Electromyographic and Kinematic Analysis of Hockey Skating

Kari Jo Guttormson
University of North Dakota

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Electromyographic and Kinematic Analysis of Hockey Skating

by

Kari Jo Guttormson
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 Kari Jo Guttormson 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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Date 12-19-97
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Many thank yous go out to my friends, who made survival through physical therapy school a great deal easier. The last three years have been a true test in what friendship really means. Best of luck to you all!

I want to thank the Lord for blessing me with this opportunity to fulfill my dreams and continuing to “show me the light at the end of the tunnel” even when times were hard. There were many times when all that could be done was to pray.

Last, but not least, I would like to thank my family. The morals and beliefs you instilled in me are invaluable. Without your love and support, none of this would have been possible.
DEDICATION

I would like to take this opportunity to dedicate this project to a personal friend, Kathy Christianson. You believed in my abilities and gave me the confidence to pursue my dreams.
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.
Professional athletes are constantly looking for ways to improve their skills and abilities. If an athlete can become bigger, stronger, and faster, he will have a definite advantage over his opponent. This holds true for most competitive sports, including hockey.

Ice hockey is a high velocity and sometimes violent sport. The sport is characterized by short, intermittent bursts of speed and frequent changes in direction. During the course of a game, playing time is divided into shifts on the ice. Each shift is intense, all out skating that lasts from 30 seconds to 2 minutes. Play is followed by a 1-5 minute rest period. The average hockey player totals 17-28 minutes of playing time in a typical 60 minute game. As a result, hockey players must demonstrate cardiovascular endurance, for both anaerobic and aerobic demands, amongst other aspects of their sport including speed, agility, power, hockey skills, and proper skating biomechanics.

Hockey is a highly technical sport. There are so many components involved in playing the game that oftentimes, the primary skill of skating is overlooked. According to Greer, "The ability to accelerate quickly from a stationary or "gliding" position has been recognized as an important element of ice hockey performance." Skaters are able to increase their velocity by keeping a low body posture, which is horizontal in orientation,
and have their knees flexed allowing for a more effective push off and better leg propulsion.⁹ According to van Ingen-Schenau et. al,¹⁰ a non-horizontal trunk position will decrease the amount of speed generated with the same level of energy expenditure. With the ability to skate proficiently and at faster speeds, the athlete will get to the puck quicker, create more unbalanced offensive situations, and be more effective defensively.⁹ When enhanced skating velocity is combined with increased physical size and conditioning, today’s hockey players are much more powerful than their predecessors.¹¹

With the level of competitiveness in professional sports, athletes can ill afford to arrive at training camp without preparation. For many, training in the off-season is often the direct reason for their current successes. Just the same, individuals who display a high level of physical fitness and train specifically for their sport may be given that one chance they need to make the team.

Other advantages to optimal physical condition are preventing injury and countering the onset of premature fatigue. Injuries are inevitable with the sport of hockey because of the hard contact and strenuous, demanding play which occurs, especially at the professional level.⁸,¹⁶ Most injuries encountered in the sport are musculoskeletal in nature and are quite minor.⁸,¹¹ Typically, the majority of ice hockey injuries result from fatigue and occur as the game progresses.¹¹,¹⁴ Statistics indicate that 36 per cent of all injuries happen during the third period. There is a thirty per cent injury rate in the second period of play, while during the first period the rate decreases to 27 per cent.¹⁴ Sources report the most common site of injury is the knee, with injuries to the shoulder, groin, and low back less prevalent.⁸,¹¹,¹⁴ However, one study revealed that a hockey skater’s stride
involves such a forceful contraction of the hip adductors that the groin area is a predominant site for injury.\textsuperscript{14}

When a skater’s body fatigues, numerous physical and biomechanical changes occur, thus predisposing the athlete to injury. Most noticeably, the player’s skating technique will be affected. Indications for fatigue in the lower extremities and trunk in a hockey player include: the trunk is placed in a position of greater forward lean, the leg is in a more vertical position with less flexion at the knee, and the athlete is unable to maintain a low posture relative to the ice.\textsuperscript{9} This characteristic posture validates fatigue in the quadriceps, hip extensors and low back musculature.\textsuperscript{1}

In order to maintain performance and decrease the susceptibility to injury, athletes require fitness and conditioning programs that utilize sport specific methods.\textsuperscript{11,14,16} Agre\textsuperscript{8} et al. states that, “Ideally, each player’s program should be individually designed to correct specific deficits in the player’s profile in order to reduce the risk of injury and possibly enhance performance.”

