1998

Electromyographic and Kinematic Analysis of Hockey Skating

Michelle M. Fox
University of North Dakota

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Electromyographic and Kinematic Analysis of Hockey Skating

by

Michelle M. Fox
Bachelor of Science in Physical Therapy
University of North Dakota, 1997

An Independent Study
Submitted to the Graduate Faculty of the
Department of Physical Therapy
School of Medicine
University of North Dakota
in partial fulfillment of the requirements
for the degree of
Master of Physical Therapy

Grand Forks, North Dakota
May
1998
This Independent Study, submitted by Michelle M. Fox 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

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This study is dedicated to my family who has always been the driving force behind all I have accomplished.

You have made me the person I am today.

Thank you!
ABSTRACT

A limited amount of research has been done on the hockey treadmill and on the response of hockey players to individualized exercise programs. **PURPOSE:** To evaluate muscle activity and joint motion of the trunk and knee of hockey players skating on a hockey treadmill. **METHODS:** Seven male subjects, ages 18 to 25 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 simultaneously. **RESULTS:** There was an overall increase in activity and duration of the muscles while skating on an incline as compared to level skating. There was also a greater range of motion in the trunk and knee joints with inclined skating. **CONCLUSION:** The hockey treadmill may be advantageous in the rehabilitation and training of hockey players.
INTRODUCTION

Chapter 1

The athlete, who is able to excel in his or her sport, is rewarded not only by a sense of accomplishment but often by endorsements and media coverage. 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.\textsuperscript{1,2,3,4} The sport of hockey is a good example.

In recent years, the amount of research in the field of sports medicine and acceleration 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, sports medicine lacks objective research that supports the effectiveness of different training and rehabilitation methods. Therefore, more studies need to be actively conducted to abate the lack of data.

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.\textsuperscript{5,3,6,7,2} 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 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. 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 out dated and well-controlled studies of exercise science as applied to this sport are few.

PURPOSE

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

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 significant changes in muscle activity at different grades of incline on a hockey treadmill.

Alternate hypothesis One: There is a significant change in muscle activity at different grades of incline on a hockey treadmill.
LITURATURE REVIEW

Chapter 2

The sport of hockey is a fast paced, intense and physically demanding sport. Ice hockey is characterized by intermittent bursts of speed and frequent changes in direction.\textsuperscript{8,9,2,10} During a shift, a player may skate from 30 to 120 seconds.\textsuperscript{5,8,3,11} This can total up to approximately 28 minutes of playing time over a 60 minute game.\textsuperscript{5,1} An athlete is required to have a capacity to endure both anaerobic and aerobic demands.\textsuperscript{2,5} Compared with the previous generation hockey players, today's athletes have enhanced physical size, and better physical conditioning.\textsuperscript{3}

Training with individualized programs has been an important factor in the overall improvement of today's athletes. The days of reporting to training camp and using it as conditioning time are gone. The professional arena is too competitive not to arrive at camp in optimal condition. Therefore, it is essential for the elite athlete to be well trained in their sport in order to perform with the utmost success.\textsuperscript{3,7}

Appropriate training is not only an important part of playing proficiently, but also in guarding against injury and counteracting the effects of fatigue.\textsuperscript{3} Daly, Sim and Simonet\textsuperscript{4} state that, "Effective training and conditioning is essential for the prevention of injury." A player, who is not physically prepared, cannot withstand the fast, explosive movement necessary to play hockey. The rough and demanding nature of the sport creates an arena where musculoskeletal injuries are common.\textsuperscript{6} However, most injuries
caused by ice hockey are minor and happen when players are fatigued. Injury incidence gradually increases as the game continues. Daly, Sim and Simonet reported that in the first period of play there is a 27 percent injury rate, in the second a 30 percent injury rate, and the highest rate is found during the third period at 36 percent.

Twenty percent of the injuries experienced by hockey players are due to overuse. Inadequate strength is a major factor in sustaining musculoskeletal injuries. The most common injuries were first, those to the knee, followed by the shoulder, groin, and back injuries. Groin injuries are the most prevalent injury due to the strain on the adductor muscles during the forceful skating stride.

The idea behind the consideration of certain injury patterns is determine causative aspects that could prevent injury. It may be possible to decrease or halt certain types of injuries through improved training techniques targeting these areas. The best way to treat an injury is to prevent it. Once an injury is sustained, it is important to maintain the cardiovascular level of the player as well as preserve proprioception and balance to facilitate a successful return to ice. The rehabilitation program should be adapted to fit the athlete's sport, playing position and the stresses that the injured area is required to withstand.

