1999

Electromyographic and Kinematic Analysis of Hockey Skating

Tylan P. Schmidt

University of North Dakota

Follow this and additional works at: https://commons.und.edu/pt-grad

Part of the Physical Therapy Commons

Recommended Citation

https://commons.und.edu/pt-grad/400

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.
Electromyographic and Kinematic Analysis of Hockey Skating

By

Tylan P. Schmidt
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 Tylan P. Schmidt 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 Electromyographic and Kinematic Analysis of Hockey Skating

Department Physical Therapy

Degree Master of Physical Therapy

In presenting this Independent Study Report in partial fulfillment if 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

Date 12.15.98
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figures</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Reflective Marker Placement</td>
<td>15</td>
</tr>
<tr>
<td>2. Kinematic and Electromyographic at 0% at 8 mph</td>
<td>24</td>
</tr>
<tr>
<td>3. Kinematic and Electromyographic at 30% at 8 mph</td>
<td>25</td>
</tr>
<tr>
<td>4. Averaged EMG Activity at 0% and 30% Grades</td>
<td>26</td>
</tr>
<tr>
<td>5. Percent Increase of EMG Activity from 0% to 30% grade</td>
<td>27</td>
</tr>
<tr>
<td>6. Averaged Joint Angles at 0% and 30% Grades</td>
<td>28</td>
</tr>
<tr>
<td>7. Muscle Activity at 0% Grade</td>
<td>30</td>
</tr>
<tr>
<td>8. Muscle Activity at 30% Grade</td>
<td>31</td>
</tr>
</tbody>
</table>
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Subject Characteristics</td>
<td>13</td>
</tr>
<tr>
<td>2. Surface Electrode Placement</td>
<td>17</td>
</tr>
<tr>
<td>3. Averaged Muscle Activation in Percent</td>
<td>29</td>
</tr>
</tbody>
</table>
TABLE OF CONTENTS

List of Figures ............................................................................................ v
List of Tables ............................................................................................ vi
Acknowledgements ................................................................................. vii
Abstract .................................................................................................. viii
Chapter 1. Introduction ............................................................................. 1
Chapter 2. Literature Review ................................................................... 4
Chapter 3. Methods ................................................................................. 13
Chapter 4. Results ................................................................................... 21
Chapter 5. Discussion/Conclusion/Clinical Implications ...................... .32
Appendix .................................................................................................. 42
References ................................................................................................ 52
ACKNOWLEDGEMENTS

I would like to thank

My Mum and Dad for having me;

Tom for teaching and guiding me;

Reese for putting up with me;

The Sun for shining on me;

And Science for instilling a dependence upon observation, experience and reason within me.
ABSTRACT

There is a paucity of controlled studies concerning the off-season dryland training of hockey players. **PURPOSE:** To evaluate muscle activity and joint motion of the trunk and hip of hockey players skating on a hockey treadmill. **METHODS:** Seven male subjects, ages 18 to 21 years, were tested skating at 8 Mph on 0 percent and 30 percent grades on the treadmill. Electromyographical (EMG) data was collected from the following muscles: Rectus femoris, biceps femoris, adductor longus, gluteus maximus, rectus abdominus, and erector spinae. Motion analysis equipment was used to simultaneously collect kinematic data. **RESULTS:** There was an overall increase in the activity of all the muscles and a greater range of motion in the trunk and knee joints while skating on an incline as compared to level skating. Similar activation patterns were demonstrated in the rectus femoris, biceps femoris, gluteus maximus, adductor longus, and erector spinae muscles during level and inclined skating. **CONCLUSION:** The hockey treadmill may be beneficial in the training, rehabilitation and prevention of injuries in hockey players.
INTRODUCTION

Chapter 1

To advance in sports takes a high level of commitment, hard work, and the right type of training. An exceptional amount of preparation precedes any athletes’ competition in their field. The preparation is not only to ensure their peak performance but also to prevent injury. The sport of hockey is a good example.

In recent years, the amount of research in the field of sports medicine has exploded. Consequently, new techniques to train the fastest and most skilled athlete are rapidly being introduced. Nevertheless, it is important to realize that in hockey, hockey skating lacks objective research that supports the effectiveness of different training and rehabilitation methods. Therefore, more studies are needed to validate the various methods of training athletes.

Hockey requires a great amount of strength, speed, and endurance. According to the “theory of specificity of training”, the best workout an athlete can sustain is to actually do the activity for which he is training for. However, in some places the ice time that hockey players need for training is unavailable or limited. As a result, dryland activities that simulate the skating motion are used to train players. One such training activity is the hockey treadmill. The information collected from this study on the hockey treadmill will contribute to the understanding of how this particular training technique affects the muscles of the athlete skating on the device.
The data will be applied to the training of individuals for optimal game fitness, as well as for the rehabilitation of injured players.

**PROBLEM STATEMENT**

A limited amount of research has been done on the hockey treadmill and on the response of hockey players to individualized exercise programs.\(^3\) Also, little or no research has been done on the cycle of muscular activity that the lower extremity and trunk exhibit when skating on a hockey treadmill at different levels of incline. Much of the research that has been conducted on hockey in general is becoming outdated and well-controlled studies of exercise science as applied to this sport are few.\(^3\)

**PURPOSE**

The purpose of this study is to evaluate both the kinematic and muscle activity of six major muscle groups in the trunk and hip of an athlete skating on a hockey treadmill at two different grades of incline.

**SIGNIFICANCE**

The results of this study will aid in a better understanding of the biomechanics of skating on a hockey treadmill. In turn this will help in the development of better rehabilitation and injury prevention training since the activity of certain muscle groups will have been identified. Specific muscles can be targeted in training and recovery programs as a result. This study will help form a baseline of research for other studies on hockey skating.

**RESEARCH QUESTIONS**

Null hypothesis One: There are no changes in muscle activity at different grades of incline on a hockey treadmill.
Alternate hypothesis One: There is a change in muscle activity at different grades of incline on a hockey treadmill.
LITERATURE REVIEW

Chapter 2

Hockey is a game of skating ability. I would contend that skating superiority, more than any other quality (including hand-eye coordination, physical strength and cardiovascular capacity), distinguishes elite hockey players from the others. The Canadian Hockey Development Program concurs, as it believes that a better skater will be a better hockey player 90% of the time. Greer also agrees by stating that "the ability to accelerate quickly from a stationary position has been recognized as an important element of hockey performance."9

Premier players are able to skate with exceptional power, agility, speed, and acceleration.10 Players’ skating skills are most effectively developed on the ice whether it is outside or during the season in practice or a game. Unfortunately, in most climates, ice is impractical and expensive during the warmer months and so the athlete is unable to skate. This impedes the player’s development. Dryland training has thus become popular in conditioning the athlete year-round to improve the player’s on-ice performance, decrease rehabilitation time and prevent injuries.

