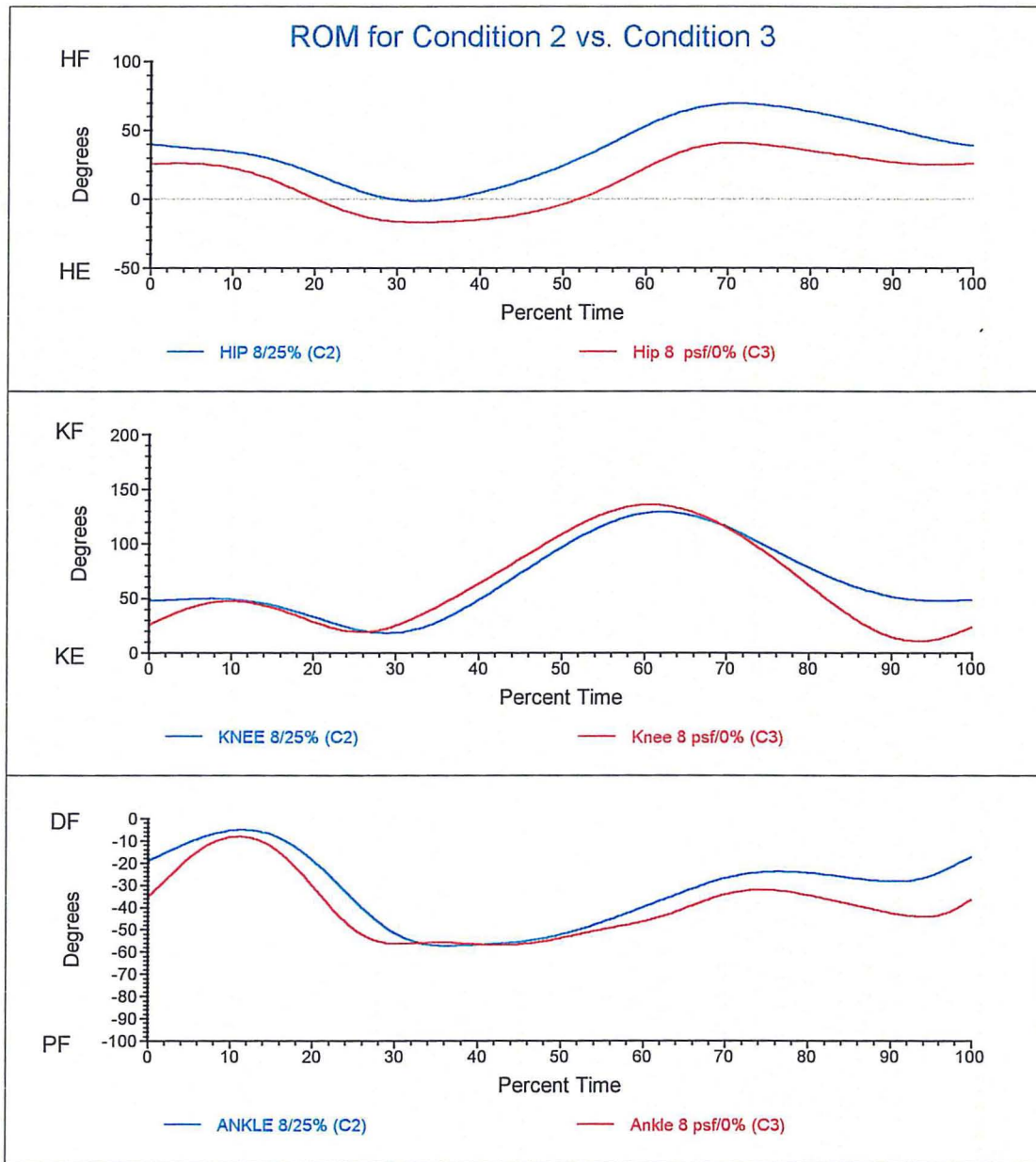


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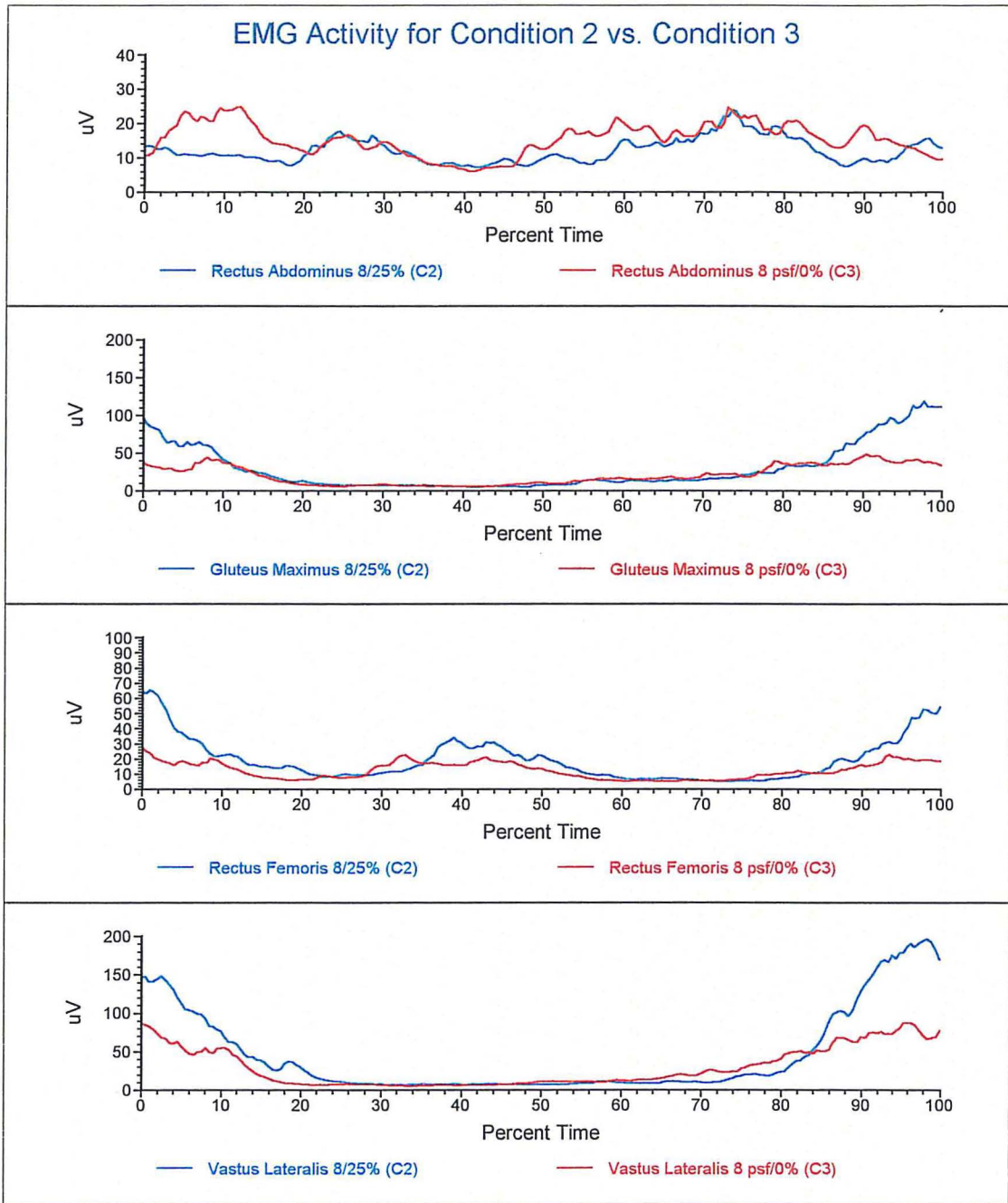