The training a hockey player undergoes is a year round regimen consisting of dryland and ice activities. The goal is to prepare a player for the upcoming season, or rehabilitate an injury, so he is in optimal playing condition. Each hockey has their own set of strengths, weaknesses, and history of previous injuries. Because of the individual contrasts in muscle execution and the different responses to similar training, programs should be geared for the needs of that player.
Continual conditioning will help avert both early season and severe injuries.\textsuperscript{11,12} According to Prentice,\textsuperscript{12} off-season training will also decrease the rehabilitation time of an injury occurs, and preserves the athlete’s “previous education of task performance.” Traditional hockey training programs include the elements of cardiovascular endurance, muscle flexibility, strength and power development and drills to improve hockey skill.\textsuperscript{1,5,6}

For hockey, endurance is defined as, “the capacity for maintenance of strength and skills at high speed, intermittently through the entire game.”\textsuperscript{5} This statement outlines the key to training a hockey player. A player must work to develop great strength and power, maintain that level of strength, and keep his technical skill at a peak, for the whole game.\textsuperscript{5} To accomplish this goal, various dryland and ice approaches are used in a training schedule.

Since ice time is not always available, or practical, players are expected to continue their training during off ice times.\textsuperscript{2} To gain cardiovascular endurance, nonspecific activities such as running, jumping and in-line skating are used. This variety of training is beneficial because continuous submaximal exercise increases the heart and lung’s oxygen capacity.\textsuperscript{2} Since the cumulative length of time that a player must be on the ice during a game can be relatively long, these workouts are important to build up an aerobic capacity.\textsuperscript{2,5} Aerobic fitness is vital for a quick recovery from the intense bursts of energy a player undergoes and allows him to be able to endure workloads with less strain.\textsuperscript{2} Stamina and endurance are integral elements in the prevention of injury.\textsuperscript{4,1}

Aerobic interval training, which promotes “peripheral adaptations”, is a variation on the conventional aerobic training that conditions the body’s cardiovascular system. Instead of a long duration of exercises executed at a submaximal threshold, bursts of high
intensity work, lasting two to three minutes, with interspersed rest periods of two to three minutes, are performed. Several benefits are thought to occur with this type of training. The oxidative capacity of muscles is thought to increase and fast twitch muscle fibers are preferentially recruited. Glycogen depletion of fast twitch, type II fibers is theorized to take place in reoccurring periods of concentrated effort. Since hockey is characterized by intermittent activity, and type II fibers are subsequently theorized to be recruited, this type of training has more specificity.

It is also important for the athlete to apply anaerobic training to whatever exercise he is currently doing. Anaerobic endurance creates a greater store of energy and provides a tolerance to the decreased efficiency of muscle contraction that occurs when lactic acid builds up during exertion.

Strength in hockey can be described as dynamic. The body is in motion as forces are applied. This aspect of training cannot be overlooked since one of the primary factors in the success of skaters is the ability to develop great levels of muscular tension very quickly which generates speed. In other words a hockey player must be able to accelerate rapidly from a stationary or “gliding position”. This creates an advantage for the player allowing him to reach the puck first, and create an unbalanced defense in his opponent. The development of strength in a hockey player, will, “increase skating speed, efficiency, improve shooting skill, reduce injury and increase confidence.” The trunk and lower extremity musculature, specifically the quadriceps, hamstrings, hip extensors and adductor muscles, are areas of concentration in strength training programs. However, the upper chest, trapezius and shoulders are also developed due to the rough
contact the players must endure. Progressive weight training and plyometrics have been used to develop a players power and strength in these areas.

Athletes cannot however, just increase their strength and expect it to translate into increased sports ability. Since neural changes in the muscle itself are involved, strength must be developed, taking into account the interrelation between the neural and muscular components of the muscle. These aspects must be developed together to meet sport demands. Increases in strength are influenced by the way the muscles are loaded, the intensity, frequency, duration, and velocity of contractions. The goal of training, both on and off the ice, should be the cultivation of muscle power at high speeds. Strength should be gained through lifting weights, and also dynamically by skating.

In addition to endurance and strength activities on land, the athlete must train on the ice in a manner specific to hockey. Even the most advanced dryland activities do not replicate the muscle contractions in regard to the specific angles, power and frequency. Thus, training programs will include workouts on the ice.

