1999

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

Carrie Anderson  
*University of North Dakota*

---

Follow this and additional works at: [https://commons.und.edu/pt-grad](https://commons.und.edu/pt-grad)  
Part of the [Physical Therapy Commons](https://commons.und.edu/pt-grad)

---

**Recommended Citation**  
[https://commons.und.edu/pt-grad/13](https://commons.und.edu/pt-grad/13)

---

This Scholarly Project is brought to you for free and open access by the Department of Physical Therapy at UND Scholarly Commons. It has been accepted for inclusion in Physical Therapy Scholarly Projects by an authorized administrator of UND Scholarly Commons. For more information, please contact zeinebyousif@library.und.edu.
AN ELECTROMYOGRAPHIC AND VIDEO MOTION ANALYSIS STUDY OF ELITE SPRINTER S AT VARYING SPEEDS AND INCLINES

by

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

An Independent Study
Submitted to the Graduate Faculty of the
Department of Physical Therapy
School of Medicine
University of North Dakota

In partial fulfillment of the requirements
for the degree of
Master of Physical Therapy

Grand Forks, North Dakota
May
1999
This Independent Study, submitted by Carrie Anderson 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

In presenting this Independent Study Report in partial fulfillment of the requirements for a graduate degree from the University of North Dakota, I agree that the Department of Physical Therapy shall make it freely available for inspection. I further agree that permission for extensive copying for scholarly purposes may be granted by the professor who supervised my work or, in his/her absence, by the Chairperson of the department. It is understood that any copying or publication or other use of this Independent Study Report or part thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and the University of North Dakota in any scholarly use which may be made of any material in my Independent Study Report.

Signature Carrie Anderson

Date 12-17-98
# 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 ............................................................................................................. 14
CHAPTER 5 DISCUSSION ....................................................................................................... 25
APPENDICES ......................................................................................................................... 31
REFERENCES ......................................................................................................................... 42
LIST OF FIGURES

Figure 1: Electrode Placement ................................................................. 12
Figure 2: Ensemble Averaged Curves for ROM at 13 & 20 mph ............... 17
Figure 3: Averaged EMG Activity for 13 & 20 mph ................................. 18
Figure 4: EMG Activity ........................................................................ 19
Figure 5: Ensemble Averaged Kinematic & EMG Data at 20 mph & 0% grade .... 20
Figure 6: Ensemble Averaged Kinematic & EMG Data at 13 mph & 30% grade .... 21
Figure 7: Muscle Activation for Sprinting at 20 mph & 0% grade ............... 23
Figure 8: Muscle Activation for Sprinting at 13 mph & 30% grade ............ 24
LIST OF TABLES

Table 1: Descriptive Statistics of Subjects .................................................................8
Table 2: Origin, Insertion, and Action of Selected Muscles ....................................10
Table 3: Muscle Activation Patterns .......................................................................22
ACKNOWLEDGEMENTS

First, I would like to thank Tom Mohr for all of his assistance with this study and his patience and humor throughout the program. His dedication and late night work is greatly appreciated. I would also like to thank John Frappier for his time and expertise and those who volunteered to be our subjects, even if they had to wear spandex.

To the PT class of 1999, thank you for 3 years full of laughter and love. Thank you to Anna Hillig, Sam Gould, and Teri Parker, my research buddies. I wish we could work together forever. You guys ROCK!

A special thank you to Mom, Dad, Cris, and Adam for all of your continual support, encouragement, and love. I would not have made it this far without you. You have always been there for me and I love you.
ABSTRACT

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

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

From our results we conclude that the sprinter does adopt different strategies and muscle recruitment patterns to compensate for increases in slope. Examination of range of motion (ROM) revealed that there was greater overall motion of the hip during incline running, increased ROM at the knee during level running, with the ankle remaining relatively constant. EMG data revealed greater average muscle activity while sprinting at 13 mph on a 30% grade versus sprinting at 20 mph on a 0% grade.
CHAPTER 1

INTRODUCTION

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

Problem Statement

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

Purpose of Study

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

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

Research Questions

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

Hypotheses

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

Alternate: Muscle recruitment and joint angles increase with increased speed an incline.
Sprinting involves a complex series of events with speed and success dependent upon many factors. In an attempt to identify these factors and maximize a sprinter’s potential, several studies have investigated the kinematics, lower extremity electromyographic (EMG) activity, and types of sprint training techniques.