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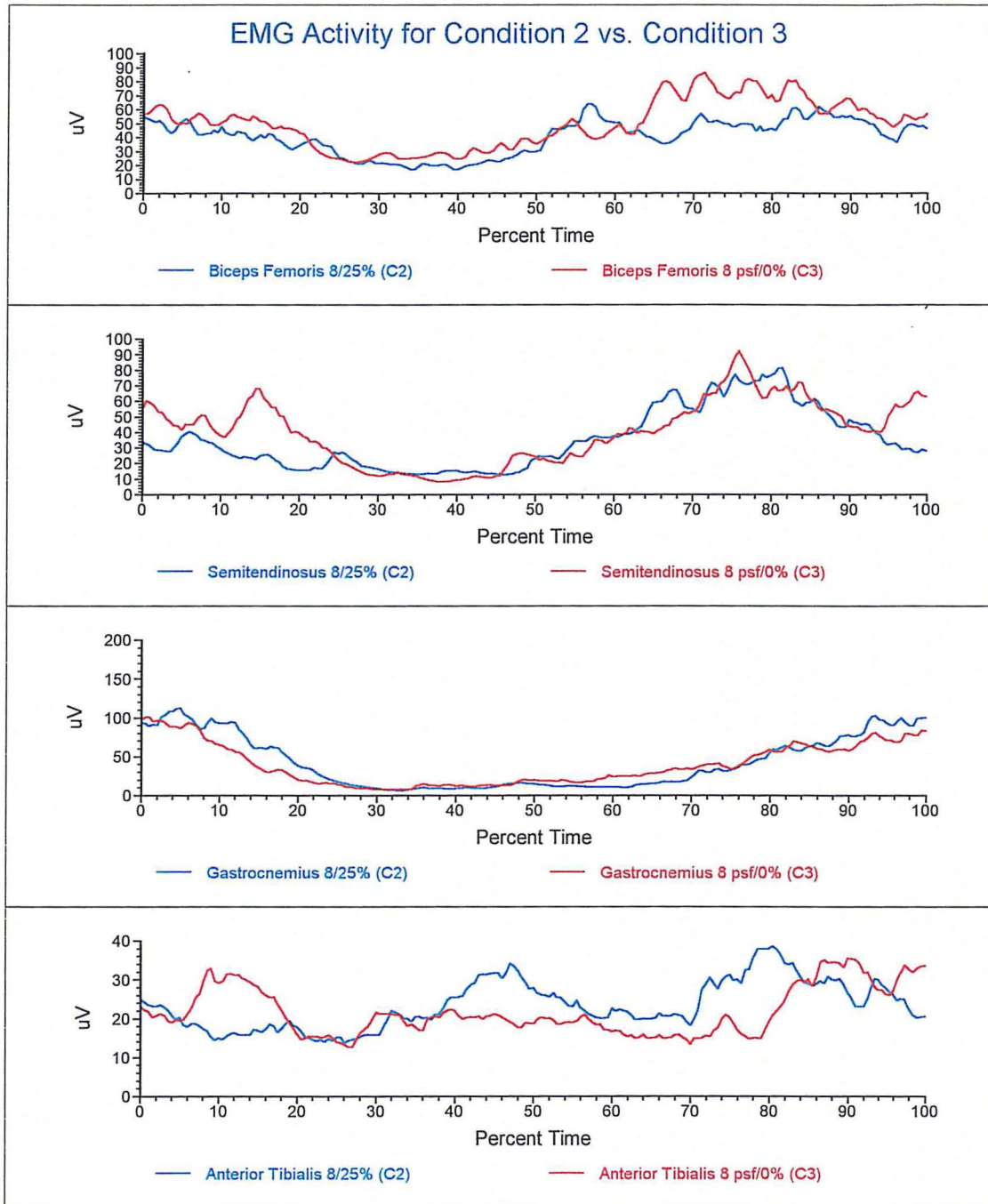