Hockey utilizes a distinct type of speed skating called power skating. This type of skating employs maximum speeds in a short amount of time. This skating characteristically has repeated direction changes, short sprints, and rapid starts. This type of skating is important for successful competition in hockey. Research has shown that through high velocity training, an improvement in output could be achieved at lower velocities with a training effect that was specific for muscle endurance and forces at or below the exercise speed. On ice, training programs should incorporate these techniques.
Another important aspect of training is skating mechanics. Proper technique has been cited as being possibly more important than conditioning level. Of all the many skills a hockey player must possess, skating is paramount. Faster skaters have characteristically low body positions to the ice. Their knees are flexed, and the truck is held in a horizontal orientation. This gives greater ground reaction forces on push off and better leg propulsion. As a player fatigues, changes occur in the skating technique that can affect the ability of the player to reach optimum speeds. The leg is held in a more vertical position with less knee flexion, which puts the trunk in a greater forward lean. This posture reflects the fatigue of the quadriceps, hip extensors and the low back musculature. It also makes it impossible to maintain a low posture relative to the ice. If the player cannot maintain a non-horizontal truck orientation, the speed obtained will be decreased as compared to a horizontal trunk at the same power output. Because all out efforts of skating that last longer than 15-20 seconds cause poor technique, emphasis when training should be put on the quality and intensity of a workout rather than on the volume of this type of skating.

The biomechanical changes that occur due to fatigue can also predispose a player to injury, especially in the low back region. One of the leading factors in prevention of this type of injury is the development of strong abdominals. An adequate back and abdominal strengthening program is crucial in any training program for the prevention of injury.

Despite the technique used, an overall goal of training is to be as sport specific as possible. One study compared speed gains between three training programs, the group that practiced speed skating with instruction became faster. The other two groups, which
either did leg squats or pushed a partner for resistance while skating had no significant improvement in speed. This reiterates the theory that to become a faster skater, one must skate fast.⁵

Other activities such as biking and in-line skating are more specific to hockey because they use the same large muscle groups.² One study reported similar patterns of glycogen depletion in the vastus lateralis when comparing skating to cycling.¹⁵ However, the technique and mean power output was considerably different between the two. During cycling the moderate mean power output only reaches 300-400 Watts, while the peak value that occurs during pushoff in skating measured over 2,000 Watts. This number reaches two to three times the mean power output compared to cycling.¹⁵ This difference is due to the forceful push off that occurs during skating.¹⁶

Hockey skating has different movement patterns than activities such as running, or jumping. The standard leg strengthening exercises were designed to be more conducive to up and down movements. The biomechanics of the skating stride do not allow the same vertical components that running and jumping do.² In order to gain speed, the pushoff forces against the ice must be at an angle which is perpendicular to the direction of the skate gliding on the ice.¹⁶ Training should be specific regarding movement, velocity, contraction type and force. Therefore, atypical activities are often used.² One recently devised dryland training method, thought to be more specific to the skating motion, has been the use of a hockey treadmill. In a study by Hinrich,⁵ the treadmill was shown to simulate skating on ice “reasonably well.” The work requirement for both ice and treadmill at the same velocity was comparable despite the higher coefficient of friction on the treadmill. The treadmill was also analogous to ice in the
stride time the subjects used. Another important factor that supports the specificity of the hockey treadmill is the recruitment patterns of the muscles. Ice and treadmill skating were similar in the tibialis anterior, vastus medialis, and rectus femoris. However, there was a significant difference in recruitment for the gastroc-soleus, adductor longus, biceps femoris and gluteus maximus muscles. The main difference occurred at the highest velocities (8.7 and 10.3 mph). The adductor longus was recruited earlier on ice than in the treadmill. The differences in the biceps femoris and gluteus maximus occurred in the last 4 percent of the stride (stride was defined as heel strike to heel strike). One reason for this discrepancy could have been the incline of the treadmill and accordingly the foot making contact with the surface at an earlier time than seen with flat ice. A suggested grade for close simulation between the ice and the hockey treadmill was 2.5 percent. Another difference that could account for different recruitment patterns is that the treadmill is moving under the feet versus the skates moving over the ice.

