THE EFFECT OF AN EIGHT SESSION SKATE TREADMILL AND AGILITY TRAINING PROGRAM ON THE DEGREE OF SEPARATION IN ICE HOCKEY PLAYERS

Daniel J. Harriss

Submitted in partial fulfillment of the requirements

for the degree of Master of Science in Applied Health Science

Supervisor: Kelly L. Lockwood, Ph.D.

Faculty of Applied Health Sciences

Brock University

St. Catharines, Ontario

Abstract

The sport of ice hockey places multiple simultaneous demands on the physiological, mechanical, and cognitive abilities of individual players. The purpose of the study was to investigate the effect of an eight session degree of separation (DOS) training intervention on sport specific measures of skating, stick handling and puck control movements in competitive ice hockey players. All participants completed a battery of pre and post skill and DOS specific tests designed to evaluate DOS abilities: T-test of agility, a modified Cunningham Faulkner test of anaerobic capacity performed on a skate treadmill and a DOS skate treadmill test. Statistically significant differences were found between groups on the post test scores, meaning that the training intervention had a specific effect on the post test scores of the experimental group ($p \leq 0.05$). Results of this investigation suggested that a DOS specific training program has the potential to enhance the integration and automation of or sequencing and coordination of uncoordinated ice hockey movements.

ACKKNOWLEDGEMENTS

It has been a long road traveled over the last few years filled with many highs and of course some lows. With great pride, I can say now that the trip has come to an end, and I could not have made it through if it were not for the great group of people I met along the way.

I would first like to thank Dr. Kelly Lockwood for taking me on as a grad student and giving me an experience well beyond a Masters degree. We have had a great time over the last few years working with professional teams, national sport organizations, traveling to conferences, opening up new skate labs and how can I forget building decks and fences! Kel as I have said before, I don't think I could have done this without you and I want to thank you for giving me the opportunity to complete a Master of Science.

I would like to thank my committee Dr. Phil Wilson and Jae Patterson for all of their support and input, not only for this study but at Brock in general. Also I would like to thank my external examiner Dr. Michael Kennedy for making the trip out from Alberta, and his contribution to the final document.

The skate lab group Brent, Andy and my partner in crime Briar. Briar we started this little trip together and you have been a great friend along the way. I am truly going to miss working with you in the lab.

Mom and Dad - I am really not sure how to put it in words, but you guys are the best. You have given me nothing but love and support over my extended school career! I cannot thank you enough for all that you have done.

And lastly I would like to thank Courtney. You joined me halfway through my trip and I just can't explain how you make me feel, you are my best friend and you mean the world to me. Now that this trip has come to an end, I just can't wait to jump on the open road ahead and get started on our next adventure together!

Table of Contents

List of Figures

List of Tables

CHAPTER 1: INTRODUCTION

The sport of ice hockey places multiple demands on the physiological, mechanical and cognitive abilities of individual players in a synchronized nature. At the elite levels of play, athletes are required to intuitively forecast and react to game play while performing complex mechanically based tasks at intense levels of physical exertion. Typical mechanical tasks in ice hockey include skating, shooting, stick handling and puck control. What makes the tasks complex is the uncoordinated, yet sequenced and instantaneous nature of their execution. Furthermore, decisions with regard to task execution are made in response to a given stimuli during real time. The time, strength and speed of the task execution not only adds to the difficulty, but also heightens or elevates the level of performance. Addressing the ways that hockey players can develop skills requires an in-depth understanding of the integration and automation of the three coordinated training systems: physiological, mechanical and cognitive. Despite the fact that, the demands of the game have been investigated and detailed by many (Twist and Rhodes, 1993; Cox, Miles, Verde and Rhodes, 1995; Montgomery, 1988; 2000; Burr, Jamnik, Baker, Macpherson, Gledhill, and McGuire, 2008) and player profiles have been tracked longitudinally (Montgomery, 2006; Quinney, Dewart, Game, Snydmiller, Warburton and Bell, 2008), studies investigating optimal training methodologies for integrating systems are limited. Traditional training regimes for ice hockey have focused primarily on isolated physical systems. For example, improving the strength (Greer, Serfass, Picconatto and Blatherwick, 1992; Pan, Campbell, Richards, Bartolozzi, Ciccotti, Snyder-Mackler, and Waninger, 1998) and power (Fergenbaum and Marino, 2004; Lockwood and Brophey, 2004; Reyment, Bonis, Lundquist and Tice, 2006; Farlinger and

Fowles, 2008). Although these are necessary foundations to physical aspects of ice hockey training and performance, the application of these results in isolation and the translation to performance is limited, as they fall short of training integrated systems to simutaneously meet demands of the game. Cook (2003) claims that, "athletes need it all and they need it all together" (pg.5), suggesting that training systems in isolation is not the best practice in order to optimize game performances. For the purpose of this study, the integrated systems or degree of separation (DOS) could be defined as, the players' ability to simultaneously skate, shoot, stickhandle, control the puck and read and react to the play.

Literature outside the sporting realm has identified the process of taking individual units of information (i.e. chunks) and grouping them into larger units as the chunking theory (Chase and Simon, 1973). Although it appears to be applicable to sport, there has been limited application of the chunking theory to sport training, technical analysis, and sport performance. In the sport of ice hockey, it would seem that coupling upper and lower body movements or a proposed method of chunking of sport specific tasks, (i.e. skating, shooting, stick handling, puck control and the reading or forecasting of the play) is by definition, an optimal example that requires further investigation.

Preliminary investigations conducted in our laboratory have explored the concept of 'chunking' as a part of training the sport of ice hockey and further defined the assessment and training of sequenced yet uncoordinated tasks of sport or game demands as degree of separation (DOS) (Harriss, Piper and Lockwood, 2007). In hockey, the combined skills of lower body (skating) and upper body (stick handling and puck control) sport specific movements, performed simultaneously however at different or varying cadences and frequencies is an isolated example of DOS. Based on this work, the following study was conducted to further examine the effectiveness of a novel DOS specific assessment and training protocol in a cohort of competitive ice hockey players.

1.1 Purpose

The purpose of the study was to investigate the effect of an eight session DOS training intervention on sport specific measures of sequenced yet uncoordinated sport specific movements of lower body (skating) and upper body (SPC) in male, Major Bantam and Minor Midget AAA ice hockey players (n=26).

1.2 Null Hypothesis

There will be no effect of the prescribed DOS training intervention on the sport specific measures of sequenced yet uncoordinated sport specific movements of lower body (skate) and upper body (SPC) in male Major Bantam and Minor Midget AAA ice hockey players (n=26).

There will be no effect on the sport specific measures of sequenced yet uncoordinated sport specific movements of lower body (skate) and upper body (SPC) between the experimental and control groups (n=26).

1.3 Alternative Hypothesis

There will be an effect of the prescribed DOS training intervention on the sport specific measures of sequenced yet uncoordinated sport specific movements of lower body (skate) and upper body (SPC) in male Major Bantam and Minor Midget AAA ice hockey players (n=26).

There will be an effect of the prescribed DOS training intervention on the sport specific measures of sequenced yet uncoordinated sport specific movements of lower body (skate) and upper body (SPC) between the experimental and control (n=26).

CHAPTER 2: REVIEW OF LITERATURE

2.1 Demands of the Game

Ice hockey is a game that requires the precise coordination of hockey specific skills; these skills are executed under a variety of situations, high speeds and frequently in the presence of intimidation and interference by the opposition (Green, 1994). Technical skills such as skating, shooting, puck control and passing in the sport of ice hockey are often sequenced or performed at the same time. These skills are evaluated by scouts, coaches and experts alike, and are used to define a player's ability. Beyond technical ability, a player's hockey sense or athletic intelligence is also highly considered in the evaluation process. Hockey sense includes play making ability, decisions under pressure and versatility of the individual within game situations (NHL Central Scouting, 2009).

During a game of ice hockey, the physiological demands placed on the player can vary from several seconds to upwards of two minutes resulting in 20 to 30 minutes of total work performed per game. A player's total energy output varies depending on not only the time on the ice and position played, however the intensity that the individual works at. Due to high intensity bursts of energy over short periods of time, physiological profiles in ice hockey have identified the anaerobic system as the main energy system used by ice hockey players (Green, 1979; Green, 1994; Arnett, 1996; Montgomery, 1988, 2000; Twist and Rhodes, 1993; Cox et al., 1995; Green, Pivarnik, Carrier and Womak, 2006). Positional profiles also suggest that defensemen have longer shifts on average and play more of the game (Montgomery, 1988, 2000; Twist and Rhodes, 1993). Typically they also skate slower and have less time between shifts to recover, making the reliance on the aerobic system for recovery greater in defensemen compared to forwards (Twist and Rhodes, 1993; Cox et al., 1995; Geithner, Lee and Bracko, 2006 and Quinney, Dewart, Game, Snydmiller, Warburton and Bell, 2008). Furthermore, overall fatigue in ice hockey is attributed to energy expenditure of the lower body required to skate combined with the high intensity upper body movements of shooting, stick handling and body contact (Green, 1979; Twist and Rhodes, 1993; and Cox et al., 1995).

2.2 Predictors of Performance

Off-ice physiological measures in the sport of ice hockey have traditionally been used to assess physical characteristics, anaerobic power and capacity, strength and muscular endurance and flexibility (Montgomery, 2000). Typical physiological measures used for the assessment of draft eligible ice hockey players are: height, weight, body composition, anaerobic capacity, power, upper body strength/endurance, core strength/endurance and trunk flexibility (Gledhill and Jamnik, 1997; Montgomery, 2000). Isolated attempts have been made to predict or profile on ice performance from traditional physiological measures (Mascaro, Seaver, and Swanson, 1992; Bracko and George; 2001; Behm, Wahl, Button, Power and Anderson, 2005; Farlinger, Kruisselbrink and Fowles, 2007; Burr, Jamnik, Baker, Macpherson, Gledhill, and McGuire, 2008). For example, the Wingate test is a traditional measure of the individual's anaerobic power and capacity. Studies conducted by Montgomery (2000) and Farlinger et al. (2007) investigated the relationship between mean power and mean peak power assessed by the Wingate and on ice skating speed, assessed by both the Repeat Skate Sprint (RSS) test and a 35 m skate sprint test. Montgomery (2000) found significant correlations between the off and on ice measures of mean and peak power ($r = 0.87$, $p \leq 0.05$) ($r = 0.78$, $p \leq$

0.05). Farlinger et al. (2007) also found significant correlations between off and on ice measures of relative mean power and peak power generated by the Wingate and an on ice skating sprint over a distance of 35 m ($r = 0.73$, $p \leq 0.001$) ($r = 0.71$, $p \leq 0.001$). Leg power, assessed by the vertical jump test has also been correlated with on ice performance. Mascaro et al. (1992); Bracko and George (2001); Farlinger et al. (2007) found significant correlations between the vertical jump height and skating speed, acceleration and on ice anaerobic capacity in male and female, novice to elite level ice hockey players ($r = 0.62$, $p \leq 0.05$) ($r = 0.71$, $p \leq 0.001$).