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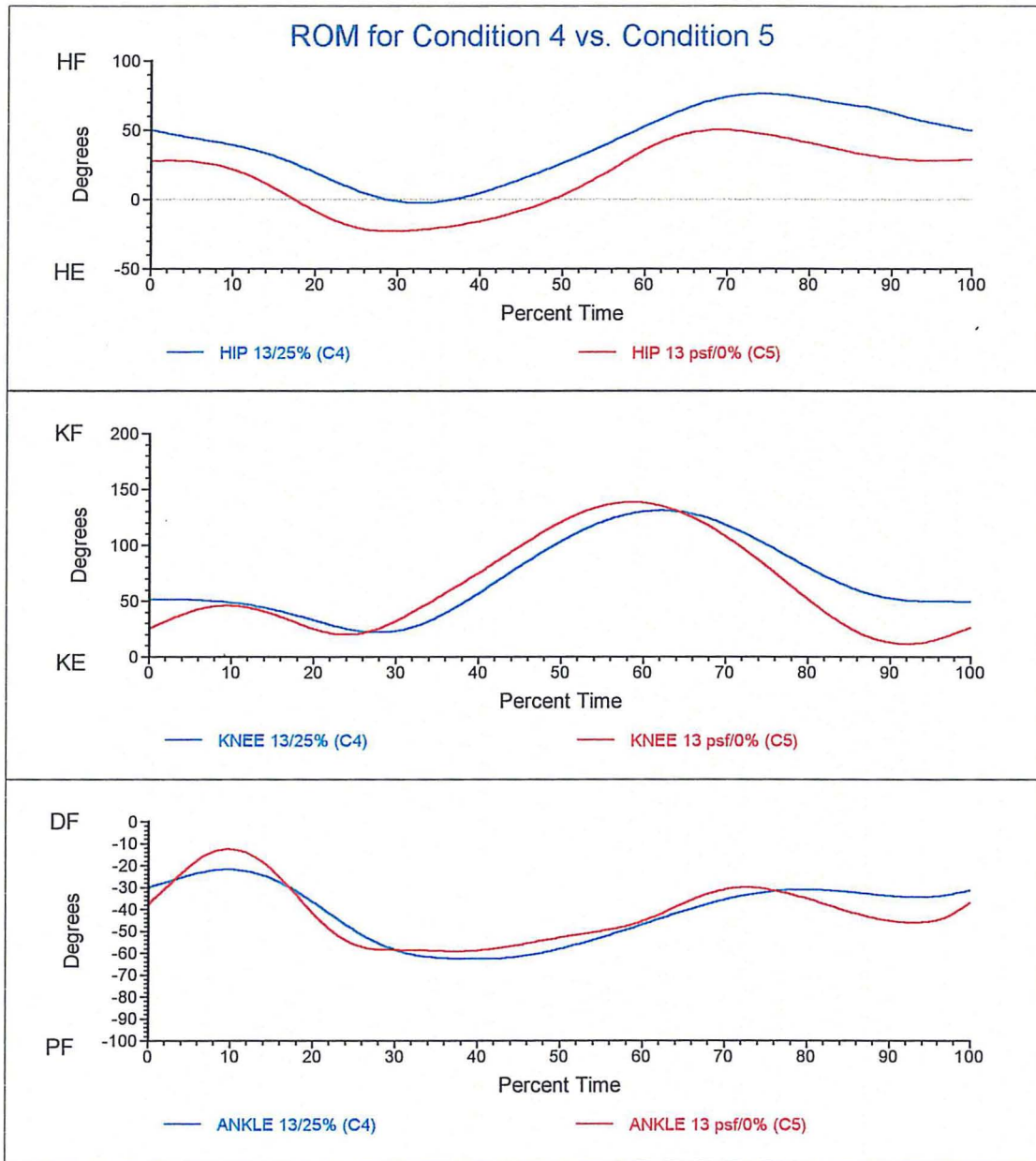