Sprinting consists of a stance phase and a swing phase. Stance is further divided into three separate phases: 1) foot contact, the period from initial contact through full weight acceptance, 2) midsupport, the period following full weight acceptance until plantar flexion begins, and 3) toe off, from initiation of plantar flexion until actual toe off. Following toe off, the extremity enters swing phase. This is also divided into three separate phases: 1) follow-through, which begins at toe off and lasts until maximum hip extension is reached, 2) forward swing, which begins with hip flexion and ends with maximum hip flexion, and 3) foot descent, which lasts until foot contact. As the speed of gait increases, the amount of time spent in stance phase decreases, and during sprinting, stance phase only accounts for 22% of the gait cycle.

**Kinematics**

As the speed of gait increases, the body acts to lower it’s center of gravity by increasing the flexion at the hips and knees and increasing ankle dorsiflexion. With the increased speed of sprinting, hip flexion has the greatest impact on forward movement.
with the remainder of the lower extremity following.\textsuperscript{2,3} During sprinting, the hip reaches \(10^\circ - 15^\circ\) more hip flexion than during running.\textsuperscript{3} The sprinter's hip is in \(50^\circ\) of flexion at foot contact, reaches maximum extension (\(20^\circ\)) at toe off, and flexes to \(80^\circ\) during swing.\textsuperscript{2,3}

The knee never reaches full extension during sprinting.\textsuperscript{2} It is flexed \(30^\circ\) at foot contact. It then flexes \(20^\circ\) during stance, followed by progressive flexion throughout swing.\textsuperscript{2,3} This flexion is secondary to the rapid acceleration of the thigh during forward swing.\textsuperscript{3} The knee reaches a maximum flexion of \(140^\circ\) during forward swing.\textsuperscript{2}

Unlike walking and jogging where the entire foot contacts the ground during stance, sprinters are always on their toes.\textsuperscript{3} At ground contact, dorsiflexion is occurring but the heel does not touch the ground. This is followed by rapid planter flexion just before toe off.\textsuperscript{2,3} During swing phase, the ankle dorsiflexes to neutral and then planter flexes to \(20^\circ\).\textsuperscript{3} Dorsiflexion then begins again prior to ground contact.\textsuperscript{2,3}

**Electromyography**

Similar to range of motion, EMG muscle activity also increases with increasing speed.\textsuperscript{4} Most of the lower extremity muscle activity occurs prior to and during stance.\textsuperscript{5} This increased activation allows the body to withstand a large impact force which occurs during ground contact.\textsuperscript{4} There is minimal activity of the lower extremity muscles during the swing phase of sprinting.

The rectus femoris has been found to have two periods of amplified activity.\textsuperscript{3,5-8} The first, occurring during the middle of stance, was found to be 56\% of the maximum voluntary contraction.\textsuperscript{8} During this time, the rectus femoris contracts eccentrically to stabilize the knee joint as flexion occurs.\textsuperscript{2} The second period occurs during the last 50\%
of swing phase where EMG activity of the rectus was found to be 108% of maximum voluntary contraction.\textsuperscript{3,8} Before this period of concentric knee extension, strong hip flexion provides the momentum necessary to initiate knee extension.\textsuperscript{2,4}

During the first part of the swing phase, the heel moves toward the buttock without associated EMG activity in the hamstrings, gluteus maximus, or gastrocnemius.\textsuperscript{4,6} This flexion is the result of the reaction forces produced at toe off. Hamstrings and gluteus maximum muscle activity starts one-third of the way into swing and continues until approximately two-thirds of the way into the stance phase.\textsuperscript{6} They both reach a maximum EMG activity just before foot strike to decelerate the swing of the thigh.\textsuperscript{2,6} This heightened area of hamstring and gluteus maximus activity was found to be 81% and 108% of the maximum voluntary contraction, respectively.\textsuperscript{8}