In addition to decreasing the risk for injury, further benefits of proper physical conditioning are: 1) a decrease in rehabilitation time once injury has occurred, 2) maintenance of an athlete’s previous education of task performance, and 3) formation of a close positive bond between the athlete and the sport.\textsuperscript{18} Therefore, the major goal of off-season conditioning is to enter the season with the highest level of fitness possible.

Hockey training is a year round process. In order for the player to make gains and improvements, he must exhibit dedication and commitment during the off-season. If the athlete enters the season in prime physical condition, less time needs to be spent on getting into shape and more time can be devoted to perfecting the skills of the game.
including puck handling, passing, shooting, and body checking. The hockey training regimen must stress all areas of the game.

The chief problem hockey players encounter is the unavailability of ice time. It is impractical in many parts of the country to have an ice arena to train on all year long. As a result, many hockey players must look to alternative methods to improve or maintain their performance. The utilization of appropriate dry-land activities encompassed with on-ice training will allow the athlete to compete at higher levels and condition his body for the up-coming season.

Traditional training methods center around strengthening the involved muscles groups, improving muscle flexibility and cardiovascular endurance, and maximal performance of skill drills.\(^1\)\(^,\)\(^8\)\(^,\)\(^16\) Much of the dry land training is accomplished through the use of weight machines, plyometrics, running, biking, swimming, and aerobics. According to Hinrich,\(^1\) numerous methods have been developed to simulate the skating component, including low walking, dry skating, skate jumps, and slide boards but, the most specific training method to hockey is roller blading. The limitation of such training methods however, is that even with the most effective off-ice workouts,

“it is still virtually, impossible to duplicate the angles, power and frequency, as far as what the muscles are asked to do on the ice. Because skating is such a fluid sport...it has become almost effortless for them, the problem lies in the fact that weight machines and other devices use for rehab (and training) are actually too mechanical.”\(^1\)\(^17\)

This does not mean that these training methods should be excluded though. Since hockey is a game that combines high performance and technical skill, the various training
approaches will develop different aspects of the sport and make the athlete a “well-rounded” player.

Strength training is important to the hockey player for various reasons. The addition of muscle strength will help give the athlete more durability and protect him from injury, build power, and influence speed and agility. Weight training should not be overlooked because a primary factor determining the success of a hockey player is his ability to develop a great amount of muscular tension very rapidly. It must not be assumed however, that lifting weights and performing plyometric exercises will directly correlate with improved play. The specific adaptations to imposed demands (SAID) principle must be taken into account when establishing a weight training program. This theory states that training methods must be specific to the sport movement including velocity, contraction type, and contraction force. The body learns to adapt to the stresses placed on it. Since neural changes in the muscle itself are also involved with strength gains, strength must be developed taking into consideration the interrelation between the neural and muscular components of the muscle. Trained together, these aspects will meet the requirements involved with hockey. How well strength improves is influenced by the way the muscles are loaded. The goal of on and off-ice training should be the cultivation of muscle power at high speeds. Strength gains should not only be increased through a weight training program, but also dynamically through skating.

The performance of cardiovascular endurance activities to build stamina is crucial to limiting the number of injuries which may occur initially when the season begins. With the nature of the game of hockey, training for cardiovascular endurance must include exercises for the aerobic and anaerobic systems. The intermittent bursts of
activity build the anaerobic system while the periods of moderate activity draw on the aerobic system. The major source of energy is derived from the anaerobic system, which supplies the ATP for muscle contraction during the game. The recovery from maximal explosive movements must come from the aerobic system. Development of both systems will delay the onset of fatigue and limit the amount of lactic acid build-up. As a result, players can play longer shifts and more total minutes of a game. Energy utilization during the course of a hockey game greatly affect the player’s power output and skating velocity. According to two studies conducted by Green, there was a reduction of muscle glycogen, especially in the Type II (fast twitch) fibers during the third period of play. This is due to the constant change of tempo in skating and power output. When compared with continuous skating, Green observed a predominance of Type I (slow twitch) muscle fibers being activated. As a result, a relationship can be drawn between cycling and ice skating in regard to activity and energy depletion.

In addition to dry land training, a program conducted on the ice incorporating strengthening exercises, endurance building activities, and drills developing hockey skills should be organized. One source denoted the possibility that having “natural” hockey ability and skill may be of greater value than the “conditioning level.” Since skating is the ultimate hockey skill upon which all others are perfected, emphasis should be placed on proper skating mechanics during all drills. Hockey utilizes a unique type of speed skating called power skating. This type of skating involves attaining maximum speeds in the shortest amount of time. Power skating is non-rhythmic and explosive in nature and is depicted by repeated velocity and direction changes, short sprints, and rapid starts. Hinrich states that, "Muscular power (high velocity tension) is enhanced through high-
velocity training that may also improve output at slower velocities.” The reverse has not been proven scientifically and is not applicable, however. These findings reiterate the basis for the theory regarding training specifically for the sport the athlete is playing.