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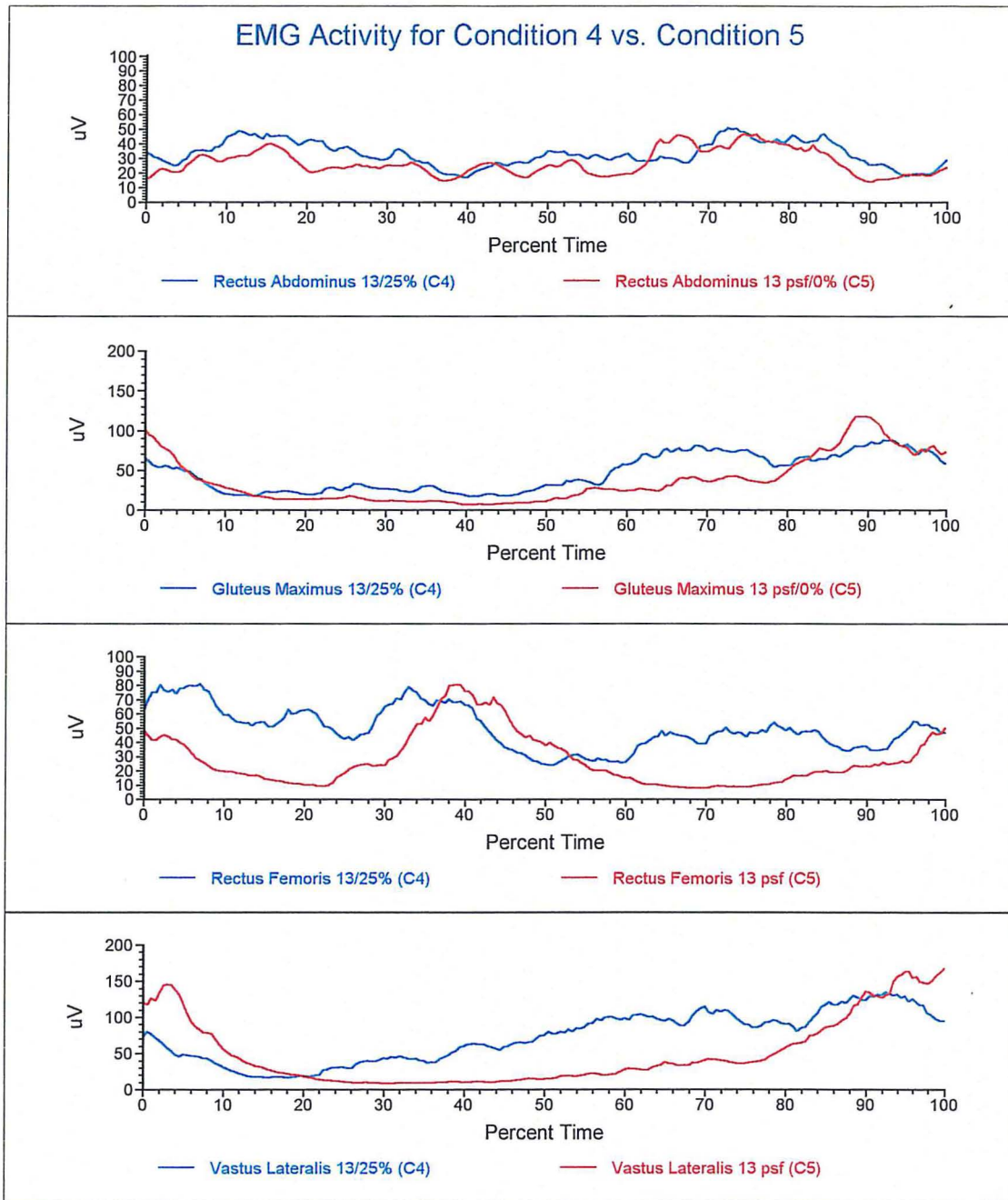


Figure 13.