The gastrocnemius is active throughout all of stance phase and the last half of swing.\textsuperscript{3} It contracts eccentrically during foot contact and mid-swing to control the forward movement of the tibia over the foot.\textsuperscript{2} It then concentrically contracts to initiate plantar flexion for toe off. Mann et al\textsuperscript{2} found this concentric muscle activity to be minimal, suggesting that there is little or no actual push-off. This implies that the majority of forward propulsion during sprinting is, instead, due to the rapid flexion of the hip during swing. However, other authors point out that the gastrocnemius muscle activity is significant at the end of stance, indicating consequential push off and a primary role in the propulsion of sprinting.\textsuperscript{4,8}

Like the rectus femoris, the anterior tibialis has two peaks of activity.\textsuperscript{2,6,8} The first occurs just after toe off and peaks at 91% of maximum voluntary contraction.\textsuperscript{8} Here, this muscle concentrically contracts to bring about ankle dorsiflexion.\textsuperscript{2} The anterior tibialis is
also active during forward swing to assist with foot clearance.\textsuperscript{6} The second EMG high point is found just before foot strike.\textsuperscript{6,8} This reaches a height of 85\% of maximum voluntary contraction.\textsuperscript{8} This contraction helps to stabilize the ankle and control the rate of plantarflexion.\textsuperscript{2}

The muscle activity of the abdominals is related to the anterior and posterior tilt of the pelvis.\textsuperscript{2} Just before toe off, hip extension reaches a maximum and the abdominals eccentrically contract to control the posterior pelvic rotation. Before the onset of hip flexion, the concentric contraction of the abdominals bring the pelvis into an anterior tilt.

\textbf{Training Techniques}

There is no single, specific mechanism that is entirely responsible for the speed, strength, or endurance necessary for successful sprint training. There are many biomechanical variables which contribute to the complex events occurring during sprinting.\textsuperscript{4} Researchers have conducted various studies in an attempt to identify some of these factors and design the most beneficial training protocols.

Supramaximal sprinting utilizing horizontal towing, down-hill running, or a high-speed treadmill has been found to be an additional stimulus for the neuromuscular system.\textsuperscript{4} This training produces an increase in both stride rate and stride length when compared to voluntary maximal sprinting.

Incline sprint training has also be suggested and has been found to increase maximum speed and quickness.\textsuperscript{5,9} The main goal of this training is to develop increased muscle power.\textsuperscript{9} Swanson, Frappier, and Caldwell\textsuperscript{9} conducted a study to quantify the kinematics and muscle activity generated during incline sprinting as compared to similar level sprinting conditions. At foot contact, all joints were in a greater amount of flexion,
and the hip and knee were extended more during toe off phase. During stance, there was increased EMG activity in the gastrocnemius, rectus femoris, and gluteus maximus, while there was a decrease in the biceps femoris muscle activity. During swing phase, the EMG activity was similar to that of level sprinting. These increases in motion and muscle activity suggest greater force and energy production. Following incline sprint training, there is also a significant increase in stride length, speed, and hip range of motion during level running.\(^5\)
CHAPTER 3

METHODS

Subjects

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

Table 1. Descriptive Statistics of Subjects

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Range</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>22.67 (years)</td>
<td>21 – 27</td>
<td>2.21</td>
</tr>
<tr>
<td>Height</td>
<td>72.33 (inches)</td>
<td>67 – 78</td>
<td>3.86</td>
</tr>
<tr>
<td>Weight</td>
<td>191.67 (pounds)</td>
<td>173 – 215</td>
<td>14.44</td>
</tr>
</tbody>
</table>

Instrumentation

Electromyography

The electromyographic information was collected by a Noraxon Telemyo 8 telemetry unit (Noraxon USA, 13430 North Scottsdale Rd., Scottsdale, AZ 85254). This information was then sent to a Noraxon Telemyo 8 receiver and then digitized by an analog digital interface board in the Peak Analog Module (Peak Performance
Technologies, 7388 S. Revere Parkway, Suite 601, Englewood, CO 80112-9765). The video data and the electromyographic data were synchronized using the Peak Event Synchronization Unit. To start the EMG data collection, the synchronization unit was triggered by a footswitch.