Off-ice training programs should focus on the development of aerobic endurance, anaerobic power and endurance, muscular strength, and skating speed.10 This has been conventionally done with the use of weights and various cardiovascular apparatuses, especially the cycle ergometer. Weight training is an important element to a player’s development. Superior muscular strength will increase skating speed,
efficiency, improve shooting skill, reduce injury and increase confidence. Superior strength of the hip and knee extensors, which are responsible for a powerful push-off, will produce an advantage for the player allowing him to reach the puck faster, and create an unbalanced defense in his opponent. 

Cardiovascular activities are crucial when considering players’ stamina. Plyometrics, swimming, biking and aerobic activities are commonly used. It is important that the activities focus on both the aerobic and anaerobic systems. Seliger et al. characterized hockey as “an activity showing mostly a submaximal metabolic rate with a great participation of anaerobic metabolism (69%), but simultaneously with high requirements for aerobic metabolism (31%).” With typical shifts lasting 45 to 60 seconds and games consisting of three 20-minute periods, the demands of hockey require both intense glycolytic activity and exceptional aerobic endurance. Explosive skating strides are supplied by the anaerobic system while recovery from these maximal movements will be accomplished through the aerobic system. A well, aerobically and anaerobically conditioned player is thus able to forestall the effects of fatigue and play longer and more effectively.

Training regimes should also emphasize developing endurance levels specific to hockey players. Hockey endurance is defined by “the capacity for maintenance of strength and skills at high speed, intermittently through the entire game.” The principles of aerobic interval training are often used as an alternative to conventional aerobic training programs to heighten this “hockey specific endurance”. This type of training promotes “peripheral adaptations” through high intensity, 2-3 minute activities interspersed with rest periods of equal duration.
Players can not expect increased muscular strength, aerobic endurance, and anaerobic stamina to translate into increased hockey ability. Conventional dryland methods are lacking in the principles of sport specificity. That is, in order for a training regime to be effective it must be similar to the sport’s movement, velocity, contraction type, and contraction force. The cycle ergometer was once thought to be the ideal training apparatus in terms of similarity to the skating stride. However, Kandou et al. established that substantial differences, both biomechanical and physiological, existed between maximal speed skating and cycling because the movement patterns of the hip and knee exhibit a low degree of similarity. Even the most advanced dryland activities do not replicate the muscle activity of skating in regard to fluidity, specific angles, power, and frequency.

Recently, inline skating has become a popular method within dryland training programs. De Boer et al. established that inline skating was similar to speed skating in terms of power, work per stroke, stride frequency, push-off effectiveness, and skating technique. Hinrich also agrees that inline skating is the most specific dryland training method as compared to other activities including low walking, dry skating, skate jumps, and slide boards. However, there have been numerous, unpublished anecdotal reports from player’s that long-term inline skating over off-season months has detrimental effects on the athlete’s stride and technique once back on the ice.

Effective training and conditioning programs act by readying athletes for competition, amplifying players’ potential, and also in aiding in the prevention and treatment of injuries. “Effective training and conditioning is essential for the prevention of injury”. The game of hockey is a very physical and sometimes violent
sport which predisposes its players to injuries. A player can expect an injury after playing 7-100 hours with the majority of these taking place during games rather than practices. While most hockey injuries are minor, the incidence and severity increases as the player fatigues. Daly, Sim, and Simonet reported that the first period had a 27% injury rate, the second a 30% injury rate, and the highest rate was found during the third period at 36%.

Overuse accounts for 20% of all hockey injuries. Injuries to the knee, shoulder, groin, and back are most common. Inadequate muscular strength and endurance are primary contributors to these types of injuries. Tyler et al. identified hockey players to be predisposed to hip and lumbosacral strains secondary to a decrease in extensibility of the iliopsoas muscle. Force plate analysis of the push-off mechanism also demonstrated high posterior and lateral forces along with a twisting moment at the skate. This is believed to put the hip and groin musculature at a biomechanical disadvantage leaving them susceptible to strains.

Direct trauma is responsible for the majority of injuries that manifest in lacerations, contusions, fractures, and ligamentous injuries. High skating and puck velocities, increasing player size, aggressive stick use, fighting, and body checking are the primary factors for these types of injuries. Common injuries of the upper extremity involve AC separations, scaphoid fractures, and “gamekeepers thumb”. Lower extremity injuries involve primarily soft tissue structures: groin strains, quadriceps contusions, and knee sprains. Along with proper protective equipment and strict establishment and enforcement of rules, effective training is essential for injury prevention.
Hockey incorporates a unique style of skating called power skating. This entails non-rhythmic strides, repeated direction changes, short sprints, and rapid starts to achieve maximum speed in as little amount of time. A complete cycle begins at IC and ends at IC of the same skate. The time between PO and IC of the same skate makes up SwP, while SGP of the reference skate occurs when the opposite skate is in SwP. DGP spans from IC of the reference skate to PO of the opposite skate. Propulsion occurs in a direction essentially perpendicular to that of the gliding skate and begins approximately mid-way through SGP, lasting until the end of DGP.

Skating velocity, just as running, is dependent upon two factors: stride rate and stride length. At their maximum, elite hockey players are able to skate at speeds of 50km/h. It is stride rate rather than stride length which has been found to be highly correlated with velocity. Similarly, Hoshizaki established that the decrease in skating velocity of a fatigued player was secondary to a slower extension of the leg and a longer glide phase, consequently decreasing the stride rate.

Elite players are also able to accelerate up to 8m/sec after 4 strides. The ability to accelerate is associated with “a high stride rate, significant forward lean at the point of touchdown of the recovery skate, short single support periods, and placement of the recovery foot below the hip of the recovery leg at the end of the single support period”. Maximal stride length is achieved with full ankle, knee, and hip extension at PO, allowing a straight line to be seen from the ankle through the ipsilateral knee, hip, and then shoulder. However, it has been argued that full ankle extension or
plantarflexion would hinder speed as it would dramatically increase the coefficient of friction between the skate and ice as the blade is pushed downward.\textsuperscript{22} Page reported a significant correlation between maximal skating velocities and knee extension at push-off as well as knee flexion prior to propulsion.\textsuperscript{28} Proper knee bend at push-off, approximately 3 degrees \textsuperscript{22}, will lead to greater hip extension and stride length while a poor knee bend will lead to short strides impeding acceleration and speed.\textsuperscript{27} In order to extend the knee during propulsion\textsuperscript{29} and stabilize the knee when shifting weight\textsuperscript{10}, superior muscular strength is required in the quadriceps, hamstrings, and gastrocnemius respectively.\textsuperscript{29,10}