Due to the lack of obtainable training time on the ice, designing conditioning programs utilizing machines and devices becomes more critical. The goal of training or rehabilitation is to be as sport specific as possible. Movements associated with the skating stride are quite different from other activities. Training approaches must consider the joint angles and range of motion occurring in the trunk and lower extremities during the skating motion. For example, standard leg strengthening exercises are more conducive to running and jumping, activities involving vertical movements. The activities of cycling and roller blading utilize similar muscle groups and energy consumption in comparison to the sport of hockey. Despite the parallelism, cycling and various other forms of locomotion that involve propulsion of the lower extremities (running, cross country skiing) differ substantially in style, most noticeably the direction of push off, and average power output. Nonetheless, with the lack of well controlled scientific research regarding the game of ice hockey, there is little evidence and knowledge on what training methods are optimal. The only concept that can be agreed upon is that training specificity is imperative for successful performance of the elite athlete.

Most recently, an innovative device has been developed to possibly enhance off ice training in the hockey player. This device is the hockey treadmill. The philosophy behind the development of this piece of equipment is that it will be specific to the skating movement pattern exhibited on the ice. Benefits to this training method include the
player is able to use his own hockey skates, can stress the cardiovascular and musculoskeletal systems above the level they are accustomed to, ability to control the speed and elevation of the task being performed, the possibility of using resistance or sport cords for enhanced training, and the opportunity for the player to work on conditioning and skating fundamentals in a controlled environment with continued monitoring of the biomechanics of skating.\(^1\) According to Hinrich,\(^1\) although the coefficient of the treadmill is slightly higher in comparison with ice, the skating treadmill simulates the skating stride and physiologic demand on ice reasonably well. The results of his study report that muscle activation patterns were comparable between the treadmill and on ice in the rectus femoris, anterior tibialis, and the vastus medialis oblique muscles. Significant differences, however, were noted in the adductor longus, biceps femoris, gluteus maximus muscles. Possible explanations for such variances are that the treadmill is slightly elevated and the skating surface is moving under the feet rather than the feet moving over the ice as in hockey.

The hockey treadmill offers a new opportunity in training hockey players. With the ability to alter so many training variables, the possibilities are endless. The novelty of the training device leaves many research questions unanswered, however. Combined with the limited data on the game of ice hockey and the efficacy of various training methods, more scientific studies must be conducted to determine which factors enhance hockey performance or decrease the amount of rehabilitation time an injured athlete may experience.
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>
<th></th>
<th>MEAN</th>
<th>RANGE</th>
<th>STANDARD DEVIATION</th>
</tr>
</thead>
<tbody>
<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>
</tbody>
</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>
<thead>
<tr>
<th>Muscle</th>
<th>Measurements for Electrode Placement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectus Abdominus</td>
<td>2 cm superior and 2 cm lateral to umblicus</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 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). More muscle force is presumed to be required in order to maintain the same speed when skating on an incline. 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 increased energy demands required by the incline of the treadmill.

Trial One

Trial 1 displayed maximal rectus femoris activity just prior to 50 percent of the skating cycle. During this same period, the knee joint was moving into extension. It is hypothesized that the rectus femoris muscle elicits peak activity level during this phase of the skating cycle because it is concentrically contracting to extend the knee at push off.

The maximal gluteus maximus activity also occurs at approximately the same time as the maximal rectus femoris activity. The hip is extending as the knee is extending, and the least amount of trunk flexion takes place just after the gluteus maximus contracts maximally. The gluteus maximus muscle probably works synergistically with the rectus femoris as the hip and knee both extend at push off. The
gluteus maximus is also active at the very end of the stroke, and most likely functions eccentrically to control hip flexion.

The biceps femoris has the majority of its activity from 42-62% of the stroke. Activation occurs just after the firing of the rectus femoris, presumably to extend the hip in conjunction with the gluteus maximus.

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

Maximal rectus abdominus activity occurs after the contractions of the hip and knee musculature. The peak occurs at the point just prior to the minimum angle of trunk flexion, where it may be functioning in controlling trunk extension. We speculate the moderate activity takes place at the very end and beginning of the stroke to stabilize and prevent a lateral tilt of the trunk and pelvis during push off and initial contact.