Further to the studies investigating physiological contributions, Trepanier (1998) and Montgomery (2000) suggested that on ice assessments should contain a technical component to more completely measure the ability and skill component of ice hockey players in addition to the physiological measure. Merrifield and Walford (1968) revealed that, an on ice puck carrying test, consisting of 7 pylons which the subjects were required to weave through while skating and carrying a puck, was the strongest predictor of overall ice hockey ability in novice level players. Although Merrifield and Walford (1968) and Montgomery (2000) suggested that the addition of a technical component is a stronger predictor of an ice hockey player's overall performance ability, several on ice skill tests have not been validated and normative values for comparison have not been published. In summary, past research suggests that the anaerobic system is the primary system contributing to the physiological demands of the game of ice hockey with the lower body being the principal cause of fatigue within the system. In general, these studies support the use of both on and off-ice testing to predict isolated on ice performance measures, however fall short of predicting game performance or addressing the complete (i.e. physiological, mechanical and cognitive) demands of the game.

2.3 Traditional Training Practices

Building both upper and lower body strength and power through resisted weight and plyometrics training are the primary focus of dryland programs used by ice hockey coaches and trainers (Montgomery, 2000). In a study conducted by Greer, Serfass, Picconatto and Blatherwick (1992) participants completed a hockey specific strength training program consisting of both resisted weight and on ice training. The off-ice training focused on developing lower body strength, while the on ice program emphasized speed. Results of the program suggested that, a hockey specific program consisting of dryland strength training and on ice training can significantly improve vertical jump height, on ice acceleration, top speed and cornering in Bantam level ice hockey players.

Traditionally plyometric exercises have been used to develop explosive power in ice hockey players. Reyment, Bonis, Lundquist and Tice (2006) found that a 4 week ice hockey specific plyometric program had a significant effect on overall power endurance and single leg vertical jump. Lockwood and Brophey (2004) found that a lower body plyometric program had a significant effect on skating speed measured by a 40 m on ice sprint, in junior level ice hockey players. Farlinger and Fowles (2008) found that a skating specific plyometric program improved on ice sprint performance. The program designed by Farlinger and Fowles (2008) mimicked the actions and muscle involvement related to the biomechanics of the skating stride. Fergenbaum and Marino (2004) and Pan et al. (1998) tested the effect of an upper body strength and plyometric program on upper-body isometric strength, stick velocity and puck velocity of the slapshot. Results of these studies suggest that an upper body strength and plyolometric program had a significant effect on stick velocity and puck speed. Furthermore, Fergenbaum and Marino (2004) found that upper body plyometrics significantly improved ballistic coordination between the upper and lower limbs in ice hockey players. Traditional training methods of strength training and plyometrics have shown a positive result on isolated specific ice hockey skills such as; skating speed, puck velocity and puck speed. However, these studies did not integrate or combine the performance of the skills as executed in game play. Furthermore, limited research has attempted to integrate the coordination of training the physiological, mechanical and cognitive systems involved within the sport of ice hockey.

2.4 Coordination of Skills

In the sport of ice hockey, players demonstrate high levels of coordination by completing sport specific movements such as skating, controlling a puck and reacting to game play all in one motion. As identified by Davids, Araujo, Shuttleworth and Button, (2005) a significant number of components contribute to the coordination of athletic movement(s), it is these interactive parts that combine and form coordinative structures. The number of components or motor systems involved in the movement(s) in which an individual carries out relates directly to the complexity of the task. In early stages of development the body develops preferred or stable coordinative states. These stable states are the foundation that complex or goal directed actions in sport are built on. (Turvey, 1990; Davids, Araujo, Shuttleworth and Button, 2005). Furthermore, Davids et al. (2005) suggested that, athletes have an ability or flexibility to actively exploit their stable states in order to solve problems within the environment.

Sommer (2005) identified that the sport of ice hockey requires the bimanual coordination of limbs (Sommer, 2005). However, there is a stronger display of bilaterality in the lower body when turning and using the lead foot for stopping, versus the upper body and the use of the left or right hand(s). Sommer (2005) stated that as a player gains more experience, the individual will achieve a level of automatism within the individual skill of skating. This is identified, as a skill appears to become a fluid component of the action (Boyle and Ackerman, 2004). In the case of ice hockey, the sequencing of skating paired with puck control is two individual skills that are executed as one continuous movement. As the two skills are carried out across different planes of motion (frontal and sagittal), it can be identified as a complex movement requiring the coordination of multiple systems to carry out the movement successfully. In addition to the success of the sport specific movement(s), players have been identified to successfully change the speed, direction and position in which the movements are completed based on the development of the play.

Limited research has been conducted in the area of sport and the coordination of movements within a game setting, more specifically the coordination of the lower body (skating) movements and the upper body (stick handling and puck control) movements in ice hockey.

2.5 Development of Expertise

With continued exposure and practice, an ice hockey player's skill development progresses and select abilities are refined due to the demands of the game. The exposure to the environment and relatively similar situations allows a player to develop strong links to reoccurring situations (Raab and Johnson, 2007). These links have been identified as chunks; pieces of information that are grouped and stored in the long term working memory (LT-WM) (Chase and Simon, 1973).

Studies carried out by Helson and Starkes (1999); Ward and Williams (2003) and Raab and Johnson (2007) revealed that in a sport setting, the comparison of expert and near expert soccer players and handball players, experts displayed a greater ability to rapidly execute the correct decision versus non experts. Furthermore, Martell and Vickers (2004) found that in a comparison of elite and near elite ice hockey players, that elite level players were able to select and identify key points of a game situation and in turn showed faster more accurate response times, both with and without pressure. These results support the development and progression of expertise. The primary focus of the past research has been on the speed and accuracy of the decision that is carried out by experts and near experts. Little research has looked at the stability of a skill under game like situations, more specifically the skill of skating and controlling a puck in the game of ice hockey.

2.6 Summary

Traditional practices of testing and training in the sport of ice hockey are well documented. However, traditional testing and training of independent systems in isolation fail to address the complete demands of the game and abilities of the players. A limited amount of research has been conducted investigating the testing and training of integrated systems (i.e. physiological, cognitive and mechanical) as required by ice hockey players. Furthermore, as the game of ice hockey evolves, testing and training of ice hockey players must also evolve to be able to accurately profile their abilities and potentially predict potential game performance. This study attempted to address some of the challenges associated with testing and training the integrated systems of the lower body (skating) and the upper body (stickhanding and puck control) movements of ice hockey players, superimposed by the cognitive demands in the game of ice hockey.

CHAPTER 3: METHODOLOGY

3.1 Participants

Sixteen male (n=16) Major Bantam and Minor Midget AAA ice hockey players, mean age of 14 yrs. and ten male age matched controls (n=10), mean age 14 yrs. were recruited to participate in the study (Table 3-1.). All participants were recruited based on age, level and ability (i.e. Minor Novice {level}, AAA {ability}) from local teams in the Ontario Minor Hockey Association (OMHA). Recruitment was limited to players in the positions of forward and defence who were free of any injury and had previous exposure to skate treadmill training. More specifically, participants had completed a minimum of four skate treadmill sessions prior to participating in the study. Subjects were restricted from any other training programs beyond their scheduled on ice practices and ice hockey games, to ensure that no other uncontrollable variables would impact the outcome of the study. All participants were required to complete consent forms (if under 18, parental consent forms were required to be completed) prior to the initiation of the study (Appendix A). The study was approved by the Research Ethics Board of Brock University prior to data collection (File #08-268).

3.2 Study Design

A quasi experimental design method was used to investigate the effectiveness of a DOS specific skate treadmill and agility training program on the specific measures of sequenced yet uncoordinated sport specific movements of lower body (skating) and upper body (stickhandling and puck control). Both groups completed a pre and post battery of tests, scheduled a minimum of four weeks apart. The experimental group received two 90-minute training session per week for four weeks with a minimum of 48 hrs between training sessions. Each training session included: 45 minutes of skate treadmill and 45 minutes of Speed, Agility and Quickness (SAQ) training over the allotted four week training period. During the four week training period, both groups were restricted from participating in any other dryland training programs, however, were permitted to participate in regular on ice practices and games during the study. Total duration of the study was six weeks.

3.3 Testing Protocol

Familiarization to testing and training protocols was completed prior to the initiation of the test battery to ensure that all participants understood what was involved in each testing and training session. The test battery included anthropometrics, a cognitive baseline measure and both dryland and treadmill tests. Due to the intensity of the testing, the test battery was conducted over two days. Prior to each testing session, the participants performed a standardized warm up consisting of 500 skips.

3.4 Dryland Tests

Anthropometric measures: Height (cm.), weight (kg.) and player demographics detailing years of experience (yrs.) playing ice hockey, handedness (R, LT), position (forwards, defense) were recorded. (Appendix A).

Cognitive Baseline Measure: A cognitive baseline measure was completed and recorded during the pre test only. A pen and paper instrument was used to establish how well the participants were able to answer ice hockey related questions without the added distraction of skating, stick handling and puck control as required by the DOS tests. The participants were presented with ice hockey related questions in the same format as the cognitive measure used in phase II of the DOS test.

T-Test: The T-Test is a measurement of agility that combines forward, backward and lateral movement into one movement pattern. Participants were instructed to run a 'T' pattern as fast as possible (Figure 3-1.). Timing lights (HL 610 Training, Tag Heuer Professional Timing. Marin, Switzerland) were used to measure total time {measured in seconds (s)}. Time started when the participant initiated their first forward movement through the timing lights and stopped when subject crossed the finish line. Participants completed three trials with a 3 minute rest period between each trial. Verbal encouragement was given by the trainer as the participant completed each trial. The best of the three trials was recorded.

3.5 Skate Treadmill Tests

The skate treadmill tests were completed on a skating treadmill. Due to the intensity of the treadmill tests, the Cunningham Faulkner (CF) skate treadmill test was performed on the first day of testing and the Degree of Separation (DOS) Skate Treadmill test was conducted on the second day, separated by 48 hours of rest. During both skate treadmill tests, participants wore their own ice hockey skates sharpened to their own specifications and used their own hockey stick. Prior to accessing the treadmill, subject's were fit with a climbing like harness, and then harnessed to an overhead safety gantry. Safety and procedural instructions were provided to prevent any chance of injury to the athlete while on the skating treadmill.