Along with hip and knee position, it is important for the entire body to be in a biomechanically sound posture in order to skate with an efficient stride. The head must remain relatively stationary, the chest should be parallel with the bend of the forward knee, the pelvis should have a slight anterior tilt, and both the hands and the arms should drive straight forward, never crossing the mid-line.\textsuperscript{27}

Unlike the hockey skating stride, that of speed skating has received much scientific attention regarding its technique.\textsuperscript{21,22,23} Though substantial differences exist between the styles of hockey skating and speed skating, there is much to be learned from speed skating research regarding velocity-oriented, biomechanically-efficient strides. The three tenets which differentiate skating from other types of locomotion (running, cycling, cross-country skiing) are propulsion against an unfixed location, push-off in a direction perpendicular to that of the gliding skate, and constrained plantarflexion.\textsuperscript{21,22,23} These tenets all hold true for both speed and hockey skating.
Elite speed skaters are able to skate at speeds of up to \(1.5 \text{ m/s}\) while holding a horizontal trunk position and maintaining a small pre-extension knee angle without an excessive dependency on anaerobic metabolism.\(^{21}\) Gliding takes up 80\%\(^{22}\) of the speed skating cycle and thus it is imperative that the push-off is both efficient and powerful. A trunk position which is parallel to the ice and a knee angle which is no less than 30 degrees at push-off are also both critical factors when considering optimal biomechanical advantage for the extensors.

EMG analysis of the speed skating cycle has shown that lower extremity musculature is activated in a proximo-distal sequence.\(^{23}\) Knee and hip extensors provide most of the power during push-off. During the glide phase, the activity of the long head of the biceps femoris and the anterior tibialis peak, activity of the vastus medialis and vastus lateralis both remain constant, while that of the gluteus maximus increases. Push-off demonstrates a decrease in hamstring and an increase in rectus femoris activity.\(^{23}\)

This is comparable to EMG activity during hockey skating on a treadmill. The gluteus maximus, rectus femoris, and biceps femoris work synergistically to produce a powerful extension moment at the hip and knee during PO. The biceps femoris is activated just after the firing of the rectus femoris and gluteus maximus, which both occur virtually simultaneously at 50\% of the cycle. Maximal rectus abdominus and erector spinae activity occur after contractions of the hip and knee musculature in an attempt to control and stabilize the trunk. Activity of the adductor longus peaks at the beginning and end of the cycle. Push-off occurs at approximately 50\% of the skating cycle.\(^{20}\)
During treadmill skating on a 30 degree incline, there was an increase in “muscle activation of the appropriate muscles that produce power and speed for the hockey athlete.” Results showed an overall increase in EMG activity as compared to level treadmill skating. The greatest percentile increases were seen in the rectus abdominus, adductor longus, and rectus femoris. There were similarities, however, between the two grades concerning the timing of activation with the rectus femoris, biceps femoris, and rectus abdominus muscles. Slight differences in the recruitment levels were noted in the adductor longus, gluteus maximus, and erector spinae. Inclined skating exhibits a longer swing phase as its pushoff takes place at approximately 40% of the cycle.

Level and inclined treadmill skating are comparable to skating on ice as the two surfaces correlate “reasonably well”. Treadmill skating EMG demonstrates comparable muscle activation patterns of skating on ice in the rectus femoris, anterior tibialis, and vastus medialis oblique muscles. Significant differences, however, were seen in the recruitment of the adductor longus, bicep femoris, and glutues maximus muscles. These differences occurred at high velocities of 8.7 and 10.3 mph and were explained by the fact that the treadmill was at a slight incline and that the skating surface was moving under the feet rather than the feet moving over the ice as in hockey.

Hockey is in need of scientific research to provide some insight into its physiology and training needs. Several skating studies have analyzed the arthropometric profiles of elite players including aerobic fitness, anaerobic power, physical size, body composition, pulmonary capacities.
However, there is a paucity of controlled studies concerning the off-season dryland training of hockey players. Without objective data, the effectiveness of different dryland training methods will remain subjective and anecdotal. Several methods have been attempted, however, the only concept that is universally accepted for the successful off-ice training of hockey athletes is that the activity must be specific to the hockey stride. Secondary to the complexity and fluidity of hockey skating, few activities are comparable to the stride thus reinforcing why a player’s skills are most effectively developed on the ice.

With the innovation of the hockey treadmill, however, players are given the opportunity to skate indoors in a manner essentially identical to skating on ice on a surface with essentially the same coefficient of friction as ice at supramaximal speeds and on various levels of inclination.运动员能够以不同的强度和持续时间进行训练以具体增强其有氧耐力、无氧力量和耐力、肌肉力量和滑行速度。跑步机也已证明是有用的无氧训练设备。

This research, with its objective data, could help trainers and physical therapists to design appropriate, effective, specific training protocols in an attempt to enhance hockey performance, prevent injuries and decrease rehabilitation time.
METHODS

Chapter 3

SUBJECTS

Seven normal, healthy male subjects volunteered in the study (Table 1). None of the subjects had previous, hockey-related injuries. They all signed a letter of informed consent (Appendix). The study was approved by the Institutional Review Board at the University of North Dakota (Appendix).

Table 1. Characteristics of subjects (n=7 males)

<table>
<thead>
<tr>
<th></th>
<th>MEAN</th>
<th>RANGE</th>
<th>STANDARD DEVIATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE (years)</td>
<td>19.0</td>
<td>18-21</td>
<td>1.0</td>
</tr>
<tr>
<td>HEIGHT (inches)</td>
<td>72.0</td>
<td>68-76</td>
<td>2.8</td>
</tr>
<tr>
<td>WEIGHT (pounds)</td>
<td>183.4</td>
<td>165-211</td>
<td>15.5</td>
</tr>
</tbody>
</table>

INSTRUMENTATION

Electromyography

The electromyographic (EMG) data was collected using a Noraxon Telemyo8 telemetry unit (Noraxon USA, 13430 North Scottsdale Rd., Scottsdale, AZ, 85254). The telemetried information from the EMG electrodes was collected by a Noraxon
Telemyo 8 receiver and then digitized by an analog to digital interface board installed in the Peak Analog Sampling Module (Peak Performance Technologies, 7388 S. Revere Parkway, Suite 601, Englewood, CO, 80112-9765). The digitized EMG signals were analyzed using the Peak Motus and Data Pac III software packages. The electromyographic data was synchronized with the video data using the Peak Event Synchronization Unit. To start the EMG data collection, the synchronization unit was triggered by a footswitch attached to the subjects foot. The EMG data was collected for a period of 10 seconds with a sampling frequency of 1080 Hz.