Two peak periods of activation were present in the erector spinae. The first occurred as the trunk was preparing for initial contact, presumably to help steady the trunk. This activity coordinated with the stabilizing activity of the rectus abdominus.

The second maximal level of activity occurred around push off. We suggest this is due to a concentric contraction of the erector spinae, which assists in extending the hip.

**Trial Three**

During trial 3, the maximal activity of the rectus femoris and biceps femoris occur earlier than in trial 1. The increased activation seen at the beginning and end of the stroke
are most likely due to the increased push off force required to propel the skater up the incline and the increased need for eccentric control of flexion and extension.

The gluteus maximus is maximally contracting for a greater period of time in trial 3 versus trial 1, for the first half of the skating cycle. Because the trunk is in a greater degree of flexion during this phase, we hypothesized that the gluteus maximus helps hold the trunk and pelvis in a flexed position. The increased contraction will supposedly allow greater force during push off to propel the skater on an incline as well. There is also another maximal contraction that occurs at the end of the stroke. Presumably to eccentrically control the hip flexors at the end of swing through.

The adductor longus is active during the portion of the stroke that occurs just following push off, most likely to assist in the initiation of swing through. A longer maximal contraction of the rectus abdominus occurs during trial 3. This is presumably because of the increased need for more trunk stability at push off when skating on an incline.

The erector spinae is activated at a later point in the skating cycle in trial 3. This occurs when the trunk is flexing for initial contact and 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

Although there was more overall muscle activity in trial 3 versus trial 1, the time the muscle was activated between the trials was similar in the rectus femoris, biceps femoris and rectus abdominus. Slightly different muscle recruitment levels were found in the adductor longus, gluteus maximus and erector spinae.
The adductor longus showed an increase in activity in midcycle in trial 3, whereas the main period of activity in trial 1 occurred during the first ten percent of the cycle. We hypothesize the rationale for this difference is the increased extension that occurs in the hip on an incline. This causes the adductor musculature to assist the hip flexors in the beginning of swing through phase. At 0 percent incline, we presume that the hip flexors are the primary flexion force for swing phase in the hip. However, despite the differences in the portion of the cycle the peak level occurs, activation pattern between both trials for the adductor longus was comparable.

The gluteus maximus was also activated during the same portions of the skating cycle between the two trials, but differed in the peak duration. We hypothesize the reason is the increased activity needed to maintain trunk flexion and propulsion during incline skating.

We theorize that the erector spinae differed in its muscle pattern because of the 30 percent incline. In trial 1, more activity was needed to help extend the hip, whereas in trial 3, controlling trunk flexion required the greater activity.

There are very few studies discussing the biomechanics of the skating cycle in relation to the hockey athlete. Much of what is known about the technique of the hockey stride is adapted from speed skating techniques. For instance, speed skaters tend to maintain a more horizontal trunk, which allows for increased velocity.\textsuperscript{12,13} Hockey players use the same technique to achieve maximal bursts of speed and power skate. We propose that this could be one reason that there was an increase in the amount of activity seen in the erector spinae for trial 3. Despite the fact that the speed was constant between trials, a greater propulsive force was needed to achieve the same velocity. Therefore,
holding the trunk angle becomes increasingly important. Also, to assist in understanding the muscle recruitment patterns of hockey athletes, comparisons are typically made with the biomechanics that occur during the skating cycle of speed skaters. During the push off portion of the stroke, the gluteus maximus and vastus medialis provide the extension force for propulsion in speed skating. Hockey players also use a powerful extension thrust at push off.

One study in particular, done by Hinrich, compares hockey athletes skating on the treadmill and on ice. A valid comparison between this study and his was unable to be made because the criteria used to signal muscle activation differed. However, there were some similarities in the recruitment patterns between trial 1 in this study and in the study by Hinrich. In general, the gluteus maximus, biceps femoris, and rectus femoris were all active primarily in the first half of the skating cycle. Hinrich also concludes that treadmill skating at the lowest incline, and skating on ice simulate each other "reasonably well." There was no significant difference in muscle recruitment for the rectus femoris. However the biceps femoris, gluteus maximus and adductor longus showed significant differences in muscle activity at medium and high speeds of 8.7 Mph and 10.3 Mph.