Cunningham/Faulkner (CF) Skate Treadmill Test: A modified Cunningham Faulkner (CF) test was performed on the skate treadmill to assess anaerobic capacity (Cunningham and Faulkner, 1969). Protocol for the CF on the skate treadmill consisted of a warm up, familiarization to the test intensity followed by actual CF test. Skating speed was set at 16 kmph with the skate treadmill at an incline of 16 degrees (Table 3-2.). Participants were instructed to skate until exhaustion. The total length of time (measured in seconds) the participant was able to skate without assistance was recorded. Time was measured using a stopwatch, time started when participant removed their hands from the safety bar and stopped when the participant grabbed the safety bar or they stopped skating.

Degree of Separation (DOS) Skate Treadmill Test: The ability to sequence the uncoordinated lower body (skating) and upper body (SPC) paired with a cognitive measure was assessed using a DOS Skate Treadmill test. Participants were required to skate on the treadmill at a constant speed of 9 kmph and at an elevation of 2.5 degrees while maintaining control of the puck carrying it over a defined distance to a graded cadence as set by a metronome (Weird Metronome version 1.4 for Windows, 2008). Skating speed was pre determined to match the ability of the cohort of participants. Cadence of puck control started at 60 Hz and increased by 30 Hz after each 20 second interval. Puck control distance was set at 25.5 cm with a 15.01cm offset to the forehand and 10.49 cm offset to the backhand for both left and right handed ice hockey players. This distance was pre determined as the minimum distance that the puck traveled during normal puck control movements and remained constant throughout the test. Coloured lines were placed on the puck control platform as a visual guide to indicate the set distance the participant must carry the puck (Figure 3-2.).

Prior to the start of the DOS test participants completed a standardized skate treadmill warm up (Table 3-3). The DOS test consisted of two phases, each phase included eight - 20 second skating intervals with a work to rest ratio of 1:5. During phase

I, puck control cadence was initiated at 60 Hz (Table 3-4.) and increased by 30 Hz with each additional interval. Intervals 1 through 8 became progressively more challenging as the rate of puck control increased. Test failure was defined by three criteria: skate, puck control and/or cognitive failure as described below:

(i) Skate failure was defined as the participant's inability to maintain the skating rate set by the speed of the skate treadmill. This was identified by a break in the stride by a) stutter step, b) an over exaggerated delay between strides or c) and/or the stoppage of the feet all together.

(ii) Puck control failure was defined as the participant's inability to control the puck to a defined frequency, puck handling within the minimum width on two successive occasions or the complete loss of control of the puck.

(iii) Cognitive failure was identified only in phase II of testing by an incorrect response or the set time to answer has elapsed to a proposed question or illustration presented to the participant.

Failure point was recorded as the last successful interval completed. The athlete was permitted to complete all stages even if failure was identified at an early stage in the test. All test trials were recorded by a video camera (3CCD Mega O.I.S, Panasonic Canada Inc.), capturing the frontal view of the participants. A review of the video footage was used to confirm the failure of the interval.

Phase II of the DOS test followed the same protocol as phase I (Table 3-4.), however included a cognitive component. The protocol for phase II of the DOS test was initiated at 50% of the failure point recorded phase I. For example, if the participant completed 6 intervals in phase I, phase II would initiate at interval 3. In addition to maintaining skating speed and puck control to a graded cadence of 30 Hz per 20 second intervals, participants were also challenged by a cognitive task of answering ice hockey related questions such as penalty descriptions, identifying game situations, play options and number of players on the ice represented by illustrations. This was facilitated using a power point (Microsoft Power Point 2007, Microsoft Corporation) presentation projected on a large screen in front of the treadmill. At the beginning of each interval a slide with the description 'Skate Now' was displayed for five seconds. This allowed the participant to familiarize themselves with the set cadence of skating and puck control. The second slide displayed a question for five seconds, followed by an illustration of the question projected for the remaining fifteen seconds. Participants were required to answer the question to the best of their ability within the allotted fifteen seconds. A final slide appeared displaying 'Time', signaled the end of the interval and for the next participant to get on the skate treadmill. Correct responses were recorded. Slides were randomly selected from three slide shows, each containing 110 slides (A, B and C) to ensure that participants had not viewed questions presented to a previous skater or received the same question twice.

3.6 Training Protocol

Training sessions were scheduled twice a week for four weeks separated by a minimum of 48 hours rest between each training session. Sessions were 90 minutes in duration and consisted of a standardized warm up (500 skips), 45 minutes of skate treadmill training and 45 minutes of DOS specific agility training. For the purpose of training, the experimental group was sub divided into three groups of six athletes. This allowed for training sessions to maintain a work rest ratio of 1:5 during all skate treadmill sessions. Treadmill and agility training regimes are detailed below.

Skate Treadmill Training: The purpose of the DOS skating treadmill program was to introduce and train skills designed to improve the sequencing of the lower body (skating) and upper body (SPC). Movement skills and drills were age and ability appropriate and sport specific skill drills. Participants completed 10-14 repetitions ranging in duration from 5 – 45 seconds of intermittent training per session. Skating speed and incline, in combination with simple versus complex sport specific movements, provided a progressive training load through sessions 1 to 8.

Agility Training: The purpose of the agility program was to introduce and train sequencing of the lower body (skating) and upper body (SPC) through both upper and lower body speed, agility and quickness drills (SAQ). Dryland agility sessions included 8 upper and lower body speed, agility and quickness (SAQ) drills per session. The progression of the SAQ drills followed a similar pattern as the skate treadmill training from simple to complex movements. The simple drills were completed in isolation (i.e. upper or lower body single plane movements); whereas the complex movements combined both upper and lower body movements through more than one plane and at varying frequencies and cadences provided the progressive overload through sessions 1 to 8.

Training Session Questionnaire: At the end of each training session, participants were asked to complete a five question questionnaire. Questions were related to the level of difficulty of the training session, whether or not the subjects had incurred any injuries during that week outside of the training session and a Rating of Perceived Exertion (RPE) (Noble, Borg, Jacobs, Ceci and Kaiser, 1983) (Appendix B).

3.7 Statistical Analysis

Statistical Package for the Social Sciences (SPSS) statistical software (SPSS 17.0 for Windows, 2008, Chicago, Illinois) was used to analyze the data. Descriptive statistics were generated for all the test measurements. Multiple Paired Sample T-tests were used to compare within group pre and post test scores. Pre and post-tests scores of both groups were analyzed using a Mixed Model Factorial Analysis of Variance (MFANOVA) to determine between group pre and post-differences. Statistical significance was set as $p \leq 0.05$. Cohen's d was used to calculate the magnitude of the effect that the training intervention had on the experimental group.

CHAPTER 4: RESULTS

Descriptive statistics calculated for all test measures for both the experimental group and control group are illustrated in Table 4-1. Multiple paired sample T-tests were used to compare all within group pre and post test measures. Significant differences in all pre versus post measures were revealed in the experimental group as a result of DOS specific training (Figure 4-1.). T-test (agility) times decreased significantly (6.1%), meaning that the experimental group was able to complete the test faster after the training intervention. In phase I of the DOS skating treadmill test, a significant increase of 2.26 intervals or a 34.3% increase was revealed between pre and post testing suggesting that subjects were able to achieve a higher puck control rate set by the interval. In phase II of DOS testing, a significant increase of 2.8 intervals or a 44.5% increase was revealed. Results between pre and post tests suggested that subjects successfully completed more intervals while maintaining the skating and puck control rate and responding correctly to the cognitive task. Furthermore, results in both phase I and phase II of the DOS skating treadmill test revealed that failure rates were consistent. Pre to post test measures in phase I found a decrease from 37.5% to 25% of skate failure and a increase in stick failure from 62.5% to 75% in the experimental group. Phase II of the DOS test found a similar trend as a decrease of 37.5% to 31% of skate failure was revealed and no change was found from pre to post tests in stick failure (62.5%). However, post tests revealed a 12.5% increase in cognitive failure as the participants were not as successful in indentifying correct responses to the illustrations when challenged by the intensity of the post test.

A significant increase in Cunningham Faulkner skating treadmill test mean time and total strides taken was revealed pre to post testing, suggesting that the experimental group was able to skate for a longer period of time prior to exhaustion after the training intervention. Furthermore, strides per second were calculated as a measure of skating efficiency during this test and revealed no significant difference between pre (1.41 ± 0.1strides/s) and post (1.4 ± 0.1strides/s) measures of stride rate.

In the control group, no significant differences were found between pre and post measures of the T-test (agility) and both phase I and phase II of the DOS skating treadmill test. However, a significant increase in the Cunningham Faulkner mean total time and number of strides taken was seen between pre and post measures ($p \leq 0.05$) (Figure 4-2.). Results of strides per second calculations revealed a significant difference between pre (1.49± 0.2strides/s) and post (1.52± 0.1strides/s) stride rate measures ($p \leq 0.05$) meaning that an increase time was achieved on this test as a function of the subjects increasing the number of strides taken or in other words running on the treadmill.

A mixed factorial ANOVA was used to compare pre and post test measure differences between groups. No significant difference between groups was revealed when comparing pre tests measures of T-test (agility), phase I and phase II of the DOS skating treadmill test measures and CF strides per second calculations suggesting that the groups were not dissimilar prior to the training intervention ($p \leq 0.05$). Furthermore, no significant differences were found between groups on the cognitive baseline measures. However, Cunningham Faulkner skate treadmill test total time and number of strides independent of stride per second calculations revealed a significant difference between groups during pre testing. This result suggested that, there was either a physiological, technical, or a motivational difference between groups at the time of pre testing. The experimental group achieved a significantly higher mean total time (20.63 ± 5.7 s) and total number of strides taken (29 ± 7.4) than the control group (12.5 ± 4.4. s; 18.9 ± 6.8) on pre test scores,

Post tests revealed significant differences between the two groups on the T-test (agility) (Figure 4-3.), phase I and phase II of the DOS skating treadmill test (Figure 4-4.), (Figure 4-5.) and CF test measures of mean time, strides and strides per second (Figure 4-6.) ($p \leq 0.05$). These results seem to suggest that the DOS specific training intervention had an effect on the post test scores of the experimental group as compared to post test scores of the control group.

The magnitude of the difference between pre and post test measures was found using an analysis of Cohen's d in both the experimental and control groups. The results suggested that the training intervention had a large effect on the all tested measures in the experimental group. A medium to large effect was found for the tested measures in the control group (Table 4-2.).

Further to the quantitative data collected and analyzed, a five question questionnaire including RPE was used to confirm the intensity and progression of the DOS training intervention upon completion of each training session. This data confirmed that the participant's perception of the intensity of the each training session was in agreement with the loading progression of the eight session skate treadmill and dryland training programs (Figure 4-7.). Each session was to build upon the previous and increase in both intensity and complexity.