**Video**

Each subject was required to wear dark clothing. Seven reflective markers were placed on the right side of each subject. The locations of the reflective markers were as follows: the acromion, lateral epicondyle, ulnar styloid process, iliac crest, lateral condyle of the femur, lateral malleolus, and the 5th metatarsal head. The latter two were placed on the outside of the hockey skate (Figure 1).
Figure 1. Reflective marker placement during the skating cycle.
The camera used to film the motion was a Peak High Speed Video 60/120 Hz camera (Peak Performance Technologies, 7388 S. Revere Parkway, Suite 601, Englewood, CO, 80112-9765). The camera was set at a scanning frequency of 60 Hz. The shutter speed was set at 1/250 of a second. The video information was subsequently recorded on tape using a JVC Model BR-S378U video cassette recorder (JVC of America, 41 Slater Drive, Elmwood Park, NJ, 07407). The video tape was encoded using a SMPTE time code generator.

After recording of the subject’s movements, the video taped data was analyzed using the Peak Motus Software. A Sanyo Model GVR-S955 (Sanyo, 1200 W. Artesia Blvd., Compton, CA 90220) video cassette recorder was used to play back the video tapes for digitization.

**Hockey Treadmill**

The treadmill skating surface is composed of a high density polyethylene plastic (Frappier Acceleration Products, 2301 25th Street South, Suite E, Fargo, ND 58103). The revolving plastic slats are rotated by a motor driven belt. The coefficient of friction on the plastic slightly higher than on ice. See Appendix for specifications and measurements.17

**Protocol**

The electromyographic activity was collected from the following muscles: erector spinae, rectus abdominus, gluteus maximus, rectus femoris, biceps femoris, and adductor longus. These muscles can be monitored via surface electrodes and are prime movers of the motions occurring in the trunk and hip joint during skating.
To record the EMG activity, surface electrodes were placed over the belly of each muscle studied. The electrode placement point of each muscle was found using measurements from bony anatomical landmarks (Table 2). The skin over the motor point was prepared by cleansing the skin with alcohol before attachment of the EMG electrodes. Following removal of excess hair with clippers, the electrodes (Multi Biosensors, El Paso, TX, 79913), coated with pre-gelled adhesive, were then attached to the skin.

**Table 2. Surface Electrode Placement**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Measurements for Electrode Placement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectus Abdominus</td>
<td>4 cm inferior and 2 cm lateral from xiphoid process</td>
</tr>
<tr>
<td>Erector Spinae</td>
<td>Horizontally aligned with the L3-4 interspace, 4 cm lateral to midline</td>
</tr>
<tr>
<td>Gluteus Maximus</td>
<td>Midpoint of a line running from the inferior lateral angle of the sacrum to the greater trochanter</td>
</tr>
<tr>
<td>Biceps Femoris</td>
<td>Midpoint of a line from the ischial tuberosity to the lateral femoral condyle</td>
</tr>
<tr>
<td>Rectus Femoris</td>
<td>Midpoint of a line from the ASIS to superior pole of patella (minimum of 10 cm above the patella)</td>
</tr>
<tr>
<td>Adductor Longus</td>
<td>a line running 2/3 superior from muscle insertion, over the muscle belly</td>
</tr>
</tbody>
</table>

The EMG signals were transmitted to the receiver unit and then into a computer for display and recording of the data. The EMG information for each subject was recorded and stored on the computer hard drive for future analysis. Synchronization of the EMG and video data was achieved by utilizing an event switch, which was triggered at the initial contact of each skating cycle. The period of time from initial contact of the lower extremity to the next initial contact of the same lower extremity was defined as 100% of the skating cycle.
Prior to the trials, each subject’s age, height, and weight was recorded. The right lower extremity and trunk were used for this study. Before beginning the experiment, each subject was given the opportunity to familiarize themselves with the hockey treadmill.

Subjects were tested at both 0 percent and 30 percent inclines. The subjects skated for approximately 6-10 seconds at each grade. For both trials, the speed of the treadmill was 8 miles per hour. Each trial was run at a speed of 8 miles per hour. The subjects were placed into a support harness during the trials to prevent a falling injury.

**Skating Cycle**

There is not a standard description of the hockey skating cycle. We will use the following description for this study:

**Initial contact (IC)** is the portion of the skating cycle when the skate blade first contacts the ice. A complete skating cycle is from initial contact of a lower extremity to the next initial contact of the same lower extremity.

**Push off (PO)** is the point in the skating cycle when the skate blade leaves the ice.

**Glide Phase** is the portion of the skating cycle when the skates are in contact with the skating surface. This phase may be divided into double and single glide phases.

**Double Glide Phase** is the portion of the skating cycle when both skate blades are in contact with the ice. This phase lasts from initial contact of one leg, to push off of the opposite leg.

**Single Glide Phase** is the portion of the skating cycle when only one blade is in contact with the ice. This phase occurs while the opposite leg is performing the Swing Through Phase.

**Swing Through Phase (SwP)** is the portion of the skating cycle when the leg is not in contact with the ice. This phase takes place from PO to IC of the same leg.
DATA ANALYSIS

Prior to videotaping, the system was calibrated by videotaping a meter stick. The video footage for each skating trial was cropped to the first three completed skating cycles of each trial, and digitized using the Peak system. Event markers were placed at IC and at PO for each trial. The software calculated the angles and segmental motion. The second trial for each subject was averaged by the software to generate an ensemble average for all of the subjects in each trial. The raw analog data was scaled and matched to the video. Reports were then generated to show stickman-figure representation of the motion, joint motion, and integrated EMG data of the ensemble average.

The integrated EMG data was quantitatively processed using the Microsoft Excel software program. In order to normalize the data within subjects, a baseline of muscle activity was utilized. The baseline of muscle activity, for each muscle, was obtained by analyzing the integrated EMG waveforms from one complete skating cycles during skating at 5% grade at 8 mph. An ensemble average was computed for one complete gait cycle for each subject. The ensemble average was computed by sampling the EMG activity of an entire gait cycle at 0.5% intervals. The ensemble average was computed for one skating 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 (i.e. muscle active or not active) was determined from the grand mean, ensemble average curves for each muscle. The muscle activation was graded as maximal or moderate in relation to the peak level of averaged EMG activity that occurred during 100 percent
of the skating cycle. Maximal activation was defined as 66.6 percent to 100 percent of peak activity, moderate activity fell between 33.3 percent and 66.6 percent of the peak level, and minimal activation was from 0 to 33.3 percent of the peak. The muscle was considered to be active or non-active if the duration of on or off time was greater than 5 percent of total stride time. Gaps in EMG activity that were less than 2.5% were ignored.

The hip and knee range of motion data was processed similar to the EMG data. That is, an ensemble average was computed for one skating cycle, for each subject, and then averaged to compute a grand mean ensemble average for all of the subjects. The average joint range of motion (ROM) was evaluated for the trunk and knee during 100 percent of the skating cycle as well, noting the maximal and minimal values. Maximal was defined as the point in the skating cycle when the most joint flexion occurred, and minimal as the point when the least amount of joint flexion occurred.