Video

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

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

Protocol

The skin on the lower extremity was prepared by cleansing it with alcohol and shaving away any excess body hair for the placement of the six (6) surface EMG electrodes over the chosen muscles. These muscles were chosen because they have been shown in previous studies to be active during sprinting (See Table 2).
<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectus Abdominis</td>
<td>Pubic Symphasis</td>
<td>Xiphoid process</td>
<td>Flex trunk</td>
</tr>
<tr>
<td></td>
<td>Pubic Crest</td>
<td>Intercostral cartilage</td>
<td>Stabilize pelvis during walking</td>
</tr>
<tr>
<td>Gluteus Maximus</td>
<td>Posterior Crest of Ilium</td>
<td>Iliotibial Tract</td>
<td>Extend thigh</td>
</tr>
<tr>
<td></td>
<td>Sacrotuberous ligament</td>
<td>Gluteal Tuberosity</td>
<td>Laterally rotate thigh</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Extend trunk</td>
</tr>
<tr>
<td>Rectus Femoris</td>
<td>Anterior inferior iliac spine</td>
<td>Base of the patella</td>
<td>Extend leg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tibial Tuberosity</td>
<td>Flex thigh</td>
</tr>
<tr>
<td>Biceps Femoris</td>
<td>Ischial Tuberosity</td>
<td>Head of Fibula</td>
<td>Flex Knee</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Extend thigh</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Extend trunk</td>
</tr>
<tr>
<td>Gastrocnemius</td>
<td>Condyles of femur</td>
<td>Calcaneal tuberosity</td>
<td>Plantarflexion</td>
</tr>
<tr>
<td>Anterior Tibialis</td>
<td>Upper ½ lateral surface of tibia</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; metatarsal</td>
<td>Dorsiflexion</td>
</tr>
<tr>
<td></td>
<td>Interosseous membrane</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; cuneiform</td>
<td>Inversion</td>
</tr>
</tbody>
</table>
The placement of the electrodes was determined by finding each muscle by a previously identified measurement from anatomical landmarks. Figure 1 displays these points anatomically along with a descriptive measurement for each one. The ground, or reference, electrode was placed on the iliac crest.

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

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

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

Data Analysis

Prior to videotaping, the camera was calibrated by videotaping a meter stick. Then the video footage for each sprinting trial was calibrated in meters, cropped to the first three completed sprinting trials, and digitized using the Peak system. The software calculated the joint angles and segmental motion. The raw analog data was scaled and matched to the video. Reports were then generated to show anthropometric
Gluteus Maximus - midpoint of a line running from the inferior lateral angle of the sacrum to the greater trochanter
Rectus Abdominus - 2 cm superior and 2 cm lateral to umbilicus
Biceps Femoris - midpoint of a line from the ischial tuberosity to the lateral femoral condyle
Rectus Femoris - midpoint of a line from the ASIS to superior pole of patella (minimum of 10 cm above the patella)
Gastrocnemius - over the muscle belly 1/3 the distance of the leg (fibular head to calcaneous)
Anterior Tibialis - over the muscle belly 1/3 the distance of a line running from the lower margin of the patella to the lateral malleolus

Figure 1. Electrode Placement.
representation of the motion, joint motion, and integrated EMG data of the sprinting cycles for each trial.

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

The hip, knee and ankle range of motion was processed similar to the EMG data. That is, an ensemble average was computed for one sprint cycle for each subject, and then averaged to compute a grand mean ensemble average for all of the subjects. Due to the small sample size, statistical testing was not performed.
CHAPTER 4

RESULTS

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

Kinematics

Twenty miles per hour

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

Thirteen miles per hour

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

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

EMG

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

Figures 5 and 6 display ensemble averaged EMG activity for individual muscles at 20 and 13 mph relative to joint motion. Table 3 shows muscle activity as a percentage of the sprint cycle and Figures 7 and 8 graphically display the same information. The gastrocnemius activity showed the most activity at 20 mph during stance phase (See
Figures 5 and 6). However, at 13 mph there were two periods of peak activity, once during stance and once during mid to late swing. The anterior tibialis displayed activity throughout both the 13 and 20 mph trials. However, at 13 mph, it displayed greater average activity with two peaks, one during stance and one during early swing.