CHAPTER 5: DISCUSSION

Although traditional training practices in the sport of ice hockey are highly regarded by both researchers and practitioners and have value in successfully developing both the athleticism and the on ice skills of the players, they may not address the complete demands of the game (Greer, Serfass, Picconatto and Blatherwick, 1992; Pan et al., 1998; Fergenbaum and Marino, 2004; Lockwood and Brophey, 2004; Reyment, Bonis, Lundquist and Tice, 2006; Farlinger and Fowles, 2008). Training literature detailing traditional training methodologies associated with hockey development speaks to the positive effects and benefits associated with an athlete's ability to perform an isolated physiological test or skill such as: anaerobic capacity, leg power, skating speed, acceleration, or shot velocity. However, these studies fall short of addressing the combined complexities of physiological capacity, mechanical efficiency and cognitive ability which are all inherent to the game. Although predicting on ice performance is beyond the scope of this paper, it appears that most of the traditional assessments and training tools are designed to speak to isolated variables as opposed to the integration of variables which are representative of game play. The testing and training intervention designed for the purpose of this study focused on integrating the sport specific physiological, mechanical and cognitive systems inherent to the game of ice hockey. The ability to sequence, integrate, and potentially automate selected sport specific movements of lower body (skating) and upper body (stick handling and puck control) combined with game sense or decision making has been defined as a degree of separation (DOS).

The purpose of the study was to investigate the effect of an eight session DOS training intervention on sport specific measures of sequenced yet uncoordinated sport specific movements of lower body (skating) and upper body (stick handling and puck control) in ice hockey players. A test battery was developed to assess both the predominant physiological characteristics and the integrated performance demands (Green, 1979; Green, 1994; Arnett, 1996; Montgomery, 1988, 2000; Twist and Rhodes, 1993; Cox et al., 1995; Green, Pivarnik, Carrier and Womak, 2006) of the sport of ice hockey. The concept of DOS testing and training was developed based upon the 'chunking theory' as defined by Chase and Simon (1973). Although, there has been limited application of the chunking theory to sport training, technical analysis and sport performance, it appears that the grouping of skills may be applied to many sports and activities.

The DOS training program was developed to challenge the physiological, mechanical and cognitive demands, defined by the game. The integration of isolated systems and skill development was the target of the DOS specific training program. The training program was designed to comply with the principles of training, as the overload defined by the frequency and specificity of the drills were addressed over the eight sessions. The type and distribution of training remained constant over the eight sessions, as each session contained 45 minutes of skate treadmill training and 45 minutes dryland SAQ drills. However, as the participant's progressed through each session, the complexity of the training increased in a similar fashion in both skate treadmill and SAQ training. Progressive overload within each of the programs was defined by the frequency (number of drills) and complexity (simple versus complex) of the drills. The total number of sets and repetitions or duration of each drill did not change over the eight training sessions. However, both the frequency (number of drills) and distribution from simple to complex exercises provided a physiological, mechanical and cognitive stimulus in the program. In turn, as the participants progressed through the training program, intensity increased with the frequency or greater number of complex drills executed per training session. Sessions 1-3 contained a series of simple single plane/ single movement exercises that were used to develop a foundation in which the complex multi plane/ multi movement exercises were built on. Frequency of complex exercises increased until sessions 7 and 8 whereby each session contained all complex drills. In addition to the physiological challenges of the training program, the complexity of the drills added a significant cognitive component to each drill. Results of the participant's response to the RPE questionnaire confirmed the increasing intensity of the program over the eight sessions.

The results of the study suggested that the eight session DOS training intervention had a positive effect beyond the physiological variables in isolation. Furthermore, DOS training elicited an improvement in not only the isolated measures of agility (T-test) and anaerobic capacity (CF Time test), but also the integration of the physiological, mechanical and cognitive systems with sport specific skill execution (DOS phase I and II) in a simulated performance environment. The decrease of 6.1% in time to complete the T-test (agility) suggested that the participants in the experimental group were able to improve their agility level from pre to post test. These findings were consistent with the results of Miller, Herniman, Ricard Cheatham and Michael (2006) as participants in their study displayed an improvement of 4.86% in the T-test (agility) with a lower body plyometric training intervention. The significant increase from pre to post measures of 34.3% and 44.4% of both phase I and phase II of the DOS skate treadmill test suggested that the specific training encouraged participant's to go beyond their preferred coordinative states or skills, creating a greater range in which the sport specific skills could be performed (Turvey, 1990; Davids et al., 2005; Gierczuk and Sadowski, 2008). Beyond the overall effect of DOS training on the intervals completed, there was also a shift in the performance that defined the success of the training acquisition. Success or failure was defined as skate, puck control and cognitive failure. In phase I of the DOS skating test, a decrease in skate failure (37.5% to 25%) was found from pre to post tests in the experimental group. These results suggested that with the DOS training, subjects were able to achieve an increased number of intervals while maintaining both stride and puck control rate set by the test interval. However, it was their in ability to maintain control of the puck set by the interval versus their skating rate which caused failure of the interval. A similar shift in performance success was found as a decrease of 37.5% to 31% was found from pre to post test measures in phase II of the DOS test. However, with the addition of the cognitive measure, the mean interval level achieved was lower in both the pre and post tests in phase II of DOS versus phase I. These results suggested that the cognitive measure affected the participant's ability to maintain skating speed and puck control set by the interval, even though only a small percentage of the participant's failed the cognitive measure. The significant increase from pre to post tests (44.4%) in phase II of the DOS skating treadmill test suggested that the participants in the experimental group were challenged beyond physiological ability in training and were able to develop a level of automation in the performance skill tested.

Results of the study provided evidence to support the effect of the DOS training intervention had on both isolated physiological measures and the performance success of integrating sport specific measures of lower body (skating) and upper body (stick handling and puck control) (DOS phase I and II). Isolated measures of agility (T-test) and anaerobic capacity (CF Time test) increased significantly with integrated training. Although it was somewhat of a surprise that the control group also increased their total time significantly from pre to post CF measures, this result may be explained by some of the inherent variability within the CF test. Unlike the other test variables, familiarization to the skating treadmill, skating technique and the method by which total time was measured may have contributed to these findings. However, when strides per second or a measure of skating efficiency was calculated and compared, the experimental group revealed a significant increase not only in their CF total time however did so with no significant increase in stride rate. These results suggest that the experimental group was able to generate more power per stride therefore extending the duration of the test with less strides. The opposite result was found in the control group whereby the participants significantly increased their stride rate, suggesting that stride was broken in order to maximize the total duration of the test. In other words, the control group increased their test scores, however at the detriment of skating stride or efficiency.

Although the results of this study have provided evidence regarding the integration of training and the positive results that it had on the participants in the study, there are some limitations within the study. Participants in the experimental group and the control group were matched based on only two variables (age and ability). By matching the groups based only on age and ability it assumes that there are no other differences between the groups, in the case of this study variables such as height, weight, years experience, handedness and position are all other possible variables that can offset pre test results. Therefore, future considerations for this study suggest that a randomized selection of participants may provide stronger results. The statistical power of the control group was weakened by using a sample size of ten (n=10), versus the sixteen in the experimental group (n=16). With a larger control group, the statistical power of the study would improve. The level of familiarization to the skate treadmill that the participant's had was most evident within the control group; this may have contributed to the unexpected results found in the pre and post measures of CF Time. Both the experimental and control groups were all males of the same age and ability. However different age groups, abilities and sex of athlete may respond differently to the DOS specific training.

5.1 Practical Application

Results of this study suggested that the DOS training intervention provided a performance link from off-ice training to game like performance. As suggested by Cooke (2003) 'we can't compartmentalize training and expect the brain to put it all together in competition' (pg.5). Evidence provided by this study suggested that an integrated type of training, such as DOS, could enhance traditional isolated training practices that may potentially better prepare the athlete's for game performance. This is not to say that isolated training of fundamental systems is not essential and important to the development of an athlete. Isolated system training provides the building blocks upon which integrated training can be built upon.

It is most commonly the case that, the integration of physiological, mechanical and cognitive skills occurs during game play as opposed to training for game play. The practical application of this research suggested that an integrated approach to development should not be limited to on ice exposure and game play; it can be addressed successfully as part of dryland training. Furthermore, there is no evidence to suggest that integrated training does not have to be restricted to any specific age. The integration of skills can aid in developing movements and skills required for the game. This can be applied across all age groups young and old to further enhance their skills as they progress through development. The DOS training program draws parallels with on ice game performance by, simulating the on ice complex sequencing of movements such as skating, puck control and reading and reacting to the play. Through the integration of the physiological, mechanical and cognitive demands of the game, the specificity of training can be further enhanced to bridge the gap between training and game performance.

CHAPTER 6: CONCLUSION

Due to the characteristics of the game of ice hockey it is suggested that physiological testing alone cannot predict overall performance in ice hockey players (Trepanier, 1998; Montgomery, 2000). The assessment of overall ability of an ice hockey player would be more complete with the addition of a technical component (Merrifield and Walford, 1968; Trepanier, 1998; Montgomery, 2000). Results of the study suggested that an eight session DOS training intervention had a positive effect on the isolated measures of agility (T-test), anaerobic capacity (CF Time test) and integrating sport specific measures of lower body (skating) and upper body (stick handling and puck control) (DOS phase I and II). However the largest effect was found in both phases I and II of the DOS test. These results suggested that a level of performance success was achieved while performing the sport specific skill of skating, controlling a puck and reading and reacting to the play. In addition to identifying a possible off-ice option to assess and train the ability of ice hockey players, the results of the study supported the integration of the physiological, mechanical and cognitive systems providing a novel and effective approach to training ice hockey players.

REFERENCE

Arnett, M.G. (1996). Effects of specificity training on the recovery process during intermittent activity in ice hockey. *Journal of Strength and Conditioning Research,* 10(2), 124-126.

Behm, D.G., Wahl, M.J., Button, D. C. & Power, K.E. (2005). Relationship between hockey skating speed and selected performance measures. *Journal of Strength and Conditioning Research,* 19(2), 326-331.

Boyle, M.O. & Ackerman, P.L. (2004). Individual differences in skill acquisition. *Skill Acquisition in Sport Research, Theory and Practice,* Routledge: Taylor & Francis Group, New York, Chpt. 5, 84-103.

Burr, J., Jamnik, R.K., Baker, J., Macpherson, A., Gledhill, N. & McGuire, E.J. (2008). Relationship of physical fitness test results and ice hockey playing potential in elite level ice hockey players. *Journal of Strength and Conditioning Research*, 22, 1535-1543.

Bracko, M.R. & George, J.D. (2001). Prediction of ice skating performance with off-ice testing in women's ice hockey players. *Journal of Strength and Conditioning Research,* 15(10), 116-122.

Chase, W.G. & Simon, H.A. (1973). Perception in chess. *Cognitive Psychology,* 4, 55-81.