Statistical testing for significant differences between and within subjects was not performed due to the small number of subjects.
RESULTS

Chapter 4

Figure 2 show the averaged kinematic data, integrated electromyographic activity and, stickman figures for each subject skating at 0% incline. The same information is shown in Figure 3 skating at 30% incline. Initial contact falls at zero and again at one hundred percent of the skating cycle. An event marker showed push-off to occur at 57 percent of the total skating cycle at 0%. During skating at 30%, push-off occurred slightly earlier, at 46 percent of the skating cycle.

Quantitative Analysis

Figure 4 shows an ensemble average of the EMG activity (in microvolts) for each muscle for both trials. The ensemble average shows the amount of muscle activity during one skating cycle. This averaged curve is a composite of one skating cycle for each subject. Therefore, each curve represents the averaged activity across the seven subjects. Figure 5 shows that there was an increase in the muscle activity in all the muscles with subjects skating at 30% compared to 0%. The greatest percent increases were seen in the rectus abdominus, adductor longus and rectus femoris muscles. The biceps femoris had the least amount of change in muscle activity, with only a 56% percent increase.

The ensemble averaged data for the trunk and knee range of motion for both trials are shown in Figure 6. At 0%, the maximum amount of trunk flexion was 67 degrees occurring at 38 percent of the skating cycle, and the minimum amount of trunk flexion
was 25 degrees occurring at 67 percent of the skating cycle. At 30%, the maximum trunk flexion was 71 degrees. This angle was reached at 11 percent of the skating cycle. The minimum amount of flexion was reached at 55 percent of the skating cycle and measured to be 20 degrees.

For the knee joint at 0% incline, maximum amount of flexion was 62 degrees occurring at 79 percent, and the minimum amount of knee flexion was 35 degrees occurring at 56 percent. Skating at 30%, the knee showed the greatest amount of flexion, 75 degrees occurring at 79 percent of the skating cycle. The least amount of knee joint flexion was 31 degrees. This occurred at 48 percent of the skating cycle.

A greater range of joint motion was indicated in both segments skating at 30% incline. However, a greater percent increase in range of motion, from level to incline skating, was demonstrated by the knee (63%) as compared to the trunk (21%).

Qualitative Analysis

Table 3 shows the activation times for each muscle during both trials, given in percent of the total skating cycle. The same information is graphically depicted in Figures 7 and 8. During skating at 0%, the muscles involved in propulsion, specifically the rectus femoris, gluteus maximus and biceps femoris, showed, in general, greatest activity during the glide phase of the skating cycle. The adductor longus and erector spinae demonstrated most activity in the swing phase, while the rectus abdominus displayed constant activity throughout the cycle during level skating.

During skating at 30%, the rectus femoris, gluteus maximus and biceps femoris exhibited recruitment patterns comparable to skating at 0%. These propulsion muscles demonstrated most activity during the first third of the cycle up until 46 percent. The
erector spinae and adductor longus were recruited for the entire cycle with the latter
demonstrating most activity during glide and early swing. The majority of the erector
spinae activity took place during swing phase. The rectus abdominus displayed 3 brief
periods of activity which occurred during glide phase, push-off and swing phase.

Through kinematic analysis, the trunk demonstrated a rhythmic, alternating
pattern of moving from flexion to extension to flexion as the skater progressed from IC to
IC during both trials. For level skating, the trunk gradually flexed for the first two-fifths
of the stride at which time it began extending. The trunk began extending earlier during
trial 2 at approximately 20 percent of the cycle.

The knee displayed the reverse. It exhibited an alternating pattern of extension to
flexion to extension as the knee joint started extending immediately from the start of the
cycle until 60 percent of the stride during trial 1. Inclined skating showed the knee to
extend for a shorter duration, up until 48 percent of the cycle.

Although the knee and trunk angles reached peak flexion at slightly different
times, the same sequence in which they occurred throughout the skating cycle was
comparable during both trials. More specifically, the trunk achieved maximal flexion
first, followed by maximal extension of the knee, then minimal trunk flexion and finally
maximal knee flexion.
Figure 2. Kinematic and electromyographic data at 0 percent grade at 8 mph. The vertical line represents push off.
Figure 3. Kinematic and electromyographic data at 30 percent grade at 8 mph. The vertical line represents push off.
Figure 4. Averaged EMG activity at 0 and 30 percent inclines. Zero percent is shown in blue and 30 percent is shown in red.
Figure 5. Percent increase in EMG activity at 30% grade as compared to 0% grade.
Figure 6. Averaged joint angles at 0 and 30 percent grades.
<table>
<thead>
<tr>
<th></th>
<th>Trial One: Zero Percent Grade</th>
<th>Trial Two: Thirty Percent Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximal Activation</td>
<td>Moderate Activation</td>
</tr>
<tr>
<td>Rectus Femoris</td>
<td>36-52%</td>
<td>0-36%</td>
</tr>
<tr>
<td></td>
<td>52-79%</td>
<td>19-38%</td>
</tr>
<tr>
<td></td>
<td>91-100%</td>
<td>62-70%</td>
</tr>
<tr>
<td>Biceps Femoris</td>
<td>28-54%</td>
<td>0-28%</td>
</tr>
<tr>
<td></td>
<td>54-67%</td>
<td>29-46%</td>
</tr>
<tr>
<td></td>
<td>88-100%</td>
<td>54-59%</td>
</tr>
<tr>
<td>Adductor Longus</td>
<td>0-8%</td>
<td>8-57%</td>
</tr>
<tr>
<td></td>
<td>57-76%</td>
<td>76-82%</td>
</tr>
<tr>
<td></td>
<td>82-100%</td>
<td>86-100%</td>
</tr>
<tr>
<td>Gluteus Maximus</td>
<td>22-31%</td>
<td>0-22%</td>
</tr>
<tr>
<td></td>
<td>38-53%</td>
<td>29-46%</td>
</tr>
<tr>
<td></td>
<td>84-100%</td>
<td>54-59%</td>
</tr>
<tr>
<td>Rectus Abdominus</td>
<td>0-8%</td>
<td>8-100%</td>
</tr>
<tr>
<td></td>
<td>55-69%</td>
<td>36-41%</td>
</tr>
<tr>
<td></td>
<td>77-100%</td>
<td>51-84%</td>
</tr>
<tr>
<td></td>
<td>15-55%</td>
<td>18-36%</td>
</tr>
<tr>
<td></td>
<td>69-77%</td>
<td>51-84%</td>
</tr>
</tbody>
</table>

Table 3. Average muscle activation in percent of two skating cycles for 0 and 30% grades.
Figure 7. Muscle activity at a 0% grade.
Figure 8. Muscle activity at 30% grade.
DISCUSSION

Chapter 5

Temporal changes in the hockey skating cycle

As the degree of the incline increased, the duration of the glide phase decreased. Concomitantly, the duration of SwP was increased as the angle of treadmill increased. The results from trial trial 1 (0%) showed that the skate was in contact with the treadmill for 57 percent of the cycle versus 46 percent of the cycle for trial 2 (30%).