Various other studies have tried to equate hockey with other activities such as cycling, jumping, and running. Limitations tend to arise, however, when the methods of propulsion, including the joint angle of motion, are paralleled. Studies of running and walking on a treadmill are also not very comparable to skating on a treadmill because the force of propulsion takes place in different planes. Skating requires a push off force to be horizontal, where as running and walking utilize more vertical forces. The intensive
push off force used in skating also uses patterns of muscle activity that are rarely recruited in cycling, running, or rowing actions.\textsuperscript{16,19}

\textbf{Limitations}

There are several limitations present in this study which could have influenced the outcome of our results. First, only five subjects could be analyzed. Future studies should collect data from a larger group of skaters in order to create a more accurate and valid representation of the muscle activity that occurs during the skating cycle. The skating skill of the subjects was another limitation. Some skaters had limited experience skating on the treadmill and this could have influenced the muscle activity patterns. Also, due to a space constraint, the camera used to capture the kinematic data was unable to be positioned at a perpendicular angle to the skater. Although the angles are satisfactory when compared inside the study, a comparison with angles taken at a 90 degree angle to the skater’s sagittal plane may yield some differences. Another limitation was the fact that the foot switch became faulty as the last two subjects were tested. The foot switch remained on for the all of the skating cycles recorded. Using video analysis, manual markers were added to the videotape by computer, but may not be 100 percent accurate.

\textbf{Conclusion}

The amount of muscle activity demonstrated an overall increase in amount and duration in trial 3 in comparison to trial 1. However, the periods during the skating cycle when the muscles became maximally active were similar in all muscles except for the adductor longus and erector spinae.
Clinical Implications

The results from this study will enable the biomechanics of the hockey skating cycle to be better understood. The information regarding the level of muscle activity and recruitment patterns during incline skating will assist in developing training and rehabilitation techniques for the hockey skater.
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 by the investigator. The investigator or participant may stop the experiment at any time if the participant is experiencing discomfort, pain, fatigue, or any other symptoms that may be detrimental to his/her health. Your decision whether or not to participate will not prejudice your future relationship with the Physical Therapy Department or the University of North Dakota. If you decide to participate, you are free to discontinue participation at any time without prejudice.
The investigator involved is available to answer any questions you have concerning this study. In addition, you are encouraged to ask any questions concerning this study that you may have in the future. Questions may be asked by calling Dr. Thomas Mohr at (701)777-2831. A copy of this consent form is available to all participants in the study.

In the event that this research activity (which will be conducted at 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
APPENDIX B
REPORT OF ACTION: EXEMPT/EXPEDITED REVIEW
University of North Dakota Institutional Review Board

NAME: Thomas Mohr, Kari Guttormson, and Michelle Fox

DEPARTMENT/COLLEGE: Physical Therapy

PROJECT TITLE: Electromyographic and Motion Analysis of Skating

DATE: June 12, 1997

PROJECT NUMBER: IRB-9706-284

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.

T. Mohr, Adviser
Dean, Medical School

Signature of Designated IRB Member
UND's Institutional Review Board

Date

If the proposed project (clinical medical) is to be part of a research activity funded by a Federal Agency, a special assurance statement or a completed 310 Form may be required. Contact ORPD to obtain the required documents.

(3/96)
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,

John Frappier
President

John Frappier
President
X_EXPEDITED REVIEW REQUESTED UNDER ITEM 3 (NUMBER[S]) OF HHS REGULATIONS

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

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

PRINCIPAL
INVESTIGATOR: Thomas Mohr, Kari Guttormson and Michelle Fox TELEPHONE: 777-2831
DATE: 6/11/97

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

PROPOSED SCHOOL/COLLEGE: School of Medicine & Health Sciences DEPARTMENT: Physical Therapy
PROJECT DATES: 7/15/97 to 7/15/98 (Month/Day/Year)

PROJECT TITLE: Electromyographic and Motion Analysis of Skating

FUNDING AGENCIES (IF APPLICABLE): none

TYPE OF PROJECT (Check ALL that apply):

--- NEW PROJECT --- CONTINUATION
--- STUDENT RESEARCH PROJECT --- RENEWAL --- THESIS

--- CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT

DISSERTATION/THESIS ADVISER, OR STUDENT ADVISER: Thomas Mohr

INVOLES NON-APPROVED

PROPOSED PROJECT:
--- USE OF DRUG
--- INVOLVES NEW DRUGS (IND)
--- COOPERATING INSTITUTION

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

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

--- PRISONERS
--- ABORTUSES
--- UND STUDENTS (>18 YEARS)

IF YOUR PROJECT INVOLVES ANY HUMAN TISSUE, BODY FLUIDS, PATHOLOGICAL SPECIMENS, DONATED ORGS, 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

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 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 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

Project Director or Student Adviser

Training or Center Grant Director

(Revised 3/1996)
APPENDIX C
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