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

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

At 20 mph, the gluteus maximus attained its greatest activity during stance, then decreased during early swing, and began to rise again during late swing. In comparison, the gluteus maximus activity at 13 mph was smaller in amplitude but followed the approximate activity timing seen at 20 mph. The rectus abdominus had greater maximal activity during the incline sprint at 13 mph, but the timing of its activity was approximately the same in both trials.
Figure 2. Ensemble averaged curves for range of motion. Red line is sprinting at 20 mph and 0%. Blue line is sprinting at 13 mph and 30%.
Figure 3. Averaged EMG activity for 13 and 20 mph. Thirteen mph is shown in blue and 20 mph is shown in red.
Figure 4. EMG activity during sprinting.
Figure 5. Ensemble averaged kinematic and electromyographic data for all subjects sprinting at 20 mph and 0% grade. The vertical line represents toe off.
Sprinting at 13 mph at 30 Percent Grade

Figure 6. Ensemble averaged kinematic and electromyographic data for all subjects sprinting at 13 mph and 30% grade. The vertical line represents toe off.
<table>
<thead>
<tr>
<th></th>
<th>Sprinting at 20 mph and 0% grade</th>
<th>Sprinting at 13 mph and 30% grade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximal Activation</td>
<td>Moderate Activation</td>
</tr>
<tr>
<td>Gastrocnemius</td>
<td>10-29%</td>
<td>0-10%</td>
</tr>
<tr>
<td></td>
<td>29-34%</td>
<td>69-86%</td>
</tr>
<tr>
<td>Anterior Tibialis</td>
<td>0-66% 94-100%</td>
<td>66-94%</td>
</tr>
<tr>
<td>Rectus Femoris</td>
<td>15-31% 41-63%</td>
<td>0-15%</td>
</tr>
<tr>
<td></td>
<td>31-41% 63-79%</td>
<td>79-100%</td>
</tr>
<tr>
<td>Biceps Femoris</td>
<td>0-27% 88-100%</td>
<td>27-38% 54-88%</td>
</tr>
<tr>
<td>Gluteus Maximus</td>
<td>16-37% 91-100%</td>
<td>0-16%</td>
</tr>
<tr>
<td></td>
<td>37-48% 79-91%</td>
<td>48-79%</td>
</tr>
<tr>
<td>Rectus Abdominus</td>
<td>24-49% 78-100%</td>
<td>14-24% 49-55% 71-78%</td>
</tr>
</tbody>
</table>
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

Kinematics

The averaged curves show a difference in hip, knee, and ankle ROM between the 20 mph and 13 mph trials. During the 13 mph trial, hip flexion reached a maximum of 84° with a total excursion of 74° as compared to a maximum of 59° and a total excursion of 66° during the 20 mph trial. This increased flexion on the incline correlates to that found by Owens. We propose that this increased hip flexion motion is needed to clear the lower extremity and ensure adequate placement on the incline.

Knee flexion ROM was found to be similar between the two trials and reach a maximum during mid-swing. Knee flexion excursion during the 20 mph trial was 24° to 136° while during the 13 mph trial, it was 25° to 131°. These results on the level trial are similar to those found by Mann and associates. They reported that the magnitude of knee flexion increased from 110° during jogging to 130° during sprinting. We speculate that this increased flexion acts to shorten the lever arm and allow increased forward acceleration of the lower extremity during swing. This is necessary to accommodate for the increased speed.

Comparable to results reported by Mann et al, we found that the ankle remained in plantar flexion during the entire sprinting cycle. The total amount of ankle ROM excursion is very similar between the two trials. However, the ankle remained more
plantarflexed during the 20 mph trial as it dorsiflexed from 60° to 17° of plantar flexion. During the 13 mph trial, the ankle dorsiflexed from 57° to 13° of plantar flexion. Similar to the hip flexion, we postulate that this dorsiflexion component assists with foot clearance on the incline. This excursion is greater than that found by Mann et al.\(^2\) and Owens\(^11\), and may be due to the increased sprinting speed and training level of the athletes.

EMG

All monitored muscles except the biceps femoris and the gluteus maximus were found to exhibit increased overall activity during 13 mph sprinting on the 30% incline. This is similar to the findings of a study conducted by Swanson, Frappier, and Caldwell.\(^9\) They found that during the stance phase, all muscles except the biceps femoris and the medial hamstrings displayed significantly greater activity during incline sprinting.