Kinematic data

The results indicated an increase in both the trunk and knee range of motions during inclined skating as compared to level skating. The most marked increase was with the knee as it exhibited a 17 degree increase, from 27 degrees in trial 1, to 44 degrees in trial 2. The trunk measured a 9 degree increase in total range of motion from level to inclined skating. I hypothesize that skating on an inclined surface requires an accentuated swing phase in order to advance the leg up the slope.

Several similarities were noted when comparing the kinematic data from both trial 1 and trial 2. The trunk and knee range of motion for both trials exhibited the same sequencing patterns in relation to PO during both trials. The trunk range of motion sequence was flexion/extension/flexion. The sequencing of the knee was extension/flexion/extension. The trunk and knee, during both trials, also demonstrated the same degree of range of motion at PO. The only other time in the
skating cycle the degrees of flexion for the trunk and knee are equal, occurred during the terminal swing phase. It becomes evident with this finding that, during the glide phase trunk flexion is greater than knee flexion. Then after PO, knee flexion is greater than trunk flexion until just prior to terminal swing. This was a common finding in both skating on a level and on an inclined surface.

Although the patterns of the trunk and knee are opposite of one another and the range of motion was greater in trial 2, it is significant to note that inclined skating elicited the same style of motion in the trunk and knee as was exhibited on level skating.

**Electromyographic data**

The results indicated that trial 2 elicited more muscle activity when compared with trial 1. All six muscles, during trial 2, demonstrated at least a 56 percent increase in EMG activity during incline skating as compared to level skating. The rectus abdominis displayed the greatest amount with a 311 percent increase. The average percent increase for the six muscles was 126%. In addition, a greater percentage of significant activity (at least a moderate level) was exhibited during inclined skating (88%) as compared to trial 1(86%).

I hypothesize that more muscle force is required to skate on an incline, as compared to a level surface. This assumption is explained by the fact that although the same speed was used for both trials, a greater propulsive force is required with the inclined surface to achieve the same velocity. A powerful, forceful PO is essential to counteract the decreased glide time, shortened by the early PO (46% of cycle), which is associated with skating on an incline. I also assume that as the incline increases,
one must lift the body weight up the incline, increasing the amount of work that is required. This increased workload apparently increases muscle activity.

**Activation patterns**

*Rectus Femoris*

The rectus femoris demonstrated similar activation patterns during both trials in relation to the timing of PO and IC. Peak activity was exhibited during the glide just up to PO. During glide, both the hip and knee were extending. I speculate that the rectus femoris is primarily contracting concentrically at the knee to provide a powerful PO. However, the rectus femoris may also be recruited eccentrically at this time to help control the hip as it moves into extension.

Another similarity, related to the activation pattern of the rectus femoris, was exhibited as the knee is extending just prior to IC. I suggest that this is due to the rectus femoris working concentrically to extend the knee in preparation for IC. This compares with normal walking as the quadriceps is recruited during the deceleration phase to stabilize in preparation for heel strike.

A slight difference was also noted in the activation pattern. During trial 2, this biarticular muscle showed a period of maximal activity occurring during mid-swing at approximately 66 percent of the stride. At this time, the hip has started to gradually flex, indicating that during inclined skating, the rectus femoris is recruited in a concentric manner to assist in flexing the hip to bring the swing leg forward.

*Biceps Femoris*

The biceps femoris also demonstrated similar activation patterns during level and inclined skating. Peak activity occurred during both trials during glide phase.
Glide phase showed the hip starting to move into extension at 38 percent of the cycle during trial 1 and at 11 percent of the cycle during trial 2. I therefore conclude that the biceps femoris is recruited at this time to provide a strong extension moment at the hip during propulsion.\textsuperscript{20,23,29}

The biceps femoris also showed a short period of activity occurring at terminal swing during both trials. This activity, which occurred for approximately the last ten percent of the stride, was of a maximal level in trial 2 and of a moderate level in level skating. I suggest that the biceps femoris is functioning, at this time, to eccentrically control the extension of the knee prior to IC.

\textit{Gluteus Maximus}

The gluteus maximus exhibited the most comparable activity pattern between trials albeit inclined skating displayed more activity as compared to level skating. This is explained by the fact that during inclined skating, when the trunk is in an accentuated flexed position, the gluteus maximus is recruited maximally to stabilize the trunk by not allowing the hip to go into uncontrolled flexion.\textsuperscript{36}

In general, the majority of the EMG activity for both trials occurred during glide phase and terminal swing. As with the rectus femoris, the activity of gluteus maximus is related to the timing of PO. During level skating, activity ceased 4 percent prior to PO, while during inclined skating, the muscle displayed activity up until 2 percent of PO. I hypothesize that, just prior to PO, the gluteus maximus is predominantly activated along with the biceps femoris to extend the hip during propulsion.\textsuperscript{20,23,29}
During SwP, the gluteus maximus showed comparable activity at the end of the phase. Although this activity occurred for a longer duration during level skating, I hypothesize that this moderate activity is due to the gluteus maximus' attempt to eccentrically control the trunk as it moves into flexion.\textsuperscript{20,36}

\textit{Adductor Longus}

The adductor longus is the only muscle which demonstrated significant activity for 100 percent of cycle during both trial 1 and trial 2. In general, two comparable periods of peak activity between the trials were distinguishable. The first, which occurred during early glide, had a slightly longer duration in trial 2 (0 to 21 percent of the cycle) than in trial 1 (0 to 8 percent). This period of peak activity is explained by the fact that the propulsion skate pushes off in a direction which is perpendicular to that of the glide skate.\textsuperscript{21,22,23} This abduction force is, presumed to be, controlled eccentrically by the adductor longus.

The second period of similar maximal activity took place earlier in trial 2, during PO and early swing. This compared to that of level skating, in which the adductor longus was recruited maximally for 64 percent of SwP. This difference in the activation pattern of the adductor longus is explained by the fact that when on an incline, the increased grade recruits the adductor musculature to help the hip flexors bring the swing leg forward.\textsuperscript{20,35} In contrast to skating on a level surface, I hypothesize that, although the muscle was recruited to initiate swing, the hip flexors, specifically the iliopsoas muscle, are responsible for the major flexion force.\textsuperscript{35} Thus it is suggested that during trial 1, the adductor longus was mainly responsible for
eccentrically controlling the thigh to help position the skate in a midline position to prepare for IC.\textsuperscript{20}

*Erector Spinae*

As previously mentioned, a horizontal trunk position is critical to an effective stride as it provides an optimal biomechanical advantage for the hip extensors. The introduction of an incline had a significant effect on the position of the skater. Subsequently, there was a higher demand for an increased flexed posture. This required an enhanced recruitment of the erector spinae to maintain this position. Although the erector spinae displayed a 84 percent increase in EMG data from trial 1 to trial 2, the activation pattern of the muscle remained similar.