Cook, G. (2003) Athletic Body in Balance: Optimal movement skills and conditioning for performance. *Mind and Movement,* Human Kinetics, Champaign, Illinois, Chpt.1, 2-6.

Cox, M. H., Miles, D. S., Verde, T. J. & Rhodes, E. C. (1995). Applied physiology of ice hockey. *Sports Medicine,* 19(3), 184-201.

Cunningham, D. A. & Faulkner, J. A. (1969). The effect of training on aerobic and anaerobic metabolism during a short exhaustive run. *Medicine and Science in Sports,* 1(2), 65-69.

Davids, K., Araujo, D., Shuttleworth, R. & Button, C. (2003). Acquiring skill in sport: A constraints-led perspective. *International Journal of Computer Science in Sport,* 2(2), 31-39.

Farlinger, C.M., Kruisselbrink, D. & Fowles, J. R. (2007). Relationship to skating performance in competitive hockey players. *Journal of Strength and Conditioning Research,* 21(3), 915-922.

Farlinger, C.M. & Fowles, J. R. (2008). The effect of sequence of skating-specific training on skating performance. *International Journal of Sports Physiology and Performance,* 3, 185-198.

Fergenbaum, M. A. & Marino, W.G. (2004). The effects of an upper-body plyometrics program on male university hockey players. *Safety in Ice Hockey: Fourth Volume,* ATSM STP, 1446, 209-221.

Geithner, C. A., Lee, A.M. & Bracko, M.R. (2006). Physical and performance differences among forwards, defensemen, and goalies in elite women's ice hockey. *Journal of Strength and Conditioning Research,* 20(3), 500-505.

Gierczuk, D. & Sadowski, J. (2008). The influence of coordination training on the index Level of coordination motor abilities in greco-roman wrestlers aged 13-14. *Biomedicinos Mokslai,* 3(70), 27-32.

Gledhill, N. & Jamnik, V. (1997). Detailed fitness and medical assessment protocols for NHL entry draft players. *York University, Toronto.*

Green, H.J. (1979). Metabolic aspects of intermittent work with specific regard to ice hockey. *Canadian Journal of Applied Sort Science,* 4(1), 29- 34.

Green, H.J. (1994). Physiological challenges induced by participation in ice hockey-implications for training. *Journal of Testing and Evaluation,* 22(1), 48-51.

Green, M.R., Pivarnik, J.M., Carrier, D.P. & Womack, C.J. (2006). Relationship between physiological profiles and on-ice performance of a national collegiate athletic association division I hockey team. *Journal of Strength and Conditioning Research,* 20(1), 43-46.

Greer, N., Serfass, R., Picconatto, W. & Blatherwick, J. (1992). The effects of a hockey-specific training program on performance of bantam players. *Canadian Journal of Sport Science,* 17(1), 65-69.

Harriss, D.,Piper, S. & Lockwood, K.L. (2007). The effect of off-ice training on the degree of separation in ice hockey players. (Abstract) *Canadian Society for Exercise Physiology Conference*, London, Ontario

Helsen, W.F. & Starkes, J.L. (1999). A multidimensional approach to skilled perception and performance in sport. *Applied Cognitive Psychology,* 13, 1-27.

Lockwood, K.L. & Brophey P. (2004). The effects of a plyometric program intervention on skating speed in junior hockey players. *The Sport Journal,* 7(3), 184-201.

Martell, S.G. & Vickers, J.N. (2004). Gaze characteristics of elite and near elite athletes in ice hockey defensive tactics. *Human Movement Science*, 22, 689-612.

Mascaro, T., Seaver, B.C. & Swanson, L. (1992). Prediction of skating speed with off-ice testing in professional hockey players. *Journal of Orthopedic Sports Physio Therapy,* 15(2), 92-98.

Merrifield, H.H. & Walford, Gerald, A. (1968). Battery of ice hockey skill tests. *The Research Quarterly*, 40(1), 146-152.

Miller, M.G., Herniman, J.J., Ricard, M.D., Cheatham, C.C. & Michael, T.J. (2006). The effects of a 6-week plyometric training program on agility. *Journal of Sports Science and Medicine*, 5, 459-465.

Montgomery, D.L. (1988). Physiology of ice hockey. *Sports Medicine,* 5, 99-126.

Montgomery, D.L. (2000). Physiology of ice hockey. *Exercise and Sport Science,* Lippincott Williams & Wilkiins, Philidelphia, Chpt.52, 815-828.

Montgomery, D.L. (2006). Physiological profile of professional hockey players: A longitudinal comparison. *Applied Physiology, Nutrition, and Metabolism,* 31(3), 181-185.

NHL Central Scouting. (2009). NHL Central Scouting: *Forward Check List.* Retrieved October 10th, 2009 from NHL Central Scouting Web site: http://centralscouting.nhl.com/

NHL Central Scouting. (2009). NHL Central Scouting: *Defensemen Check List.* Retrieved October 10th, 2009 from NHL Central Scouting Web site: http://centralscouting.nhl.com/

Noble, B. J., Borg, G. A. V., Jacobs, I., Ceci, R., & Kaiser, P. (1983). A category-ratio perceived exertion scale: relationship to blood and muscle lactates and heart rate. *Medicine and Science in Sports and Exercise, 15*(6), 523-528.

Pan, W.T., Campbell, D.C., Richards, J.G, Bartolozzi, A.R., Ciccotti, M.G., Snyder-Mackler. L. & Waninger, K.N. (1998). Effect of upper extremity strength training on puck speed in collegiate ice hockey players. *Medicine and Science in Sports & Ecercise*, 30(5).

Quinney, H.A., Dewart, R., Game, A., Syndmiller, G., Warburton, D. & Bell, G. (2008). A 26 year physiological description of a national hockey league team. *Applied Physiology, Nutrition & Metabolism,* 33, 753-760.

Raab, M. & Johnson, J.G. (2007). Expertise- based differences in search and option generation strategies. *Journal of Experimental Psychology: Applied,* 13(3), 158-170.

Reyment, C.M., Bonis, M.E., Lundquist, J.C., Tice, B.S. (2006). Effects of a Four Week Plyometric training Program on Measurements of Power in Male Collegiate Hockey Players. *Journal of Undergrad Kinesiology Research.* 1(2), 44-62.

Sommer, M. (2005). Bilaterality in sports-an explorative study of soccer and ice hockey. (Course D Thesis, Umea University)

Trepanier, A. (1998). Physiological characteristics and performance of NHL entry draft hockey players, *National Library of Canada,* (Master of Arts Thesis, McGill University)

Turvey, M.T. (1990). Coordination. *American Psychologist,* 45, 938–953

Twist, P. & Rhodes, T. (1993). A physiological analysis of ice hockey positions. *National Strength and Conditioning Association Journal,* 15(6), 44-46.

Ward, P. & Williams, M.A. (2003). Perceptual and cognitive skill development in soccer: The multidimensional nature of expert performance. *Journal of Sport and Exercise Psychology,* 25, 93-111.

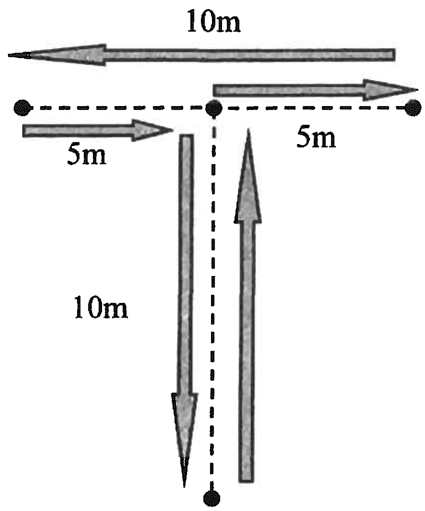

Figure 3-1. T-test Measurement of Agility.

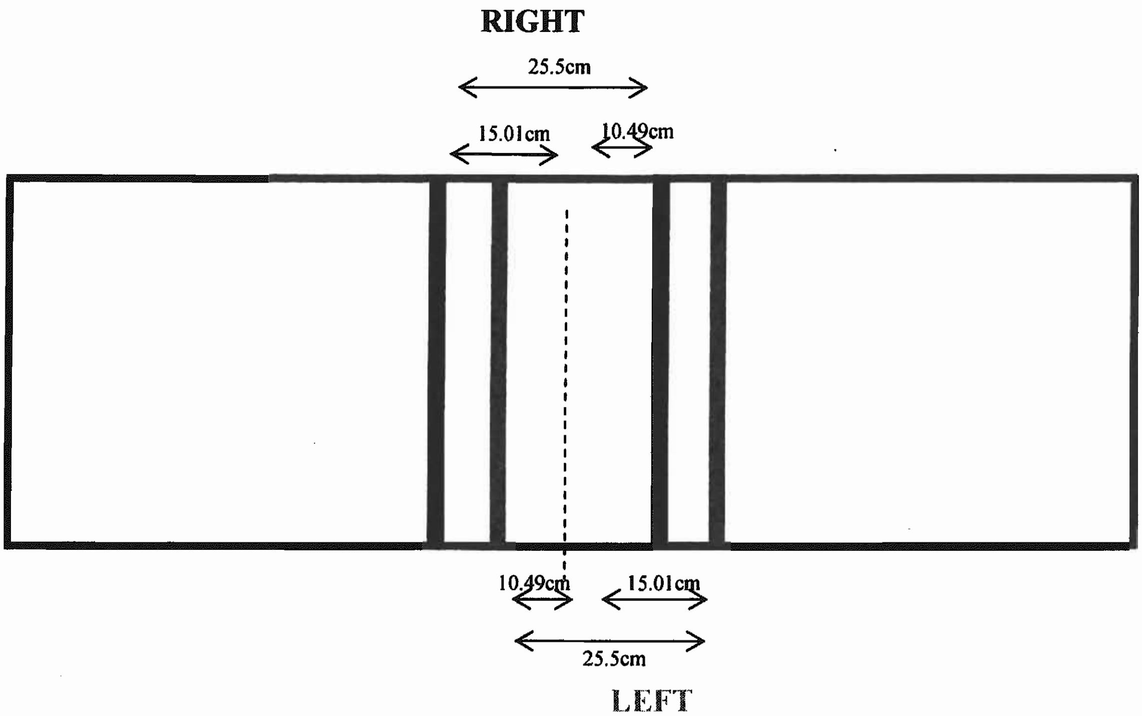

Figure 3-2. Puck Control Platform with Distances Indicated.