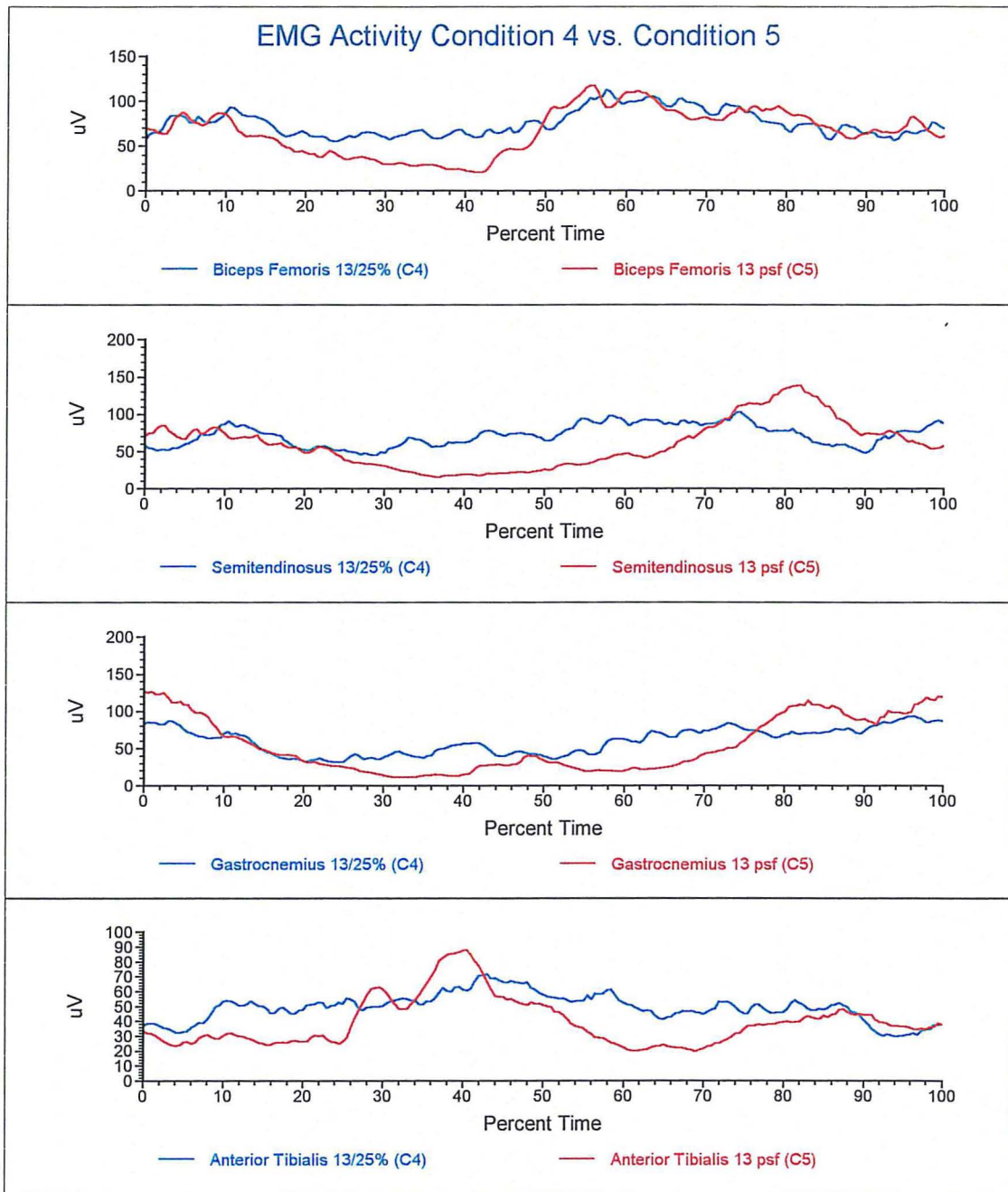


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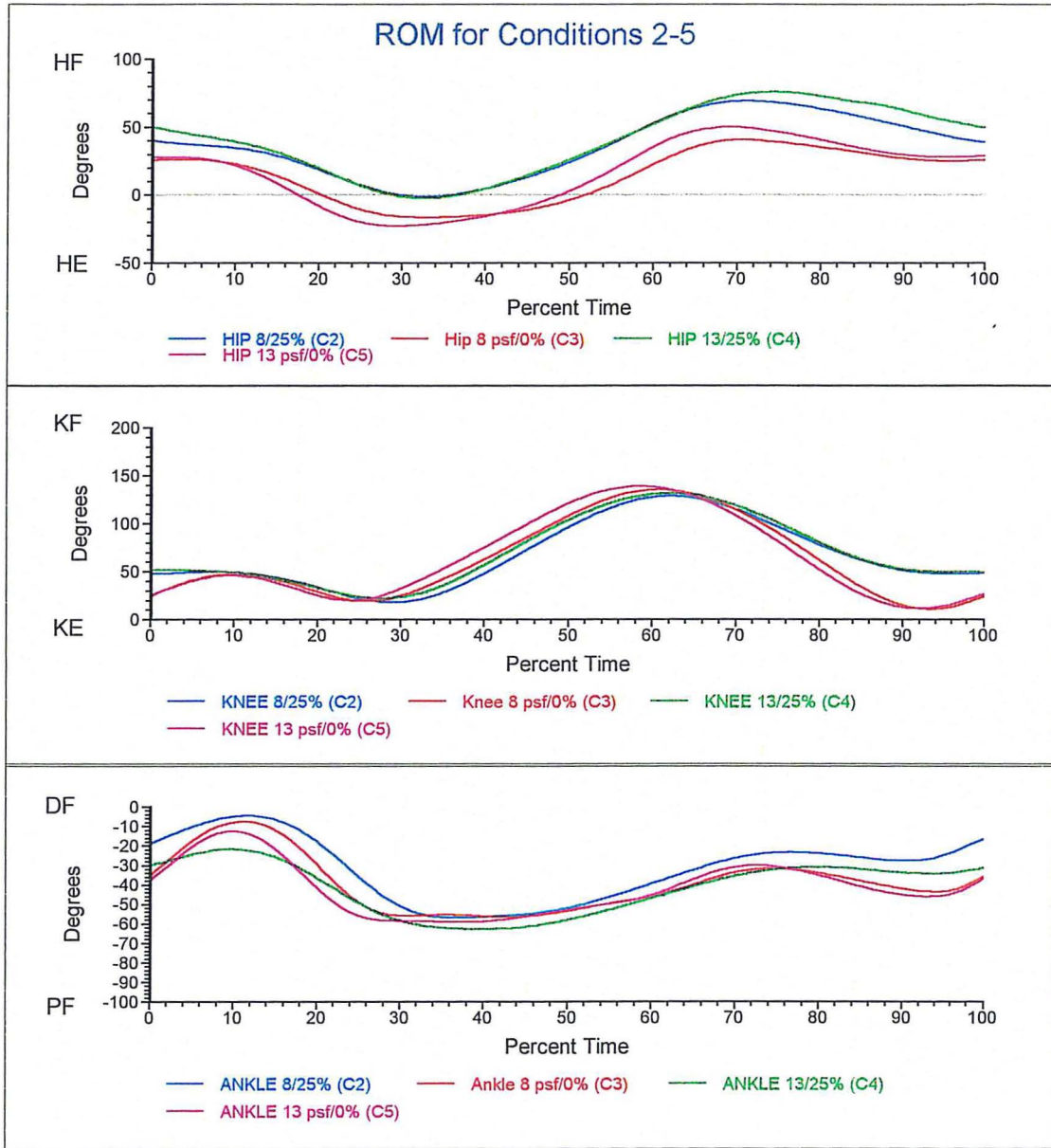


Figure 15.