One advantage the hockey treadmill offers is the ability to control various aspects of training that need to be concentrated on. The treadmill provides a means to increase strength, hockey endurance, and improve skating technique. The hockey treadmill is able to imitate power skating by virtue of its capability to produce high speed workouts that force the skater to accelerate from gliding positions very quickly. Interval skating to increase hockey endurance in situations similar to a game can be used. Power training can be incorporated into the hockey treadmill as well, through the use of resistance bands and by increasing the incline. Finally, the controlled environment of the hockey treadmill allows skating biomechanics to be monitored while still training at high intensities.
METHODS

Chapter 3

SUBJECTS

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

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

<table>
<thead>
<tr>
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<th>MEAN</th>
<th>RANGE</th>
<th>STANDARD DEVIATION</th>
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<tr>
<td>AGE (years)</td>
<td>19.7</td>
<td>18-25</td>
<td>2.4</td>
</tr>
<tr>
<td>HEIGHT (inches)</td>
<td>71.9</td>
<td>67.5-76.5</td>
<td>2.9</td>
</tr>
<tr>
<td>WEIGHT (pounds)</td>
<td>186.6</td>
<td>165-204.5</td>
<td>17.4</td>
</tr>
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</table>

Two of the subjects were excluded from the study. The first subject was not included in the final results because of faulty data collection. The third subject did not fall within the parameters set for subject selection. He had limited experience on the treadmill.
INSTRUMENTATION

Electromyography

The electromyographic 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 manual switch and 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 each subject. The position of the reflective markers was identical with each subject and trial. 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 the 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. 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 C for specifications and measurements. 17

**Protocol**

The electromyographic (EMG) 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.

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>
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<tr>
<th>Muscle</th>
<th>Measurements for Electrode Placement</th>
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<tbody>
<tr>
<td>Rectus Abdominus</td>
<td>2 cm superior and 2 cm lateral to umbilicus</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 a 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 of the subjects was given the opportunity to familiarize themselves again with the hockey treadmill (Frappier Acceleration Products, 2301 25th Street South, Suite E, Fargo, ND 58103).

Subjects were tested at two separate inclines. The subjects skated for approximately 6-10 seconds at each grade. Electromyographic activity was recorded at inclines of 0 percent (5 percent is the least amount of incline available on the hockey treadmill and considered to be level) and 30 percent (maximal incline of hockey treadmill). Each trial was run at a speed of 8 miles per hour. Subjects were placed into a support harness for safety purposes preceding the trial runs.

**Skating Cycle**

There has not been any standard method to describe the skating cycle for hockey players. For the purposes of this study, the skating cycle was broken down into three phases, and defined as follows:

- **Initial contact (IC)** is the portion of the skating cycle when the skate blade first contacts the ice. A complete skating cycle spans 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 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 camera was calibrated by videotaping a meter stick. Then the video footage for each skating trial was calibrated to meters, cropped to the first three completed skating cycles of each trial, and digitized using the Peak system. The software calculated and the angles and segmental motion. 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 three skating cycles of each trial.

The integrated EMG data was quantitatively processed using the DATAPAC III software program. In order to normalize the data within subjects, a baseline of muscle activity was utilized. The baseline of muscle activity, for each muscle, was obtained by analyzing the integrated EMG waveforms from two complete skating cycles during skating at 5% grade at 8 mph. An ensemble average was computed for two complete gait cycles for each subject. The ensemble average was computed by sampling the EMG activity of an entire gait cycle at 3% intervals. The ensemble average was computed for two skating cycles, for each subject, with the averaged curves for each subject added together to yield a grand mean curve representative of all the subjects. The qualitative analysis and timing of the muscle activity (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, moderate or minimal 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.

The hip and knee range of motion data was processed similar to the EMG data. That is, an ensemble average was computed for two skating cycles, 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

Figures 2 and 3 show the stickman figures, kinematic data, and integrated electromyographic activity for each individual subject for trial 1 (skating at 0%). The same information is shown in Figures 4 and 5 for trial 3 (skating at 30%). Initial contact falls at zero percent of the skating cycle. Push off occurs at approximately 50 percent of the total skating cycle in trial 1. During trial 3, push off occurs slightly earlier, at about 40 percent.

Quantitative Analysis

Figure 6 shows the average EMG activity (in microvolts) for each of the muscles for both trials. The ensemble average shows the quantity of muscle activity during one skating cycle. This averaged curve is a composite of two skating cycles for each subject. Therefore, each curve represents the averaged activity over ten skating cycles. Figure 7 shows that there was an increase in the muscle activity in all the muscles with trial 3. The greatest percent increases were seen in the rectus abdominus, adductor longus and rectus femoris muscles. There was greater than a 65 percent change in EMG activity in those muscles. The biceps femoris had the least amount of change in muscle activity, with less than a 15 percent increase.
The ensembled averaged data for both knee and trunk range of motion is shown in Figure 8. In trial 1, the maximum amount of trunk flexion was 57 degrees, at 5 percent of the skating cycle, and minimum trunk flexion was 27 degrees at 68 percent of the cycle. For the knee joint in trial 1, the maximum amount of flexion was 65 degrees and the minimum was 33 degrees. Those values occurred at 83 percent and 60 percent of the stroke respectively.