The gastrocnemius displayed a period of increased activity during the end of stance phase at 20 mph and 13 mph. This concentric contraction coincides with plantar flexion. Similar to other studies, we believe this is necessary for push-off and propulsion during sprinting.\(^3\,^7\) The amplitude of this peak was larger during the 20 mph trial. We theorize that during the 13 mph incline trial, this force is instead produced primarily by the strong hip flexion component as the rectus femoris shows greater activity during this stage. A second period of maximal activity occurred during mid swing through terminal swing during the 13 mph trial. Owens\(^11\) did not report this second peak of maximal activity during the incline trial. We propose this eccentric force assists the biceps in controlling knee extension and also slows ankle dorsiflexion.
Many studies have found two peaks of anterior tibialis activity during level sprinting: one peak during early swing and the other during mid-swing. At 20 mph, we found the anterior tibialis exhibited maximal activity throughout a greater percent of the cycle. We found it to be active from the end of terminal swing, throughout stance and into mid-swing. This prolonged activity may be due to the increased recruitment of muscles secondary to poorer training levels of the sprinters. Most of this activity appears to be eccentric, as it is controlling the plantar flexion moment. During mid-swing, the ankle dorsiflexes suggesting a concentric contraction. During the 13 mph trial, the anterior tibialis showed two peaks of maximal activity. At the end of stance, we propose that the activity is eccentric to control movement into plantar flexion. It then appears to concentrically contract at the beginning of mid-swing to dorsiflex the ankle and assist with foot clearance. This second peak is in agreement with results reported by Owens.

The rectus femoris showed maximally activity during late stance and early swing during the 20 mph trial. It is suggested that this contraction eccentrically decelerated the rate of hip extension and stabilized the knee joint as flexion occurred. A second peak of activity also occurred during early and mid-swing. Since the hip is flexing and then knee extending, we assume this activity is concentric. This activity is similar to the rectus femoris muscle activity found in other studies. Similar to results reported by Owens, we found the rectus femoris activity to peak during mid-swing during the 13 mph trial. The amplitude of this contraction is larger than that produced during the 20 mph trial. We believe this concentric contraction provides the strong force, which contributes to the large amount of hip flexion and momentum produced during incline sprinting.
During the 20 mph trial, the biceps femoris maximally contracted during terminal swing and again toward the end of stance and into early swing. We suggest that it acts to stabilize the leg and hip during stance and concentrically contracts toward the end of stance and into early swing to produce hip extension and knee flexion. We are in partial agreement with other authors. We agree with results that report that maximal activity occurs during terminal swing and into stance.\textsuperscript{2,6} However some authors report that knee flexion during early swing is the result of reaction forces and the biceps is not active during this time.\textsuperscript{4-6} During the 13 mph trial, maximal activity of the biceps femoris was found during terminal swing. Because the knee was extending and the hip was flexing, we theorize that the biceps femoris eccentrically contracts to limit both of these motions.

The gluteus maximus was found to have 2 peaks of maximal activity during the 20 mph trial. From the end of stance and into early swing, it is suggested that it concentrically contracts to extend the thigh. However, similar to the knee flexion mentioned above, authors believe this to be due to the reaction forces produced during stance.\textsuperscript{4-6} During terminal swing, we postulate that the maximal contraction is eccentric and acts to slow the forward momentum of the thigh. This finding is comparable to other studies.\textsuperscript{2,6,11} The maximal activity produced during the 13 mph trial occurred at the end of terminal swing and into early stance. During this period, hip flexion decelerated and hip extension began. Because the hip is extending, we speculate that the gluteus maximus first works eccentrically to slow hip flexion and then concentrically to extend the hip. These findings are in agreement with those reported by Owens.\textsuperscript{11}

Muscle activity of the rectus abdominus during the 20 mph trial peaked during early swing. We postulate that this eccentric contraction controls the anterior pelvic tilt
occurring with hip extension. During terminal swing, the rectus abdominus again contracts maximally. It is speculated that this contraction is concentric which acts to produce a posterior pelvic tilt during hip flexion. This is consistent with the activity found by Mann et al. A similar peak was produced during terminal swing during the 13 mph sprinting. However, the amplitude was greater during this trial as the hip was moving into greater flexion and producing greater forward momentum.