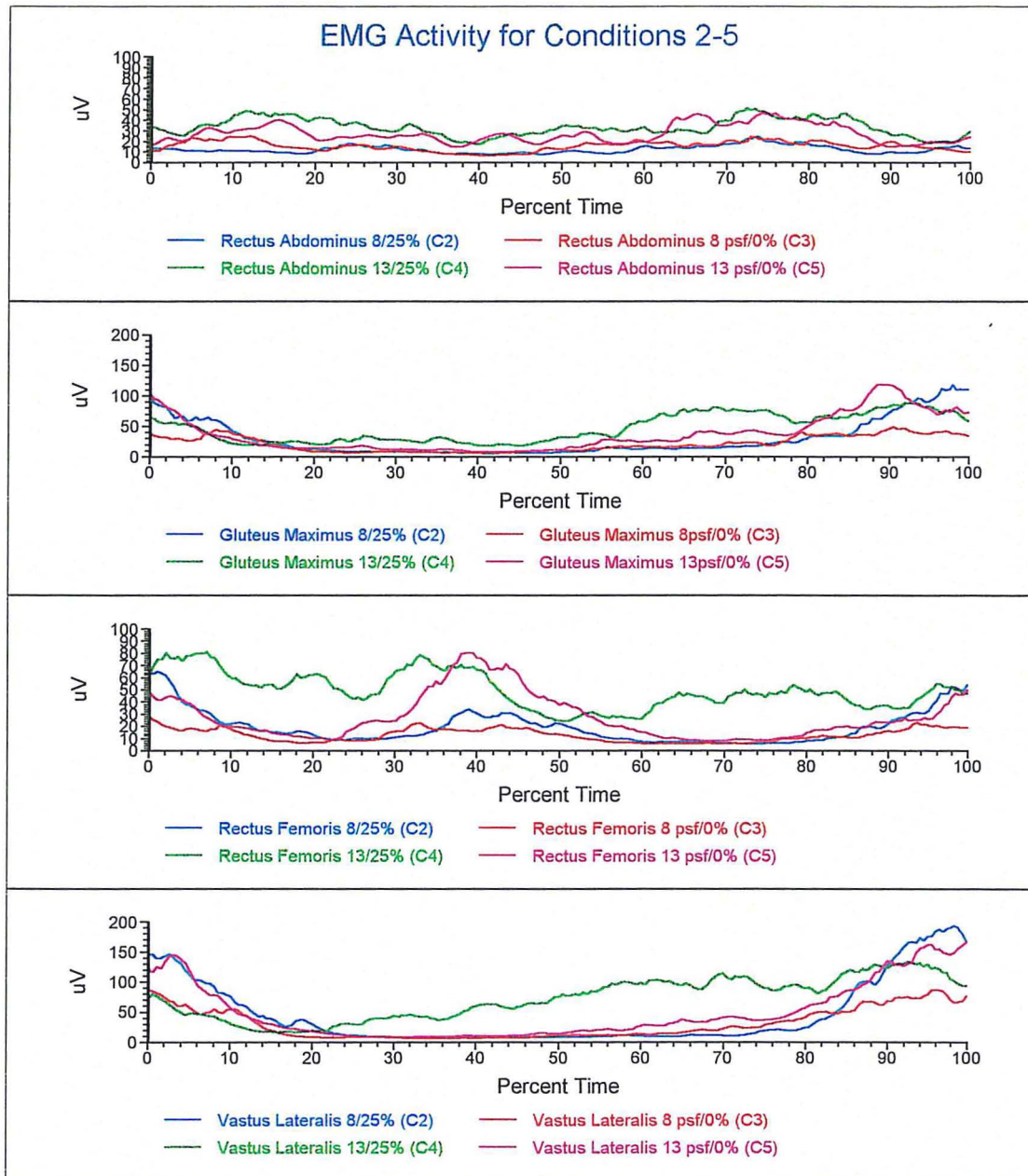


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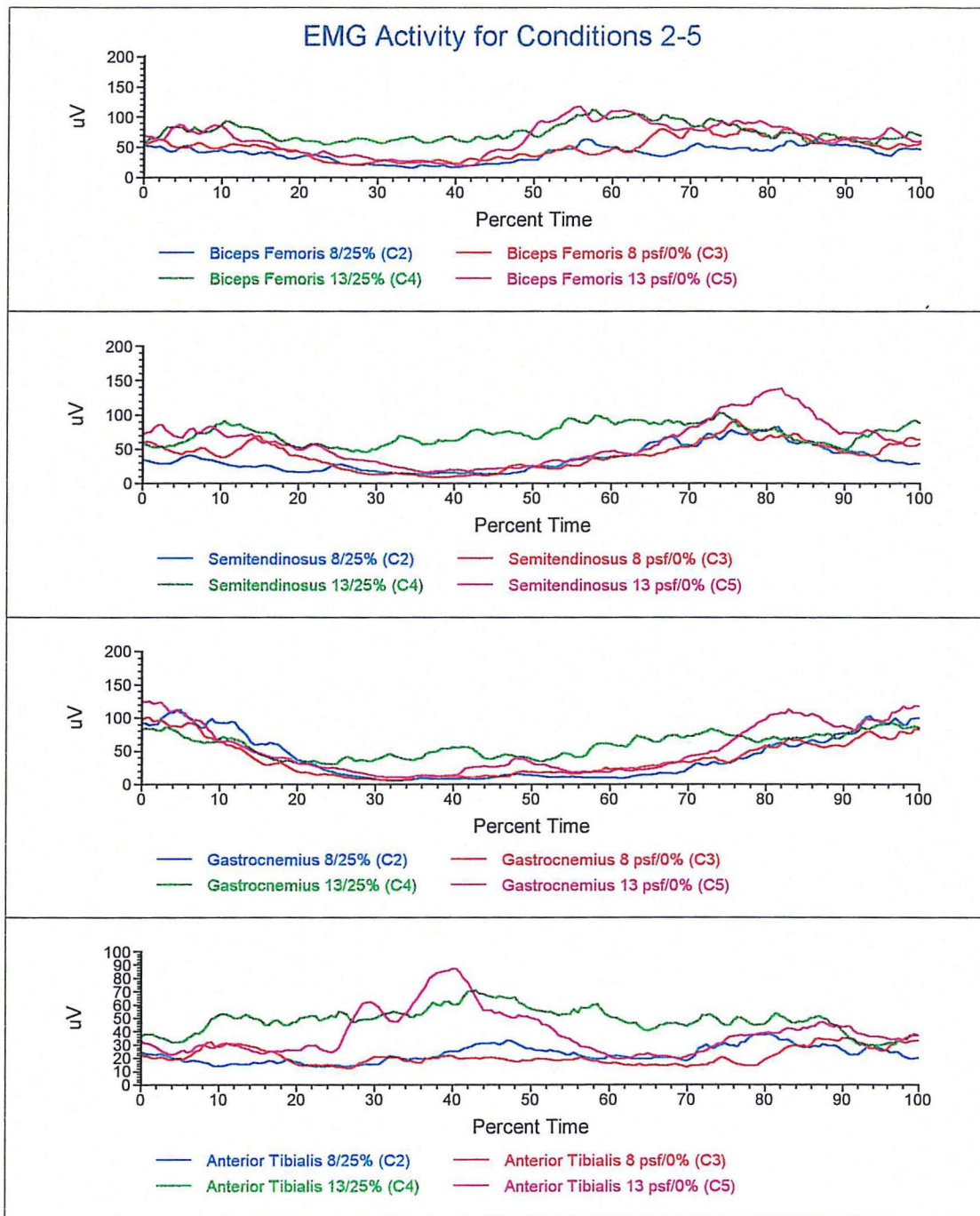


Figure 17.