During trial 3, the maximum trunk angle was 74 degrees. This angle was reached at 25 percent of total stride time. The minimum flexion angle was reached at 63 percent of the stroke and measured 16 degrees. The knee angles (trial 3) showed the greatest amount of flexion, 86 degrees, at 88 percent of the cycle. The least amount of joint flexion was 33 degrees. This occurred at 53 percent of the entire stride time.

**Qualitative Analysis**

Table 3 shows the activation times for each muscle during both trials, given in percent of the total skating cycle. This same information is graphically depicted in Figures 9 and 10. In general, the majority of peak muscle activity in trial 1 occurred around midcycle. Activity during trial 3 took place slightly earlier in the cycle. This was particularly true of the rectus femoris and rectus abdomius muscles.

However, differences in maximal muscle activation patterns were noticed in the other four muscles. The biceps femoris and gluteus maximus each had two periods of peak activity in trial 3. The muscle was active at the beginning of the cycle as well as during midcycle. This compared with a single period of activity during the middle of the cycle in trial 1. The gluteus maximus was also maximally active for a much greater
period of time in the first half of the cycle in trial 3 versus trial 1. The erector spinae was just the reverse, with two periods of peak activity in trial 1, compared with only one in trial 3. In trial 1, the main activity was in the first half of the cycle, while in trial 3, the most activity was during the last one third of the cycle. During trial 1, the adductor longus experienced peak activity during the first ten percent of the cycle. However, at 30 percent incline, the maximal activity occurred during midcycle.

The trunk and knee were in a flexed position for the duration of the skating cycle, but alternated in a rhythmic fashion. Although the knee and trunk angles reached peak flexion at slightly different times, the same pattern of flexion/extension/flexion held true for both joints. However, the period in the skating cycle when peak flexion was reached occurred earlier in trial 3 as compared with trial 1. There were also slightly different rates of extension between the trunk and knee. The trunk was held in a relatively constant amount of flexion during the first one third of the stride time and then began to extend. On the other hand, the knee started extending immediately from the start of the stroke. In addition, a greater range of joint motion was indicated in both segments during trial 3.
Figure 2. Kinematic and electromyographic data for Subject 6 skating on 0 percent grade at 8 mph. The vertical lines indicate initial contact.
Figure 3. Kinematic and electromyographic data for Subject 7 skating on 0 percent grade at 8 mph. The vertical lines indicate initial contact.
Figure 4. Kinematic and electromyographic data for Subject 6 skating on 30 percent grade at 8 mph. The vertical lines indicate initial contact.
Figure 5. Kinematic and electromyographic data for Subject 7 skating on 30 percent grade at 8 mph. The vertical lines indicate initial contact.
Figure 6. Averaged EMG activity for trial 1 and trial 3. Trial 1 is indicated in red and trial 3 is indicated in blue.
Figure 7. Averaged EMG activity during the skating cycle at two different grades.
Figure 8. Averaged knee and trunk flexion angles for trial 1 and trial 3. Trial 1 is indicated in red and trial 3 is indicated in blue.
<table>
<thead>
<tr>
<th>Muscle</th>
<th>Trial One: Zero Percent Incline</th>
<th>Trial Three: Thirty Percent Incline</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximal Activation</td>
<td>Moderate Activation</td>
</tr>
<tr>
<td>Rectus Femoris</td>
<td>38-49%</td>
<td>0-18% 30-38% 95-100%</td>
</tr>
<tr>
<td>Biceps Femoris</td>
<td>50-56%</td>
<td>0-14% 42-50% 56-62% 93-100%</td>
</tr>
<tr>
<td>Adductor Longus</td>
<td>0-9%</td>
<td>39-66% 91-100%</td>
</tr>
<tr>
<td>Gluteus Maximus</td>
<td>37-51%</td>
<td>0-37% 93-100%</td>
</tr>
<tr>
<td>Rectus Abdominus</td>
<td>53-61%</td>
<td>0-10% 95-100%</td>
</tr>
<tr>
<td>Erector Spinae</td>
<td>0-10% 40-56%</td>
<td>80-100%</td>
</tr>
</tbody>
</table>