**Limitations**

There are a number of limitations which may have impacted the results of this study. First, the small number of subjects participating in this study may not adequately represent an elite sprinting population. Secondly, the training levels of the subjects were quite different as some had trained on the incline treadmill under similar conditions and others had not. This was evident when individual results were compared between subjects and when individual results were compared with the averaged results. Electrode application also may have altered the data. Because various persons applied electrodes, the reliability of the placement and the EMG activity is reduced. Finally, we did not record a baseline of muscle activity with which to compare our EMG results. This limited the quantitative analysis of our results.

**Conclusion**

There was greater hip flexion ROM during the 13 mph trial on the 30% incline. Knee flexion and ankle plantar flexion ROM were similar between the two trials. Overall muscle activity of the gastrocmenius, anterior tibialis, rectus femoris, and rectus abdominus was greater during the 13 mph trial. Muscle activity of the biceps femoris and the gluteus maximus was greater during the 20 mph trial.
Clinical Implications

The results of this study indicate that increased hip flexion ROM and greater muscle activity are generated during incline sprinting. This suggests that incline training may be a beneficial and vital component and should be included in sprint training protocols to maximize the power and speed of the athlete.
REPORT OF ACTION: EXEMPT/EXPEDITED REVIEW
University of North Dakota Institutional Review Board

NAME: Anna Hillig, Teri Parker  DEPARTMENT/COLLEGE: Physical Therapy

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

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

☐ Project approved. EXPEDITED REVIEW NO. 3
☐ 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: Chair, Physical Therapy
Dean, Medical School

Signature of Designated IRB Member  Date
UND's Institutional Review Board

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.
X EXPEDITED REVIEW REQUESTED UNDER ITEM 3 (NUMBER[S]) OF HHS REGULATIONS

EXEMPT REVIEW REQUESTED UNDER ITEM ____ (NUMBER[S]) OF HHS REGULATIONS

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

PRINCIPAL INVESTIGATOR: Thomas Mohr, Carrie Anderson, Samantha Gould, Anna Hillig, Teri Parker

TELEPHONE: 777-2813 DATE: 4/15/98

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

SCHOOL/COLLEGE: Medicine & Health Sciences

DEPARTMENT: Physical Therapy

PROJECT DATES: 5/1/98 to 5/1/99

(Month/Day/Year)

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

FUNDING AGENCIES (IF APPLICABLE): None

TYPE OF PROJECT (Check ALL that apply):

X NEW PROJECT  CONTINUATION  RENEWAL  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 COOPERATING INSTITUTION

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

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

PRISONERS ABORTUSES UND STUDENTS (>18 YEARS)

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

IF YOUR PROJECT HAS BEEN/WILL BE SUBMITTED TO ANOTHER INSTITUTIONAL REVIEW BOARD(S), PLEASE LIST NAME OF BOARD(S):

Red River Sports Medicine, Fargo, ND

Status: Submitted; Date 6/11/97 Approved; Date 6/12/97 Pending

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 3 years.

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

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

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

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

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

**SIGNATURES:**

[Signature]

Principal Investigator  
Date

[Signature]  
Date

Project Director or Student Adviser  
Date

Training or Center Grant Director  
Date

(Revised 3/1996)
INFORMATION AND CONSENT FORM

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

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

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

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

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

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

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

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

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

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

<table>
<thead>
<tr>
<th>Participant's Signature</th>
<th>Date</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Witness (not the scientist)</th>
<th>Date</th>
</tr>
</thead>
</table>

Sprint Study - Page 2 of 2
DATE:        April 9, 1998

TO:      IRB, University of North Dakota

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

RE: Sprinting Study

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

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

The student researchers will change this year (the two from last year will graduate this year).

I have added the required information regarding retention of the consent forms to the consent form.

We anticipate that we would collect data from 10 subjects this year.

If you have any questions, please do not hesitate to contact me.
June 12, 1997

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

Dear Mr. Mohr,

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

Sincerely,

John Frappier
President

JF/jlh
September 17, 1997

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

Dear Dr. Mohr,

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

Sincerely,

Mark A. Lundeen, MD
Medical Director RRVSMI
REFERENCES