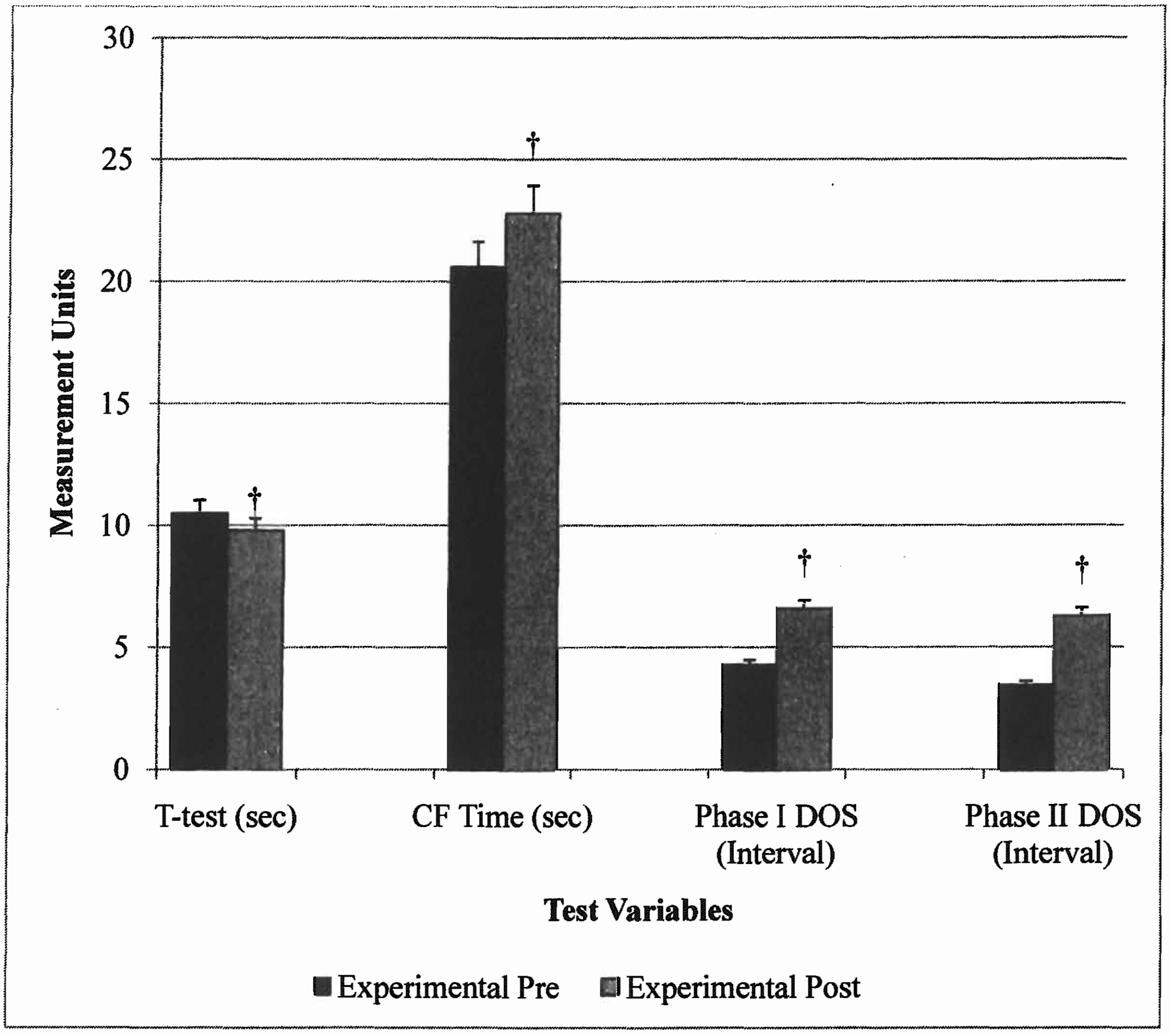

Figure 4-1. Experimental Group Pre vs. Post Test Results. Results measured in units set by test. Significant difference (†= $p \leq 0.05$).

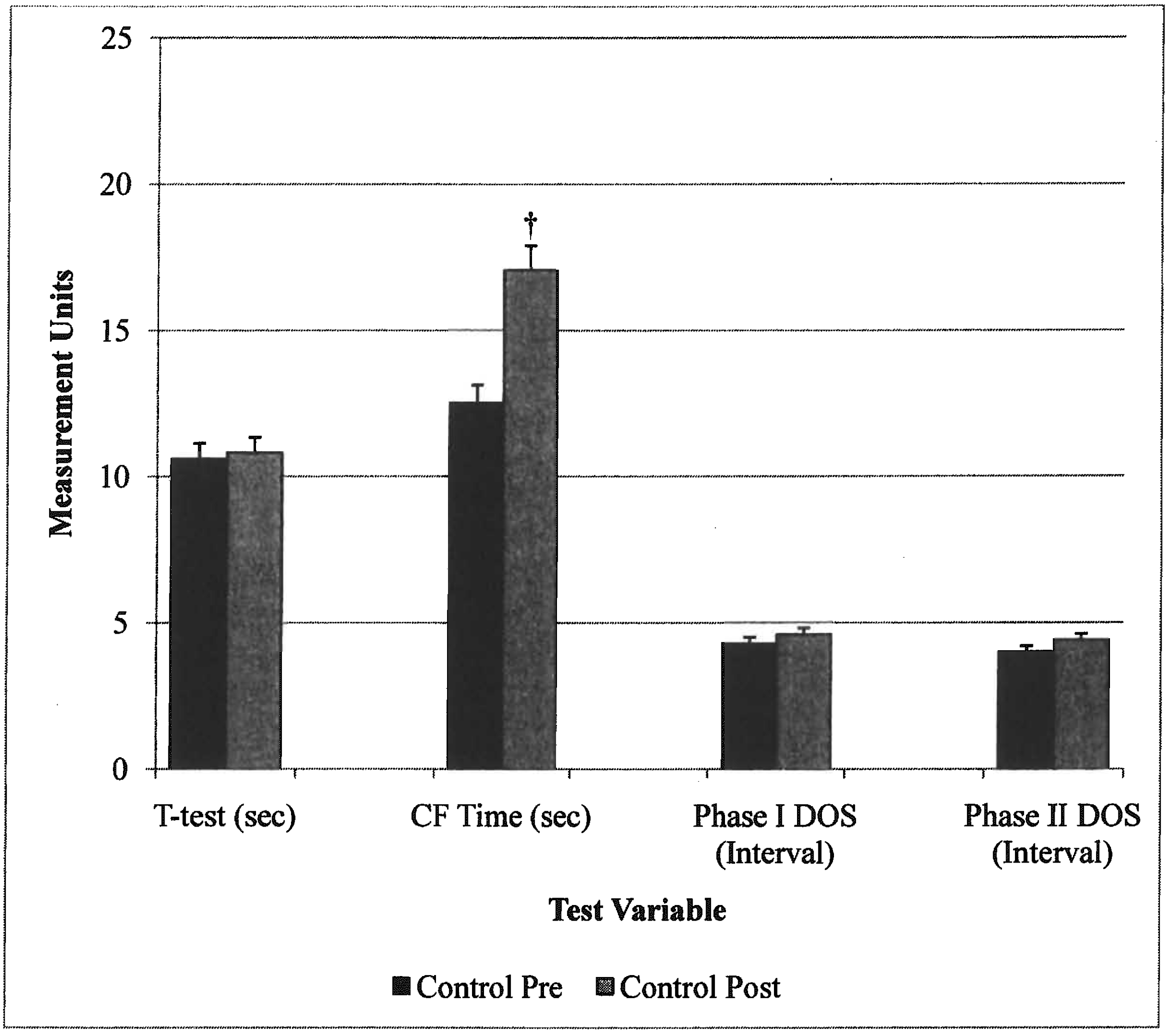

Figure 4-2. Control Group Pre vs. Post Test Results. Results measured in units set by test. Significant difference († = $p \leq 0.05$).

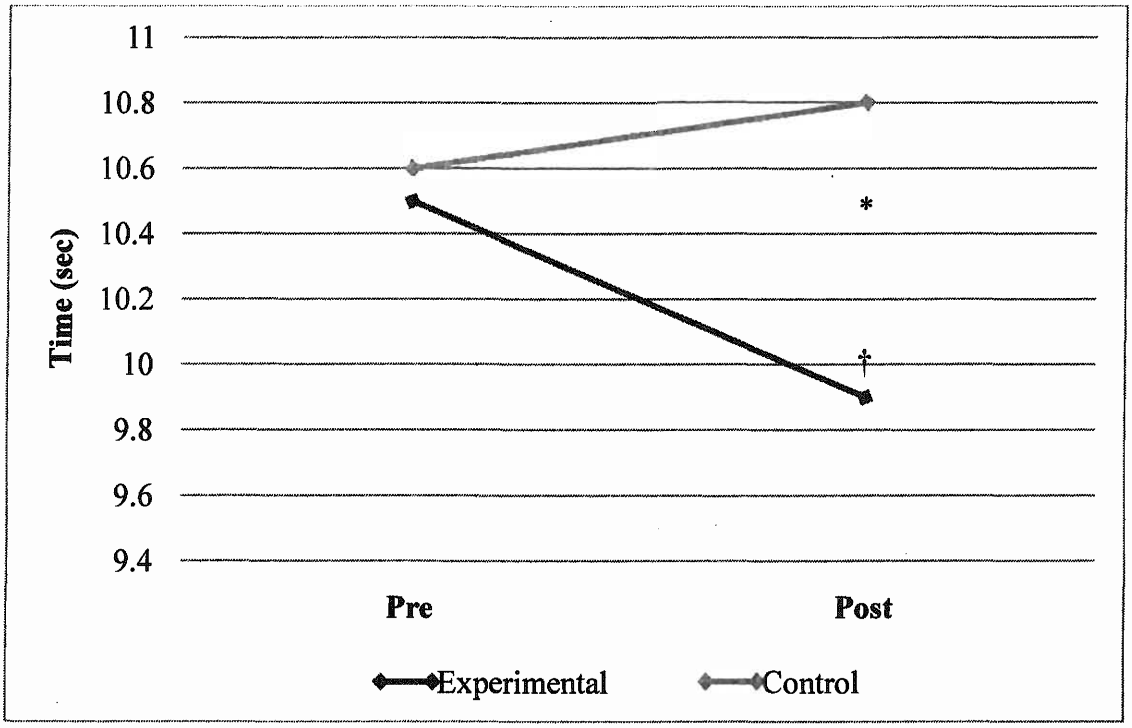

Figure 4-3. Experimental vs. Control T-Test (Agility). Significant difference († = $p \leq 0.05$) found within experimental group pre to post. Statistical significance displayed between experimental and control groups (* = $p \leq 0.05$).