CHAPTER 5

DISCUSSION

In the testing of the subjects, two basic questions were being considered. What happens to kinematics and muscle activity with an increase in speed; and what happens with an increase in incline? Conditions 2-5 were grouped into different pairs to try and find answers to these questions.

Change in Speed

Increases in speed are being considered when 8psf/0% grade (Condition 3) is compared to 13psf/0% grade (Condition 5) and 8/25% grade (Condition 2) is compared to 13/25% grade (Condition 4). Hip ROM has been found to increase with increases in speed in many articles.^{3,5,6,7} When comparing Condition 3 to Condition 5, ensemble average curves displayed greater total ROM at the hip joint with Condition 5.

Similarities were noted at the hip joint between Conditions 2 and 4, even though Condition 4 showed a greater peak of hip flexion. This is supported by Dillman⁴ who reported that as the speed of running increases, the elevation of the thigh in front of the body becomes greater.

Condition 5 displayed a greater peak of knee flexion than Condition 3. However, in Condition 3 vs. Condition 5 and Condition 2 vs. Condition 4, little difference was found in the total amount of knee ROM at the knee. This finding is different than most studies, which typically find an increase in knee ROM with increases in speed of running.^{5,6,9,7,19} Condition 4 and Condition 5 displayed greater peaks of plantarflexion

than Condition 2 and Condition 3, respectively. This is similar to Mann⁵ who found the amount of dorsiflexion to decrease as speed increases.

EMG activity has generally been found to increase with increased running speed.^{5,11,12,16,19} The results of this study are in agreement with these findings. Even though Condition 2 showed a greater peak of EMG activity for the GM, VL, and GA than Condition 4, Condition 4 and Condition 5 showed greater average EMG activity for all muscles tested than Condition 2 and Condition 3, respectively. The RF showed the largest increase in EMG activity and the GA showed the least in both comparisons.

Change in Incline

Klein et al²⁰ reported that running mechanics are not significantly altered during incline conditioned running, however they compared running horizontal to running on a 5% incline. Increases in incline are being considered when 8psf/0% grade (Condition 3) is compared to 8/25% grade (Condition 2) and 13psf/0% grade (Condition 5) is compared to 13/25% grade (Condition 4). Ensemble average curves for hip, knee, and ankle ROM were similar for the two comparisons. Condition 2 and Condition 4 displayed a greater degree of hip flexion throughout the entire stride when compared to Condition 3 and Condition 5, respectively. In a similar study, Swanson²¹ found there to be a greater maximal hip flexion angle and total hip ROM for an incline condition when compared to level conditions with the same stride frequency and same speed as the incline condition.

Conditions 3 and 5 were found to have greater knee flexion and extension peaks than Conditions 2 and 4, respectively. Swanson²¹ also found the knee to have a greater maximal flexion angle and ROM at a level condition with the same stride frequency as an incline condition at a 30% grade. Condition 2 was found to have greater ankle

dorsiflexion than Condition 3, however Condition 5 was found to have greater dorsiflexion than Condition 4. Swanson²¹ found greater ankle ROM at the incline condition.

Conflicting results were found between the incline comparisons. Condition 2 elicited a greater average EMG activity for the VL, RF, GM, GA, and TA muscles when compared to Condition 3; Condition 3 displayed greater average EMG activity for the RA, BF, and ST muscles. When comparing Conditions 4 and 5, even though Condition 5 elicited the greatest peak of EMG for 6 out of the 8 muscles tested, Condition 4 created the greatest average EMG activity for all 8 muscles. In the study by Swanson²¹, it appears that the average EMG activity was greater in the TA, RF, VL, and GM muscles in the incline condition, greater in the medial hamstrings in the level same stride frequency condition, and similar in the GA and BF muscles between the two conditions. In another study, Swanson et al¹ found the GA, RF, VL, and GM at stance phase to display significantly greater EMG activity during the incline condition (4.5m/s at 30% grade) when compared to a level same stride frequency condition, while a decrease in medial hamstring and BF activity at stance phase was found in the incline condition.

Limitations

There are a number of limitations to the results presented. All results are reported from an average of one stride from each subject. Due to the small sample size, results from one or two subjects could skew the data. It is recommended that a larger sample size be used in future studies where statistics can be calculated and a population of runners is better represented. Another limitation occurred due to problems with use of a footswitch with our runners to synchronize the EMG data with the motion analysis.

Problems occurred with the switches functioning and initial contact and toe off had to be marked manually. This prevented us from confidently reporting results of EMG activity specific to phases of the running stride. Preferred stride frequency for the 0% grade conditions were found by manually timing 5 strides at the incline conditions then finding a speed at horizontal that was within two tenths of a second. This could have been more precise had PSF been found using a video timing system. The equipment that the subjects had to wear for proper EMG and video analysis recording could have limited their natural running technique.

Clinical Implications

Speed training appears to be useful in increasing hip flexion and ankle plantarflexion as well as muscle activity of the RA, RF, VL, GM, BF, ST, GA, and TA. Incline training appears to be useful in increasing hip flexion and muscle activity of the VL, RF, GM, GA, and TA. Therefore, it could be beneficial for athletes to incorporate both speed and incline workouts into their training regimen to improve stride length and power generation.

Conclusion

Sprinting at 13mph and a 25% grade incline increased hip flexion and produced the most muscle activity in the RA, RF, VL, GM, BF, ST, GA, and TA when compared to the other conditions.