Table 3. Average muscle activation in percent of one skating cycle for trial 1 and trial 3.
Figure 9. Muscle activity at 0 percent incline. The vertical lines indicate the phases of the skating cycle.
Figure 10. Muscle activity at 30 percent incline. The vertical lines indicate the phases of the skating cycle.
DISCUSSION

Chapter 5

In general, the results indicated that trial 3 (30 percent incline) elicited more muscle activity for a longer duration when compared with trial 1 (0 percent incline). It is assumed that more muscle force is required to maintain the same speed when skating on an incline, as compared to level ice. Since there are no studies that compare hockey skating on an incline with skating on level surfaces, the underlying assumption is that the increase in activity is due to the incline of the treadmill.

Trial One

At approximately 50 percent of the skating cycle the knee joint was moving into extension. During this same period, trial 1 displayed maximal rectus femoris activity just prior to the midpoint in the stroke. We hypothesized that a concentric contraction of the rectus femoris at this point would extend the knee for push off elicit a peak activity level.

At approximately the same time as the maximal rectus femoris activity, the trunk angle was decreasing as the knee was extending. Peak gluteus maximus activity occurred during this portion of the skating cycle. Just after the greatest level activity, the least amount of trunk flexion takes place. This muscle probably assists the quadriceps in extending the hips and knees for push off. The gluteus maximus also has a second activation period at the very end of the stroke, and most likely functions eccentrically to control the hip flexors.
Activation of the biceps femoris occurs just after the firing of the rectus femoris, with the majority of activity spanning 42-62 percent of the stroke. The muscle presumably contracts to extend the hip in conjunction with the gluteus maximus.

During both the beginning and end portions of the skating cycle, the adductor longus is most active. We suggest this was because the muscle is concentrically contracting to assist in swing through of the leg, and eccentrically contracting to help position the leg into a midline orientation for initial contact.

Maximal rectus abdominus activity occurs just prior to the minimum angle of trunk flexion and after the contraction of the hip and knee musculature. Since the trunk is reaching its most extended point, the muscle is probably functioning to control trunk extension. We speculate the moderate activity, which takes place at the very end and beginning of the stroke, is to stabilize the trunk and pelvis during push off and initial contact and prevent a lateral tilt.

Two peak periods of activation were present in the erector spinae. The first maximal level coordinated with the activity of the rectus abdominus where it most likely functioned as a trunk stabilizer. The peaks occurred as the trunk was preparing for initial contact. The second maximal level of activity occurred around push off and we suggest this is due to a concentric contraction that assists in extension of the hip.

**Trial Three**

During trial three, there was an increased activity seen in the rectus femoris and biceps femoris at the beginning and end of the stroke. The maximal activity of these muscles also occurred at an earlier point than in trial 3 versus 1. The increased muscle
activation is most likely due to the increased push off force needed to propel the skater up the incline and the increased need for eccentric control of knee flexion and extension.

During the first half of the skating cycle, the gluteus maximus is maximally contracting for a greater period of time in trial 3 than trial 1. The increased activity can be accounted for because a greater during push off force is needed to propel the skater on an incline. The trunk also has a greater degree of flexion during this period. Presumably, this is because the gluteus maximus helps hold the trunk and pelvis in a flexed position.

At the end of the skating cycle there is another period of peak activity. We suggest the muscle activates to eccentrically control the hip flexors at the end of swing through.

In the portion of the stroke that occurs just following push off, the adductor longus has a maximal level of activity. The peak most likely occurs because this muscle is used to assist in the initiation of swing through.

During trial 3, there is a longer maximal contraction of the rectus abdominus. The increased need for increased trunk stability at push off, when on an incline, is the supposed reason accounting for the peak activity.

The erector spinae activates when the trunk is increasing in flexion for initial contact. In trial 3, the maximal activity also occurs at a later point in the skating cycle. It is most likely an eccentric response to control the greater range of trunk flexion achieved with the introduction of an incline.

**Comparison of Trial One and Trial Three**

The time the muscle was activated between the trial 1 and trial 3 was similar in the rectus femoris, biceps femoris and rectus abdominus. However, there was more overall muscle activity present in trial 3 versus trial 1, and slightly different muscle
recruitment levels were also found in the adductor longus, gluteus maximus and erector spinae.