The majority of the erector spinae activity, during both trials, occurred as the trunk was flexing during SwP. Contractions of the erector spinae musculature are therefore assumed to be primarily eccentric. I conclude that the back extensors functioned in combination with the rectus abdominus to control the trunk angle and thus allow for a powerful propulsion.

*Rectus Abdominus*

The rectus abdominus demonstrated the greatest variation in activation patterns between level and inclined skating. During trial 1, the muscle displayed significant activity for the entire cycle, 90 percent of which was of the moderate level. As the skater progressed from IC to IC, the trunk moved from flexion to extension and back into flexion. I conclude that the muscle must thus be alternating between concentric and eccentric contractions to stabilize the trunk.\textsuperscript{20}
This compared to inclined skating in which the rectus abdominus displayed three brief periods of significant activity which occurred during mid-glide, PO and terminal swing. This is explained by the fact that when skating on an inclined surface, the erector spinae musculature, as opposed to the rectus abdominus, are primarily responsible for stabilizing the trunk in the accentuated horizontal position to prevent the skater from falling forward.

Prior Study

In a previous trial to the present study, Fox and Guttormson\textsuperscript{20} analyzed five subjects in a similar fashion. When comparing the EMG and kinematic data of the two studies, several similarities are noted. Namely, an increase in EMG activity during inclined skating, the kinematic sequence of the trunk and knee movements, a greater trunk and knee joint range motions during skating at a 30 percent incline, and the activation patterns of the hip and knee muscles.

Although both studies demonstrated a greater amount of activity during inclined skating to level, we found the increase to be substantially greater than they. We found the increase, on average, to be 126 percent, while Fox and Guttormson\textsuperscript{20} found it to be only 60 percent.

The percent time of significant muscle activity during the skating cycle was also greater during the present study. As stated earlier, the averaged EMG activity of the six muscles during our study displayed at least a moderate level for 86 percent during trial 1 and 88 percent during trial 2. Fox and Guttormson’s data\textsuperscript{20} was much less with level skating demonstrating only significant activity for 43 percent during trial 1 for 60 percent during inclined skating.
Our kinematic data for the trunk and the knee while skating on the level treadmill compared almost identically to Fox and Guttormson's²⁰ findings. The relative sequencing of the trunk (flexion/extension/flexion) and the knee (extension/flexion/extension) was similar for both studies.

Although Fox and Guttormson²⁰ recorded slightly greater numbers, both studies found the range of motion of the knee and trunk to increase as the degree of the incline increased. We found the knee to demonstrate a greater change, from level to inclined skating, in range of motion (17 degree increase) than the trunk (9 degree increase). Fox and Guttormson found the opposite, as they concluded that the trunk displayed the greatest increase in total range of motion (28 degree increase) rather than the knee (21 degree increase) when comparing level to inclined skating.

Regarding the activation patterns of the six muscles, our data showed the biceps femoris, gluteus maximus, rectus femoris, and adductor longus all displayed a similar recruitment style, to the data of Fox and Guttormson²⁰, during both level and inclined skating. Even though Fox and Guttormson²⁰ concluded that, within their study, only the rectus femoris, biceps femoris and rectus abdominus demonstrated comparable activation patterns during level and inclined skating, the fact that our 0 percent and 30 percent data compares almost identically to theirs is a significant finding.

Limitations

During the course of the study, there were limitations which occurred that could have influenced our results. Only seven subjects were used in this study, which statistically limits the accuracy of the data collected. An improvement for future
studies would be to include a greater number of subjects to create a better representation of the muscle and joint activity.

Another shortcoming was that most of subjects had limited experience on the hockey treadmill. The muscle activation could differ when skaters are well accustomed to skating on the hockey treadmill.

The way the kinematic data was recorded was also a limitation. Due to limited space the camera that recorded joint motion was unable to be positioned exactly perpendicular to the plane of motion. Although the joint measurements are relative to each other in the study, they may not be as accurate as data collected at 90 degrees to the sagittal plane of the skater.

Conclusion

With the exception of the rectus abdominus, all six muscles demonstrated similar recruitment patterns during level and inclined skating. Overall the amount of EMG activity as well as the trunk and knee range of motion increased during inclined treadmill skating compared to level skating. The sequencing of the joint movements followed a similar kinematic pattern in both joints when comparing trials.

Clinical Implications

The results from this study may be used to gain a better understanding of the biomechanics of the hockey skating stride. The results also showed extensive activity throughout the skating cycle, not only in the muscles of propulsion (rectus femoris, biceps femoris, adductor longus, gluteus maximus) but also in the trunk stabilizers (rectus abdominus, erector spinae). Strengthening of a hockey player should thus focus on developing the abdominals and low back extensors in addition to the lower
extremity musculature. This research will be helpful to trainers and physical therapists to design appropriate, effective, specific training protocols in an attempt to enhance hockey performance, prevent injuries and decrease rehabilitation time.
APPENDIX
REPORT OF ACTION: EXEMPT/EXPEDITED REVIEW
University of North Dakota Institutional Review Board

DATE: April 14, 1998        PROJECT NUMBER: IRB-9706-284
NAME: Ty Schmidt        DEPARTMENT/COLLEGE: Physical Therapy

PROJECT TITLE: Electromyographic and Motion Analysis of Skating (Protocol Change)

The above referenced project was reviewed by a designated member for the University’s Institutional Review Board on April 4, 1998 and the following action was taken:

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

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

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

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

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

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

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

cc: Chair, Physical Therapy
     Dean, Medicine

[Signature of Designated IRB Member]
UND's Institutional Review Board

Date 11/14/98

If the proposed project (clinical medical) is to be part of a research activity funded by a Federal Agency, a special assurance statement or a completed 310 Form may be required. Contact ORPD to obtain the required documents.
1. ABSTRACT: (LIMIT TO 200 WORDS OR LESS AND INCLUDE JUSTIFICATION OR NECESSITY FOR USING HUMAN SUBJECTS.

There are biomechanical aspects of skating which have been recognized as important elements in the peak performance of elite skaters. The goal of an ice training program is to enhance the athlete's present skills to allow them to perform at their maximal level. One of the more recent devices used for the advanced training of skaters has been the hockey treadmill. During this study, hockey players will be evaluated on the hockey treadmill for muscle activity and joint motion during the skating stride. There have been only a few studies which have identified specific musculature involved with the skating stride. As a result, there is a lack of data supporting training protocols and rehabilitation techniques following injury.