APPENDIX

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

DATE: June 7, 1999 PROJECT NUMBER: IRB-9906-261
Thomas Mohr, Marc Sondreal,
NAME: Christy Rygh, Jeremy Zimney 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 June 11, 1999 and the following action was taken:

- Project approved. EXPEDITED REVIEW NO. 4
Next scheduled review is on June 2000
- 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.

cc: T. Mohr, Adviser

Linda M. Larson
Signature of Designated IRB Member
UND's Institutional Review Board

6/11/99
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.

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, Marc Sondreal, Christy Rygh, Jeremy Zimney TELEPHONE: 777-2813 DATE: 4/25/99

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: 5/1/99 to 5/1/00
(Month/Day/Year)

PROJECT TITLE: An Electromyographic and Video Motion Analysis Study of 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 Approved; Date 5/6/99 _____ 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. The subjects for the study will be recruited from the present UND track team. These subjects will participate voluntarily. These subjects will be chosen due to their 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, which included treadmill running. The project will be completed at Orthopedic Associates in Fargo, ND. Prior to performing, each subject will be asked to complete a consent form. The subjects will not be compensated.

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, 6) gastrocnemius, 7) vastus medialis and 8) erector spinae. The study will be performed by Thomas Mohr, chairman of the physical therapy department and three graduate students: 1) Marc Sondreal, 2) Christy Rygh, and 3) Jeremy Zimney.

To record EMG activity, adhesive electrodes will be placed over each muscle. The precise electrode placement will be determined from standard electrode placement charts. Prior to placing the EMG electrodes, the skin over each placement site will be prepared by cleansing the skin with alcohol. 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 walk at 0% treadmill incline, and then run at approximately 8.0 and 13.0 mph with 0% and 25% grades of the treadmill incline. At each incline the athlete will walk and then run for a total of six seconds at each level in order to obtain the necessary data for analysis. A typical trial would consist of the subject walking at 0% incline for six seconds, followed by a three minute rest period. The subject would run for six seconds at one of the four speeds and grades (i.e. 8.0 mph @ 0%, 13.0 mph @ 0%, 8.0 mph @ 25%, 13.0 mph @ 25%). The subjects will be given a three minute rest period between trials. The order of the running trials will be determined by random assignment.

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 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. Since the electrodes are used for recording only, there is no risk of injury from them. There may be a slight redness following removal of the electrodes, but this will only be temporary.

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.

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, after which time they will be shredded.

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:

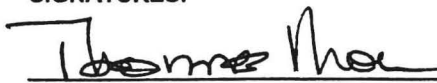
Office of Research & Program Development
University of North Dakota
Grand Forks, North Dakota 58202-7134

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.

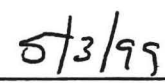
SIGNATURES:



Principal Investigator

Project Director or Student Adviser

Training or Center Grant Director



Date

Date

Date



ACCELERATION PRODUCTS, INC.

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Web Page: <http://www.accelerationproducts.com>

PRESIDENT:
John Frappier, M.S.

May 6, 1999

BUSINESS MANAGER:
Brad Holm

Dr. Tom Mohr, Chairman
UND School of Medicine
P.T. Department, Box 9037
Grand Forks, ND 58202-9037

ACCOUNT EXECUTIVE:
Brad Gorder

RESEARCH & DEVELOPMENT: Dear Dr. Mohr,
Cordell Mack, MPT, CSCS

This is to inform you that I have read the research proposal titled "An Electromyographic and Video Motion Analysis Study of Elite Sprinters at Varying Speeds and Inclines". I support this study and look forward to working together with you and the research team. Thank you for the opportunity to participate in this study.

CUSTOMER SERVICE:
Nick Reese

M.I.S.
Rich Johnson

Sincerely,

John Frappier
President of API

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

Tim Krumrie
12 Year NFL Player
Cincinnati Bengals Coach

Curt Giles
14 Year NHL Player
Canadian Olympic Team

Steve Swanson, MS
Biomechanist





May 6, 1999

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 Oppgrande, 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. Kaiser, 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
Jan Darling, L/ATC
Sonya 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 Shapiro, 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
Deron Redinger, OTR/L
Sharon Westphal, OTR/L

Exercise Physiology
John P. Froppier, 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
P.T. Department, Box 9037
Grand Forks, ND 58202-9037

Dear Dr. Mohr,

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

Sincerely,

A handwritten signature in black ink, appearing to read "Mark A. Lundeen", written over a large, stylized flourish that extends downwards and to the left.

Mark A. Lundeen, MD
Medical Director RRVSMI

INFORMATION AND CONSENT FORM

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

You are being invited to participate in a study conducted by **Marc Sondreal, Christy Rygh, Jeremy Zimney 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. Your participation, as a member of the UND track team constitutes the proper level of training required for this study.

You will be asked to run on the treadmill for a total of five (5) trials consisting of the following: 1) Walking on the treadmill at 3.4 mph with 0% grade, 2) Running on the treadmill at approximately 8 miles per hour with 0% grade, 3) Running on the treadmill at approximately 8 mph with 25% grade, 4) Running on the treadmill at approximately 13 mph with 0% grade, and 5) Running on the treadmill at approximately 13 mph with 25% grade. 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 at 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. 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 and markers attached, we will give you a brief training session to re-familiarize you with the treadmill. The amount of exercise you will be asked to perform will be moderate. There may be a slight redness following removal of the electrodes, but this will only be temporary.

Your name will not be used in any reports of the results of this study. The video taped data will be analyzed by a computer and the markers placed on your body will be used to construct a "stick man" like figure. Your real, photographic image will not be used in reporting of the findings of the study. After analysis, the video tapes are erased. The consent forms are kept in the physical therapy department for three years and then are shredded. 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 one of the investigators.

Participant's Signature

Date

REFERENCES

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