The main period of adductor longus activity in trial 1 occurred during the first ten percent of the cycle, but in trial three there was an increase in during midcycle. A possible reason for the change in muscle patterns is the increased extension that occurs in the hip when on an incline. The 30 percent grade recruits the adductor musculature in the beginning of swing through phase to help the hip flexors bring the free leg forward. In contrast, we presume that the hip flexors carry the major flexion force for swing phase in the hip during 0 percent incline. Despite differences in when the peak level occurs, the activation pattern between both trials for the adductor longus was comparable.

During the two trials, the gluteus maximus was active during the same time periods, but contrasted in the duration of peak activity. One suggested reason for this change in activity length is the need to maintain the flexed position of the trunk, and to increase push off force during incline skating.

The erector spinae showed the most difference in activation patterns between the trials. We suggest the variance between the trials is because of the 30 percent incline and the effect it had on the skaters trunk position. The subject tried to maintain a relatively horizontal trunk while skating on an incline and this caused a greater degree of hip flexion. In trial 3, controlling trunk flexion required the greater activity, while in trial 1, more activity was needed to help extend the hip.

A great deal of what is known about the skating stride in hockey has been adapted from speed skating techniques. This has been necessary because there are very few studies that describe the biomechanics of the hockey skating cycle. One technique that
has been utilized by both hockey and speed skaters is the maintenance of a horizontal trunk. In both types of skaters, it allows for increased skating velocity. This biomechanical aspect of skating could be one reason that there was an increase in the amount of erector spinae at a 30 percent incline. Although the same speed was used for both inclines (0% and 30%), a greater propulsive force is hypothesized to be used with the incline to achieve the same velocity. During incline skating, the angle the trunk is held in becomes increasingly important. Another similarity between hockey and speed skating is the explosive push off at the end of the glide phase. During the push off, speed skaters use the gluteus maximus and vastus medialis provide the extension force for propulsion. Hockey players also use a powerful extension thrust at push off, and our study indicated that the gluteus maximus and rectus femoris are the main proponents of this motion. The biceps femoris and the erector spinae assist these muscles.

There is no literature that makes a comparison of incline skating to level skating. A study by Hinrich however, does make some comparisons between level skating on ice and on the hockey treadmill. However, it is difficult to make a comparison between our study and Hinrichs because the criteria used to signal muscle activation differed. Despite this limitation there were similarities between the two studies for trial 1. In general, both studies concluded that there was activity in the gluteus maximus, rectus femoris, and biceps femoris during the first half of the skating cycle.

At low inclines, skating and ice simulate each other “reasonably well.” However there were some significant differences in the muscle activation patterns between the ice and treadmill skating in Hinrichs study. The biceps femoris, gluteus maximus, and
adductor longus showed significant differences during medium and high speeds (8.7 mph and 10.3 mph). There was no significant difference in the rectus femoris at any speed.¹

Other studies have attempted to compare hockey with other activities such as cycling, jumping, and running. It has been found that skating has a unique movement pattern that is not well emulated by other activities.³ Studies that have been done on running and walking on a treadmill are also not very comparable to skating on a treadmill. This is because the forces of propulsion lie in different planes.²,¹⁶ Running and walking require more vertical forces, but skating requires a horizontal push off force. The intensive push off force used in skating also uses patterns of muscle activity that are rarely recruited in cycling, running, or rowing actions.¹⁶,¹⁹

During the course of the study, there were limitations which occurred that could have influenced our results. Only five 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 difficulty that may have restricted the results is the fact that some 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 perpendicular to the plane of motion. Although the joints measurements are relative to each other in the study, they may not be the accurate according to data collected 90 degrees from the sagittal plane of the skater. The last limitation was a mechanical error in the foot switch. The switch remained in the on position for all of the skating cycles during testing of the
last two subjects. Thus initial contact was unable to be detected. Manual markers were added at a later time using video analysis of the skaters, but accuracy may not be 100 percent.

Conclusion

There was an overall increase in the muscle activity in trial 3 versus trial 1. Despite the increased muscle activation, most peak muscle levels occurred at relatively the same time in the skating cycle. The only muscles that demonstrated a moderate difference in muscle recruitment between trials, were the erector spinae and adductor longus.

Clinical Implications

This study will be used in gaining a better understanding of the biomechanical aspects of the hockey skating stride. The information gathered can be used to develop and validate rehabilitation and training procedures used for hockey players.
INFORMATION AND CONSENT FORM

TITLE: Electromyography and Motion Analysis of Skating Biomechanics

You are being invited to participate in a study conducted by Kari Guttormson, Michelle Fox, 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 feels 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 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.