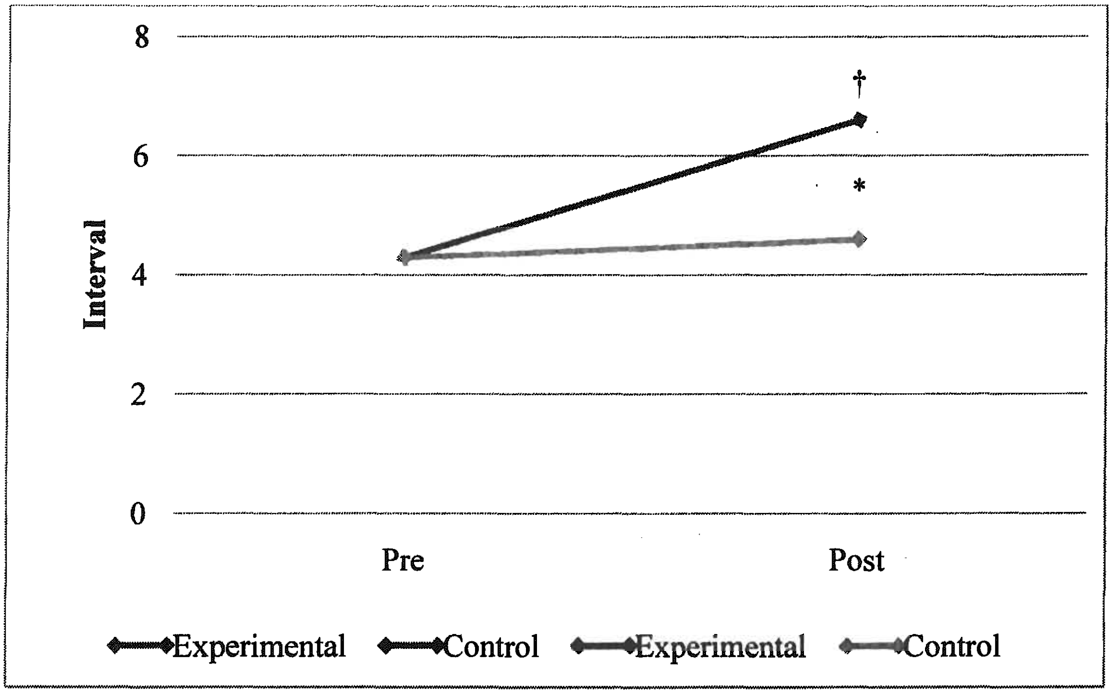

Figure 4-4. Experimental vs. Control Phase I DOS. Significant difference (†= $p \leq 0.05$) found in experimental group pre to post. Statistical significance found (*= $p \leq 0.05$) between post scores of experimental and control groups.

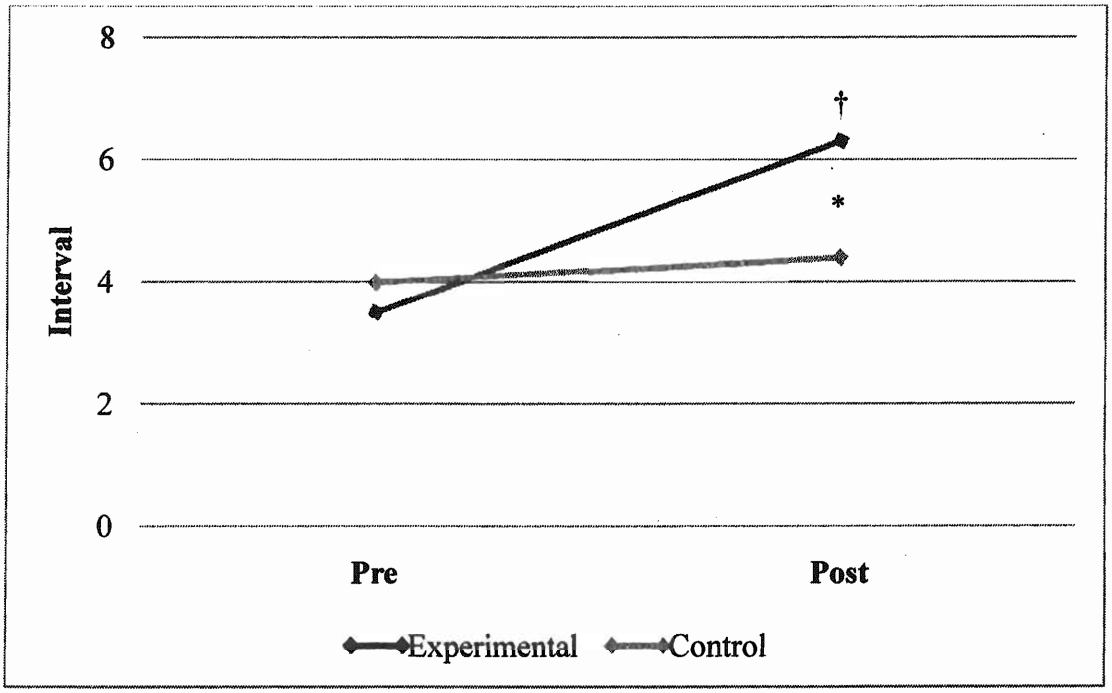

Figure 4-5. Experimental vs. Control Phase II DOS. Significant difference († = $p \leq 0.05$) found in experimental group pre to post. Statistical significance found (* = $p \leq 0.05$) between post scores of experimental and control groups.

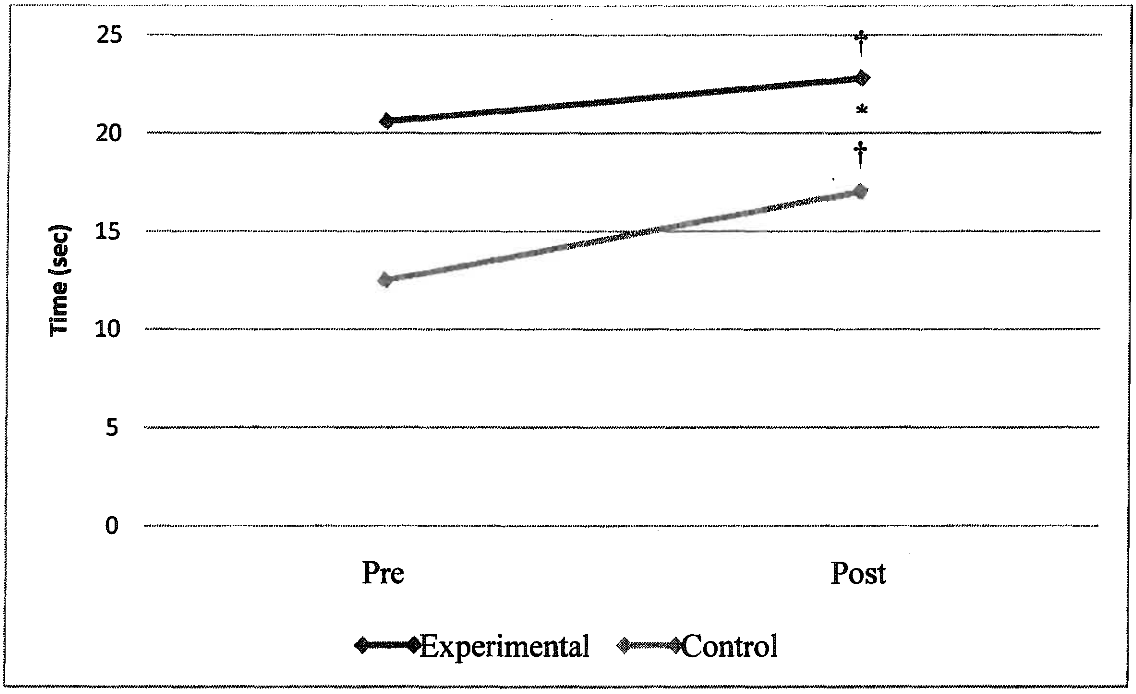

Figure 4-6. Experimental vs. Control CF Time. Significant difference († = $p \leq 0.05$) found in experimental and control groups pre to post. Statistical significance found (* = $p \leq 0.05$) between post scores of experimental and control groups.

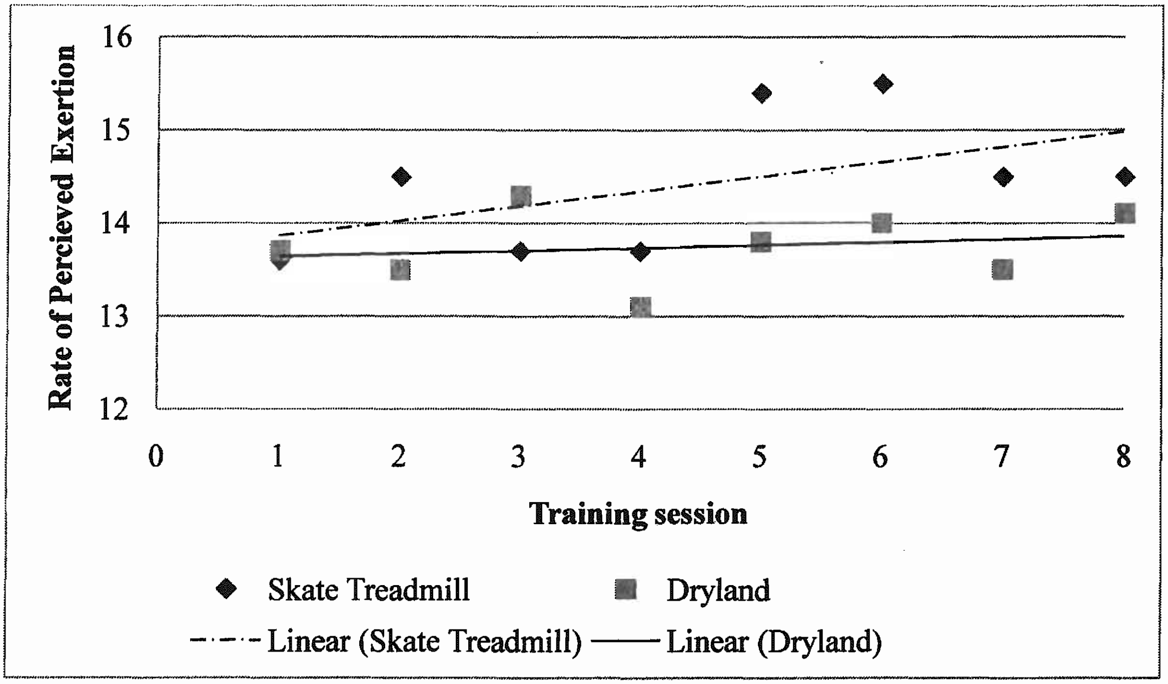

Figure 4-7. Rate of Perceived Exertion of Skate Treadmill and Dryland training sessions.