The purpose of this research study is to determine which lower extremity and trunk muscles are active, as well as when they are active, while using the hockey treadmill. The muscle activity data will be collected via electromyographic procedures using surface electrodes. Motion analysis video equipment will be utilized simultaneously to record joint motion. This will allow us to compare the EMG data with joint movement. The information learned from this study will be used to develop rehabilitative and training protocols to be used in conjunction with the hockey treadmill.

Normal, trained, healthy subjects will be used in this research project. Human subjects are needed for this research study in order to determine which muscles are active and when they are active while skating on the hockey treadmill.
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 individuals for this study. Subjects will be included in the study if they meet the following requirements: 1) Over 18 years of age, 2) a skating ability at the college/semi pro level, 3) no present pathologies, and 4) have previous experience on the hockey treadmill.

METHODS: We will measure electromyographic (EMG) activity in selected trunk and lower extremity muscles. The muscles that will be analyzed while skating on the hockey treadmill include: 1) anterior tibialis, 2) gastrocnemious, 3) rectus femoris, 4) biceps femoris, 5) rectus abdominus, and 6) lumbar erector spinae.

To record the EMG activity, the motor points of the above muscles will be located using a small electrical stimulator. The skin of the lower extremity and trunk of each subject will be prepared by cleansing the skin with alcohol before attachment of the EMG adhesive electrodes. 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 activity on the hockey treadmill can be compared. This procedure is done to normalize the EMG data for later analysis.

Video analysis will be used to measure trunk and lower extremity range of motion during the activity. Reflective markers will be attached to the trunk and lower extremity using double-sided adhesive tape. Video cameras will be placed around the subject and will film the subject's lower extremity and trunk movements during the experimental trial. This will be recorded on videotapes and will be transferred to a computer for analysis.

Before beginning the experiment, each subject will be given a short orientation session prior to skating on the hockey treadmill. EMG activity and joint motion will be recorded while skating on the hockey treadmill at grades of 0%, 10%, 20% and 30%. The subjects will skate on the treadmill for six seconds at the maximum speed they are able to achieve at each grade. The speed of the treadmill will be based according to the skaters ability. The subjects will be given a rest period between trials.

DATA ANALYSIS: Descriptive statistics describing the subjects' anthropometric profiles will be provided. Statistical analysis of the mean activity of each monitored muscle will be performed. The EMG data collected during the experimental trials will be expressed as a percentage of the EMG activity recorded during the MVC 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, limb velocity, and limb motion. The EMG data is synchronized with the video data to determine the level of EMG activity during the various exercise motions.
3. BENEFITS: (Describe the benefits to the individual or society.)

The data collected throughout this research study will be analyzed to identify the biomechanics associated with the skating cycle. This information will provide the basis for the development of individualized rehabilitation and training programs. Because there is very little research available in this area, it will also provide information for further 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 cause no discomfort to the subject, since they are both monitoring devices. The video information is converted to stickman-like diagrams, therefore the actual subject’s video is not used in data reporting; and the subject is not recognizable.

The process of physical performance testing does impose a potential risk of injury to the muscle. The subjects in this study will only perform maximal voluntary contraction for comparison purposes. The testing for maximal voluntary contraction will occur in a controlled setting, and the investigator feels that the potential for injury to the muscle is very minimal. The remainder of the trial will consist of skating on the hockey treadmill. Since all of the subjects will have skated and trained on the treadmill prior to the study, they will be familiar with the treadmill and therefore the risk of injury is minimal. The subject will be placed in a harness while skating to prevent a possible fall. 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]
Principle Investigator

[Signature]
Project Director or Student Adviser

[Signature]
Training or Center Grant Director

Date

(Revised 3/1996)
MEMO

DATE: April 9, 1998

TO: IRB, University of North Dakota

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

RE: Skating Study

I am writing to request a continuation of the study entitled "Electromyographic and Motion Analysis of Skating". The study had been approved last year (project " IRB-9706-284"). 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.
INFORMATION AND CONSENT FORM

TITLE: Electromyography and Motion Analysis of Skating Biomechanics

You are being invited to participate in a study conducted by Reese Williams, Ty Schmidt, and Thomas Mohr, at the University of North Dakota. The purpose of this study is to study the muscle activity in your lower extremity and trunk during the skating stride using a hockey treadmill. Only trained, normal, healthy subjects will be asked to participate in this study.

You will be asked to exercise on the hockey treadmill at your maximum speed. You will be asked to skate at your maximum speed for approximately six seconds or two skating cycles. The treadmill will be raised to four different inclines: 0%, 10%, 20%, and 30%. 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 Red River Valley Sports Medicine at an assigned time. You will then be asked to change into appropriate training apparel for the experiment. During the experiment, we will be recording the amount of muscle activity and the joint movement you have when you exercise on the hockey treadmill at four different inclines.

Although the process of physical performance testing always involves some degree of risk, the investigators in this study feel that the risk of injury or discomfort is minimal. In order for us to record the muscle activity, we will be placing a number of 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 attach reflective markers at various points on your legs and trunk. We will also attach a measuring device to your knee with adhesive material. 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 orientation session regarding the equipment. The amount of exercise you will be asked to perform will be moderate.

Your name will not be used in any reports of the results of this study. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. The data will be identified by a number known only by the investigator. The investigator or participant may stop the experiment at any time if the participant is experiencing discomfort, pain, fatigue, or any other symptoms that may be detrimental to his/her health. Your decision whether or not to participate will not prejudice your future relationship with the Physical Therapy Department or the University of North Dakota. If you decide to participate, you are free to discontinue participation at any time without prejudice.
The investigator involved is available to answer any questions you have concerning this study. In addition, you are encouraged to ask any questions concerning this study that you may have in the future. Questions may be asked by calling Dr. Thomas Mohr at (701)777-2831. A copy of this consent form is available to all participants in the study. A copy of this consent form will be retained in the Department of Physical Therapy for a period of 3 years.

In the event that this research activity (which will be conducted at Red River Valley Sports Medicine, Fargo, ND) results in a physical injury, medical treatment will be available, including first aid, emergency treatment and follow up care as it is to 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 Reese Williams and Ty Schmidt.

Participant's Signature Date

Witness (not the scientist) Date

Skating Study - Page 2 of 2
June 12, 1997

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

Dear Mr. Mohr,

This is to inform you that I have read the “Electromyographic and Motion Analysis of Skating” research proposal. I approved of this study as does the Red River Valley Sports Medicine Institute. I look forward to working together with you.

Sincerely,

[Signature]

John Frappier
President

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

Tim Kramrie
12 Year NFL Player
Cincinnati Bengals Coach

Jurt Giles
14 Year NHL Player
Canadian Olympic Team
REFERENCES