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 Kari Jo Guttormson and Michelle Fox.

____________________________
Participant's Signature       Date

____________________________
Witness (not the scientist)    Date

Skating Study - Page 2 of 2
REPORT OF ACTION: EXEMPT/EXPEDITED REVIEW
University of North Dakota Institutional Review Board

DATE: June 12, 1997
PROJECT NUMBER: IRB-9706-284
NAME: Thomas Mohr, Kari Guttormson, and Michelle Fox
DEPARTMENT/COLLEGE: Physical Therapy

PROJECT TITLE: Electromyographic and Motion Analysis of Skating

The above referenced project was reviewed by a designated member for the University's Institutional Review Board on June 20, 1997 and the following action was taken:

☐ Project approved. EXPEDITED REVIEW No. 3
Next scheduled review is on June 1998.

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

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

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

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

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

cc: T. Mohr, Adviser
Dean, Medical School

Signature of Designated IRB Member
UND's Institutional Review Board

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.

(3/96)
June 12, 1997

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:
Don Chu, RPT, Ph.D., ATC
Tim Krumrie
Cincinnati Bengals Coach
Curt Giles
14 Year NHL Player
Canadian Olympic Team

M.I.S.
Rich Johnson

ACCOUNT EXECUTIVES:
Brad Gander
Andy Becker

BUSINESS MANAGER:
Brad Holm

PRESIDENT:
John Frappier, M.S.
X EXPEDITED REVIEW REQUESTED UNDER ITEM 3 (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, Kari Guttormson and Michelle Fox
DATE: 6/11/97

ADDRESS TO WHICH NOTICE OF APPROVAL SHOULD BE SENT: Dept. PT, Box 9037, Grand Forks, ND

SCHOOL/COLLEGE: School of Medicine & Health Sciences
DEPARTMENT: Physical Therapy
PROJECT DATES: 7/15/97 to 7/15/98

PROJECT TITLE: Electromyographic and Motion Analysis of Skating

FUNDING AGENCIES (IF APPLICABLE): none

TYPE OF PROJECT (Check ALL that apply):

NEW PROJECT CONTINUATION
RESEARCH STUDENT RESEARCH PROJECT
CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT
DISSERTATION OR THESIS

DISSERTATION/THESIS ADVISER, OR STUDENT ADVISER: Thomas Mohr

INvolves a
PROPOSED PROJECT: INvolves non-approved
USE OF DRUG INVOLVES NEW DRUGS (IND)

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 Valley Sports Medicine, Fargo, ND

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

Pending X

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) gastrocnemius, 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 psycho-logical, emotional or behavioral risk. If data are collected which could prove harmful or embarrassing to the subject if associated with him or her, then describe the methods to be used to insure the confidentiality of data obtained, including plans for final disposition or destruction, debriefing procedures, etc.)

The risks involved in this research project are minimal. The subjects may experience a tingling discomfort while the investigator is using the electrical stimulator to elicit a muscle contraction in order to locate the motor point of the muscle to be monitored. The EMG and video analysis equipment 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 2 years.

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

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

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

For EXEMPT or EXPEDITED REVIEW forward a signed original and a copy of the consent form, questionnaires, etc. and any supporting documentation to one of the addresses above.
The policies and procedures on Use of Human Subjects of the University of North Dakota apply to all activities involving use of Human Subjects performed by personnel conducting such activities under the auspices of the University. No activities are to be initiated without prior review and approval as prescribed by the University's policies and procedures governing the use of human subjects.

SIGNATURES:

Principal Investigator ___________________________ Date

Project Director or Student Adviser ___________________________ Date

Training or Center Grant Director ___________________________ Date

(Revised 3/1996)
APPENDIX C
**Hockey Treadmill Specifications**

**Figure 1:** Hockey Treadmill Specifications

### Hockey Treadmill

- **All Measurements in Inches**
  - **Speed Range:** 1 to 15 MPH
  - **Elevation Range:** 0 to 30% Grade
  - **Weight:** 4500 LBS., 2040 KGS.
  - **Power Requirements:**
    - 200-230 VAC, 3 Phase
    - 30 Amp Circuit
    - NEMA L1530 Plug Supplied
  - **Mfg. by Standard Industries, (701) 282-7550**
  - **U.S. Patent No. 5,385,520**
REFERENCES