Table 3-1. *Subject Description: Control and Experimental Groups*

	Experimental Mean ± SD	Control Mean ± SD
Age (yrs)	14	14
Height (m)	172.5 ± 8.1	165.3 ± 9
Weight (kg)	62.5 ± 10	68.6 ± 6
Years Experience (Yrs)	8.6 ± 1.1	8.9 ± 1.4
Handedness (L) (R)	L = 6	L = 6
	R = 10	R= 4
Position (F) (D)	F = 10	F = 4
	D = 6	D = 6

Table 3-2. *Modified Cunningham Faulkner Skate Treadmill Test: Protocol*

Interval	Speed (kmph)	Incline (°)	Time (sec)
1.	13 kmph	5°	30 sec
2.	13 kmph	8°	20 sec
3.	16 kmph	14°	12 sec
4.	16 kmph	16°	10 sec
5. CF Test	16 kmph	16°	Until exhaustion
COOL DOWN			
6.	14 kmph	10°	20 sec
7.	14 kmph	10°	20 sec

Note. Interval 4 is used as familiarization interval to CF test. Subject will not let go.

Table 3-3. *DOS Skate Treadmill Warm Up*

Interval	Speed (kmph)	Incline (°)	Time (sec)	Metronome(Hz)
1.	12 kmph	0°	30 sec	0 Hz
2.	14.5 kmph	0°	30 sec	105 Hz

Table 3-4. The Degree of Separation Skate Treadmill Test Protocol: Phase 1–Phase 2.

Interval	Speed (kmph)	Metronome (Hz)	Time (sec)
1	14.4 kmph	60 Hz	20 sec
2	14.4 kmph	90 Hz	20 sec
3	14.4 kmph	120 Hz	20 sec
4	14.4 kmph	150 Hz	20 sec
5	14.4 kmph	180 Hz	20 sec
6	14.4 kmph	210 Hz	20 sec
7	14.4 kmph	250 Hz	20 sec
8	14.4 kmph	270 Hz	20 sec

Note. Phase 2. Initiates at 50% less of interval achieved in Phase 1.

Table 4-1. *Test Descriptive's (Experimental and Control)*

	Pre Test Mean ± SD Experimental	Post Test Mean ± SD Experimental	Pre Test Mean ± SD Control	Post Test Mean ± SD Control
Cog. Baseline	7.75 ± 0.5		7.6 ± 0.5	
T-Test (sec)	10.5 ± 0.6	9.9 ± 0.3	10.6 ± 0.6	10.76 ± .5
CF Time (sec)	20.6 ± 5.7	22.8 ± 5.3	12.5 ± 4.4	17.04 ± 3.4
CF Stride (strides)	29 ± 7.4	32.3 ± 6.6	18.9 ± 6.8	26 ± 5.3
CF Strides/sec	1.41 ± 0.1	1.4 ± 0.1	1.49 ± 0.2	1.52 ± 0.1
Phase I DOS (interval)	4.3 ± 1.4	6.6 ± 1	4.3 ± 1.3	4.6 ± 1.1
Phase II DOS (interval)	3.5 ± 1.6	6.3 ± 1.4	4 ± 1	4.4 ± 0.8

Table 4-2. *Effect Size*

	Experimental Effect Size (r)	Control Effect Size (r)
T-Test	0.74	0.26
CF Time	0.54	0.8
Phase I DOS	0.9	0.4
Phase II DOS	0.9	0.34

Note: small effect size, $r = 0.1 - 0.23$; medium, $r = 0.24 - 0.36$; large, $r = 0.37$ or larger

APPENDICES

Appendix A

Subject Consent Forms

LETTER OF INFORMATION & INFORMED CONSENT

The Effect of an Eight Session Skate Treadmill and Agility Training Program on the Degree of Separation in Ice hockey Players

Overview of Research:

Sport-specific training development and evaluation in sport can be an extremely complex process. The use of sport-specific simulated activities has been touted as a beneficial training methodology. However, few studies have successfully identified and quantified the effects of sport-specific training on performance measures as they relate to the sport of ice hockey, specifically the ability to sequence the uncoordinated sport specific movements of lower (skating) and upper {stick handling, shooting and puck control (SSP)}. For the purpose of this study, the sequencing of the uncoordinated sport-specific movements of skating and SSP will be termed, the Degree of Separation (DOS).

Despite the popularity of ice hockey, there has been limited research conducted for the development and training of the integrated systems required by ice hockey players, more specifically DOS. At the elite levels of ice hockey players are required to intuitively forecast and react to game play by performing complex mechanically based tasks at intensive physical exertion. Typical mechanical tasks in ice hockey include skating, shooting, stick handling and controlling the puck (SSP). In the sport of ice hockey it would seem that coupled upper and lower body movements, or a proposed method of chunking of sport-specific tasks (i.e. skating, shooting, stick handling, controlling the puck and forecasting the play). Results of preliminary investigation conducted in the On-Ice Performance Lab at Brock University suggested that sport–specific training programs could potentially enhance the sequencing and coordination of uncoordinated ice hockey movements. Based on this work, the following study is being proposed to further examine the effectiveness of a DOS specific assessment and training protocol.

You are being asked to participate in the study titled "***The Effect of an Eight Week Skate Treadmill and Agility Training Program on the Degree of Separation in Ice hockey Players***. The study will be conducted at the Brock University On-Ice Performance Lab in St. Catharines, Ontario. Dr. Kelly Lockwood, who oversees the On-Ice Performance Laboratory at Brock University, has extensive knowledge with the sport of ice hockey and will be supervising this study for MSc. candidate Daniel Harriss.

Training Program Participants:

The purpose of this study is to examine the effectiveness of an eight-session DOS training program that combines skate treadmill and dryland agility training. The specific measures of sequenced yet uncoordinated sport-specific movements of lower (skating) and upper (SSP) in ice hockey players. The duration of this study is six weeks. Thirty-six subjects will be recruited for the study, 18 will be assigned to a control group and 18 assigned to an experimental group. Both the control and experimental groups will participate in the pre testing conducted in week one and the post testing conducted in week ten. The test battery will include: T-Test (Agility), Degree of Separation (DOS) Skate Treadmill test and the Cunningham Faulkner (CF) Skate Treadmill test.

In addition to the pre and post testing sessions, subjects assigned to the experimental group will be required to complete the eight-session DOS training program. The training sessions will be performed twice a week for the four-weeks. The intensity of the training sessions will increase each week over the four-weeks. However, the intensity of the training will not exceed that of an actual game or on ice practice. Each training session will be 1.5 hours in duration.

Consistent attendance for this study will be MANDATORY. However, an alternative plan has been established, if an athlete should miss a training session due to illness, injury or conflict a supervised make up session will be scheduled the same week. If an athlete should miss more than one training session in a row they will be eliminated from the study. Consistency in the specific eight-session DOS training program is crucial for the success of the study. All testing and training sessions will be under the supervision of the principle investigator MSc. candidate Daniel Harriss.

Risks & Benefits of the Study:

Although it is not possible to predict all possible risks or discomforts that a participant may experience during a research study involving human activity, the intensity of the activities included in the above described study are not considered to be any more strenuous than a game of ice hockey. It will be the responsibility of the athlete to come to each training session prepared to exert himself. This includes adequate fuel, hydration, rest and an enthusiastic attitude. Participation in this study may potentially enhance the athlete's ability to sequence the upper (SSP) and lower (skating) ice hockey movements, as well as further progress their overall ice hockey ability. It is expected that a positive outcome will result from the eight-session specific training program. Through this study the subjects will acquire new sport-specific training drills that they can continue to use to aid in individual skill development. This project has been reviewed by the Brock University Research Ethics Board and received ethics clearance (File # 08-268). Upon completion of the study, all participants will receive a summary of the project via email. Recommendations made for further training will also be discussed.

Participant's Consent:

In order to participate in the described study, this documentation must be read and signed. If participants are 18 years of age and older, they may complete the documentation themselves. If participants are not 18 years of age, the participant consent must accompanied by parental/guardian consent as outlined below. Completed informed consents are mandatory for participation.

For participants to complete:

- In signing this form, I ________________________ *(Participant's Name),* acknowledge that, I have received an explanation about the nature of the study and its purpose. I give my permission _______________ *(Participant's Name)* to participate in the research described above at Brock University study conducted by Dr. Kelly L. Lockwood and MSc. candidate Daniel Harriss

1. Participants can withdraw from the program at any time, without prejudice.
2. Although we have strict policies in place to protect all participants in the program, accidents do happen. I understand that the instructors are qualified and will act in the best interest of the athletes.
3. Participant's names and data remain anonymous and confidential by coding each participant by number.
4. Participants will receive a copy of the Informed Consent Form and a summary of the research project upon completion.

Participant's Name: ____________________

Participant's Signature: ___________________

For participants under 18 years of age, the following Parental/Guardian consent must be completed:

- In signing this form, I ________________________ *(Parents/Guardian's Name)*, acknowledge that, I have received an explanation about the nature of the study and its purpose. I give my permission for my child __________________ *(Child's Name)* to participate in the Degree Of Separation training study conducted by Dr. Kelly L. Lockwood and MSc. Candidate Daniel Harriss, at Brock University
    1. My childcan withdraw from the study at any time, without prejudice.
    2. Although we have strict policies in place to protect all participants in the program, accidents do happen. I understand that the instructors are qualified and will act in the best interest of my child.
    3. My child's names and data remain anonymous and confidential by coding each subject by number.
    4. My child will receive a copy of the Informed Consent Form and a summary of the research project upon completion

Parent/Guardian's Name: ______________________

Parent/Guardian's Signature: ___________________

The Principal Investigator, as indicated on this form, can be contacted to answer any questions regarding the experimental procedures.

Department of Physical Education & Kinesiology:

Daniel Harriss, MSc candidate, Principal Investigator — E-mail: dh02vm@brocku.ca

Kelly L. Lockwood Ph.D., Faculty Supervisor — E-mail: klockwood@brocku.ca
Lab Phone: (905) 688-5550 X4903

Should you have concerns about the ethical conduct of the study, you may contact the Research Ethics Officer (reb@brocku.ca (905)688-5550, ext. 3035), who can provide answers to questions about the research participants rights.

Participant Information

Name: ____

Age: ________ Date of Birth (day/month/year): ______________________

Height (cm):__________ Weight (kg): ____________

Level (i.e. Minor Bantam AAA): ____________________________________

Years of hockey experience: __________________

Shoots: Left Right

Primary Position Played (circle one): Forward Defense

Appendix B

Rate Session Questionnaire

Today's Workout Date: ____________

Name: ______________________________ Session: ____________

6	no exertion at all
7	extremely light
8	
9	very light
10	
11	light
12	
13	somewhat hard
14	
15	hard (heavy)
16	
17	very hard
18	
19	extremely hard
20	maximal exertion

Indicate how ***hard*** you felt today's workout's were.

Dryland:__________ Skate Treadmill: ____________

How many med ball drills did you do today?____________

Have you been injured this week? (If Yes, what was injured?)

____

Were you on the skate treadmill first? ______________

What incline did the treadmill go to today? ____________